NATO Science for Peace and Security Series - C:
Environmental Security

GeoSpatial Visual Analytics

Geographical Information Processing and Visual Analytics for Environmental Security

Edited by
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Radovan Stojanovic
Giuseppe Conti

Springer

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GeoSpatial Visual Analytics

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Series C: Environmental Security

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FOREWORD/INTRODUCTION

Access, distribution and processing of Geographic Information (GI) are basic preconditions to support strategic environmental decision-making. The heterogeneity of information on the environment today available is driving a wide number of initiatives, on both sides of the Atlantic, all advocating both the strategic role of proper management and processing of environment-related data as well as the importance of harmonized IT infrastructures designed to better monitor and manage the environment.

The extremely wide range of often multidimensional environmental information made available at the global scale poses a great challenge to technologists and scientists to find extremely sophisticated yet effective ways to provide access to relevant data patterns within such a vast and highly dynamic information flow.

In the past years the domain of 3D scientific visualization has developed several solutions designed for operators requiring to access results of a simulation through the use of 3D visualization that could support the understanding of an evolving phenomenon. However 3D data visualization alone does not provide model and hypothesis-making neither it provide tools to validate results. In order overcome this shortcoming, in recent years scientists have developed a discipline that combines the benefits of data mining and information visualization, which is often referred to as Visual Analytics (VA).

This book addresses the specific vertical domain of VA related to the access, management, processing of Geographical Information (GI), called GeoVisual Analytics, presenting the top issues emerged during the NATO Advanced Research Workshop (ARW) on “Geographical Information Processing and Visual Analytics for Environmental Security”. The event, which took place in Trento (Italy) from 13 to 17 October 2008, provided the unique opportunity to focus on environmental issues from the regulations, technological as well as scientific point of view, involved in the access and processing of GI to increase environmental security.

This book illustrates a the top issues emerged during the event, which gathered more than 50 top experts worldwide with different expertise in disciplines ranging from Geographical Information Systems (GIS), Visual Analytics (VA), disaster management, politics, computer visualization, environmental monitoring, data processing and remote sensing. The event was also joined by representatives from regional and national authorities from NATO Countries as well as from NATO Partner or Mediterranean Dialogue countries.

The main goal of this volume is to pin-point critical issues, to define a priority list to be addressed by the research agenda as well as to put forward recommendations and guidelines. The resulting volume tackles a wide range of application domains, all relevant to environmental security, it highlights current industrial trends, technological requirements and, last but not least, possible emerging market interests.

The book reflects the dual nature of the event in that it presents the current state of art and it highlights new research trends and technologies. The volume identifies a set of guidelines to deploy a new generation of computational tools capable of providing better environmental security.

The volume is articulated into five macro sections each result of a specific topic targeted by the ARW, focusing on a different specific horizontal issues of interest for the theme of environmental security:

1. The importance of harmonization of environmental data access and processing.
2. The role of GI-based technologies for a sustainable development and protection of the environment.
3. Advanced Interactive Visualization and Analysis for environmental security.
4. International, regional and national legal frameworks and constraints.
5. Political, economical and social factors in the protection of the environment.

SPATIAL DATA INFRASTRUCTURES

A SHOWCASE OF SPATIAL DATA INFRASTRUCTURES AND RELATED TECHNOLOGIES

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Abstract. This chapter first gives a rational perspective why spatial data infrastructures are getting more and more importance. Different application fields and necessary services are introduced. The chapter tries to clean-up with the misleading usage of SDI, denoting concepts, technologies and implementations. Afterwards, it embraces on existing and necessary technologies – especially data harmonization. Data harmonization is a crucial element in sharing pan-national data. Examples are given showing working applications of these technologies in different organizations. Finally, critical question about future and missing parts of SDI are stated.

Keywords: Spatial Data Infrastructures, Interoperability, Data Harmonization.

1. Introduction and Background

Geographic information is vital to making sound decisions at local, regional, and national government levels, and it is applicable to several different areas, such as:

- Border security, primarily at the national government level.
- Emergency management, involving prevention planning, monitoring, and analysis of natural disasters and large public events.
- Infrastructure management for water and wastewater systems, transportation systems, city services (garbage, snow, parks), field equipment, and some utility systems.

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- Land information management, including cadastre, forestry, agriculture, natural resources, urban planning, environmental protection, and economic development.
- Mapping and cartographic production, primarily at the regional and national government level.
- Public services (e-Government), including businesses and citizens purchasing government information, accessing government information, and requesting services.

The above areas are just a few examples where decision makers are benefiting from geographic information, coupled with the associated spatial data infrastructure (SDI) that supports information discovery, access, and use of this information in the decision-making process. The examples also clearly indicate the importance of collaboration between organizations – interoperability for spatial data and publication of spatial information.

Figure 1 illustrates the relationships of data access in an end-to-end resource discovery, evaluation and access paradigm, forming the fundamental for each SDI activity. Successive iterations of resource discovery via a metadata catalogue, followed by resource evaluation (such as Web mapping) lead to data access either: direct as a data set or indirect via a data access service.

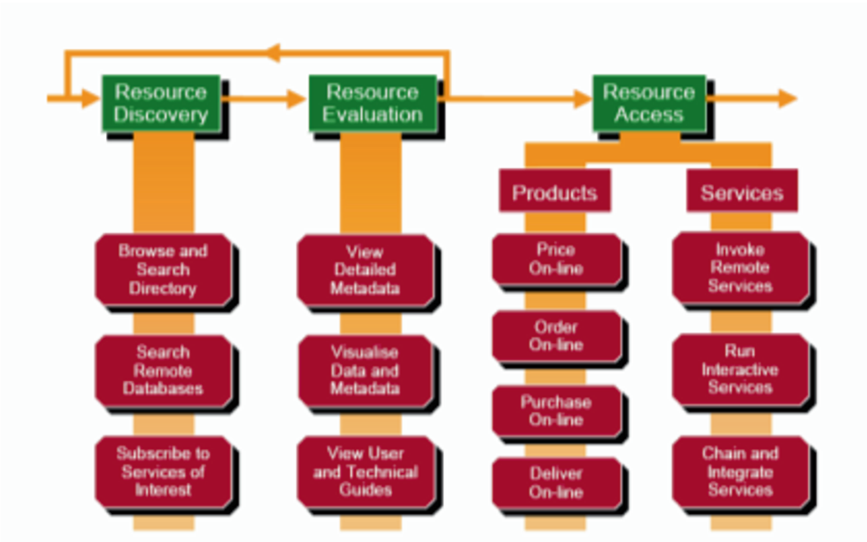

Figure 1. Geospatial resource access paradigm (Nebert, 2004).

From a software technology point of view, services are the heart of the spatial data infrastructure. These services embrace the following areas:

- Human-interaction Services (Portal Services) – Client services for the management of user interfaces, graphics, multimedia, and presentation of compound documents.
- Model/Information Services (Data and Catalogue Services) – Services for the management of the development, manipulation, and storage of metadata, conceptual schemas, and datasets.
- Workflow/Task Services – Services supporting specific tasks or work-related activities conducted by humans. These services support the use of resources and product development involving a sequence of activities or steps that may be conducted by different persons.
- Processing Services – Services that perform large-scale computations involving substantial amounts of data.
- System Management Services – Services for the management of system components, applications, networks, user accounts, and user access privileges.
- Communication Services – Services for encoding and transfer of data across communications networks.

Geospatial information, however, is an expensive resource, and for this reason, appropriate information and the resources to fully use this spatial information may not always be readily available, particularly in the developing world. Many national, regional, and international programs and projects are working to improve access to available geospatial data, promote its reuse, and ensure that additional investment in spatial information collection and management results in an ever-growing, readily available and useable pool of geospatial information. Also included in such initiatives is an emphasis on harmonizing standards for spatial data capturing and exchange, the coordination of data collection and maintenance activities, and the use of common data sets by different agencies.

For Europe, the European Commission has recognized that the availability of relevant and standardized geospatial information is a vital prerequisite for efficient political action. As such, they set up the Infrastructure for Spatial Information in Europe (INSPIRE) initiative (http://inspire.jrc.it/home.html) to coordinate activities to improve utilization of geographic information on a European level. This initiative provides a European legal standard, which, as envisaged, took effect in 2007, and will regulate the structure of a European geospatial data infrastructure (European Spatial Data Infrastructure – ESDI) by using the national geospatial data infrastructures of the European Union members.

The next chapter will give some hints for the philosophy and architecture of an SDI.

2. Philosophy and Principle Architecture for SDI

To become a node in an SDI, organizations must first accomplish several key steps:

- Identify the related parties and persons.
- Identify and define the process which is to be supported by the infrastructure.
- Identify the spatial resources and empower them with appropriate technology.
- Identify the needs of the infrastructure and outline how to meet those needs.

These steps make it clear that applying only software and hardware is not sufficient to become a node of an SDI. Indeed, becoming a well-respected node requires the implementation of a fully empowered solution covering all different aspects of processes, organization, infrastructure, and software.

From a technology point of view, being a node in an SDI requires different technologies for:

- Providing interoperable services
- Consuming interoperable services
- Structuring geospatial data according to determined models
- Publishing/displaying the geospatial data

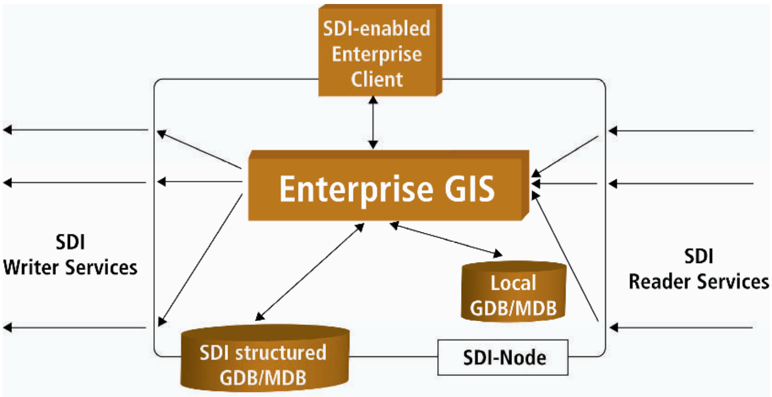

Figure 2. Principle architecture of an SDI node.

This leads to architecture for storing, reading, writing, and displaying data in an SDI-technology manner, as shown in Figure 2. Enterprise GIS includes all the existing geospatial software and infrastructure available in this node.

The mission, from the technical point of view, is to set up an SDI technology, which gives users a customizable turnkey solution. The major objective for this technology is to fulfil the core requirements of sustainability, interoperability, and flexibility.

Sustainability is important, as it pertains to the upcoming changes in related standards. The solution must be open for users to adapt the new versions in an easy-to-modify manner. Interoperability relates to the usage of standards. Model inherent, SDI is a network theme where different players each have their own role. Interoperability of data and services is reached through the use of standards. Flexibility applies to different solution characteristics. The solution must be easy to integrate into an organization's environment, adopt its security policies, and adapt to its corporate standards.

Flexibility and scalability also refer to the needs of different kinds of users. From municipalities to nations or even pan-national organizations, all must realize the node of an SDI in an appropriate scale and manner, each with their different requirements in services and scales. For example, a state or nation SDI node has a strong demand for harmonizing the data provided by services to generate a homogeneous "picture" of geospatial data, whereas a municipality's needs relate more to acquiring metadata for geospatial data.

3. Data Harmonization: A Special European Dimension

To use a very abstract image, the spatial information landscape resembles the seas around Antarctic or Antarctica filled with icebergs. Icebergs are not swimming on top of the sea; actually 90% of their compound is below the surface.

The same is true for the variety of spatial information sources. A vast amount of collected geographical information is not accessible or even not detectable by potential users.

Making spatial data searchable and accessible is only the first step. The second step to exploiting digital geographic information is the ability to seamlessly combine spatial information sources – that is where data harmonization or the standardization of data comes to the fore.

According to INSPIRE, data harmonization is a "process of developing a common set of data product specifications in a way that allows the provision of access to spatial data through spatial data services in a representation that allows for combining it with other harmonized data in a coherent way." This process also includes agreements about coordinate reference systems, classification systems, application schemas, etc. Notwithstanding, it is common understanding within INSPIRE that a total "data harmonization" across all EU nations is not achievable due to a variety of reasons. The challenge is to find solutions for a "virtual harmonization" that allows data providers to stay with their grown and established data specifications and data models but that also supports data users that need a "common geo data language" in Europe.

Data harmonization is also the common denominator of two ongoing EU projects. HUMBOLDT is funded by the 2005 GMES call and aims at enabling organizations to document, publish and harmonize their spatial information, thus contributing to the implementation of the European SDI according to the INSPIRE Directive. GIS4EU is part of the eContentPlus program and it is targeted to making digital content in Europe more accessible, usable and exploitable.

Within HUMBOLDT, data harmonization is understood as "creating the possibility to combine data from heterogeneous sources into integrated, consistent and unambiguous information products, in a way that is of no concern to the end-user".

The data harmonization process(es) from a given source to a certain target, should be examined from two perspectives: one is the target definition aspect and the other is the technical harmonization aspect itself.

Within INSPIRE, the target definition aspect comprises the work of the Data specification teams. For each data theme defined in the INSPIRE Annexes, a common target (data model) is defined. This specification of a target is based on expert decisions and is applicable for data sources that cover the same theme, for instance transportation networks or administrative units.

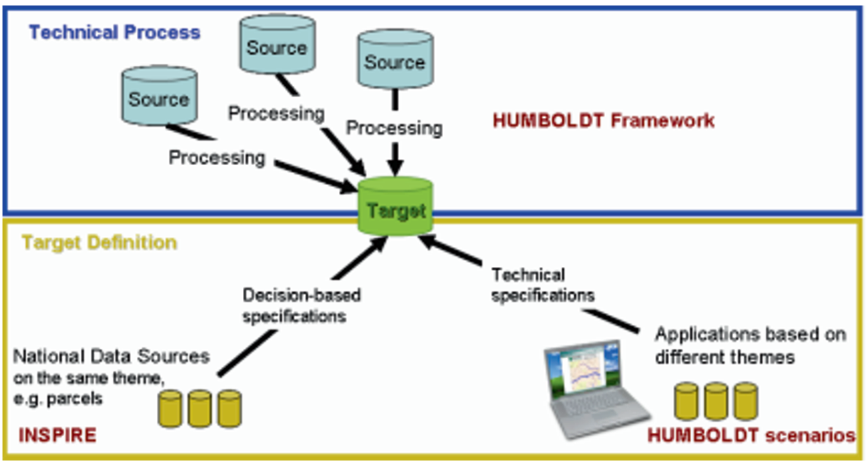

Figure 3. HUMBOLDT – data harmonization aspects (Giger, 2008).

The technical harmonization aspect comprises the actual harmonization processes, for instance the transformation between different Coordinate Reference Systems, as shown in Figure 3.

As a legal framework followed by technical implementation rules, INSPIRE has got high impact on both projects. The Drafting Team on data specifications identified 20 aspects of data harmonization that need to be tackled. Based on findings of the RISE (Reference Information Specifications for Europe) project, INSPIRE defined 20 components of data harmonization, as shown in Figure 4. The theoretical 21st component could be the computational models (process models) together with their constraints and parameters.

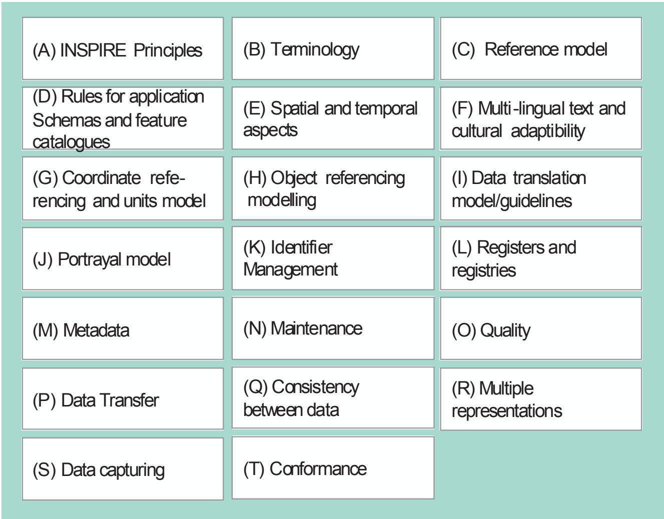

Figure 4. Twenty components of harmonization (according to INSPIRE, 2007, p. 23).

But before one gets lost in the variety of aspects, the basics of data harmonization shall be addressed: data model harmonization which is also referred to as schema mapping. The Model Driven Architecture (MDA) as promoted by the OMG (Object Management Group) proves to be the most promising approach. Figure 5 gives an impression of schema mapping idea. The conceptual schema could be an UML-model or even a textual description, mappings between the source and target model could be provided by an application expert.

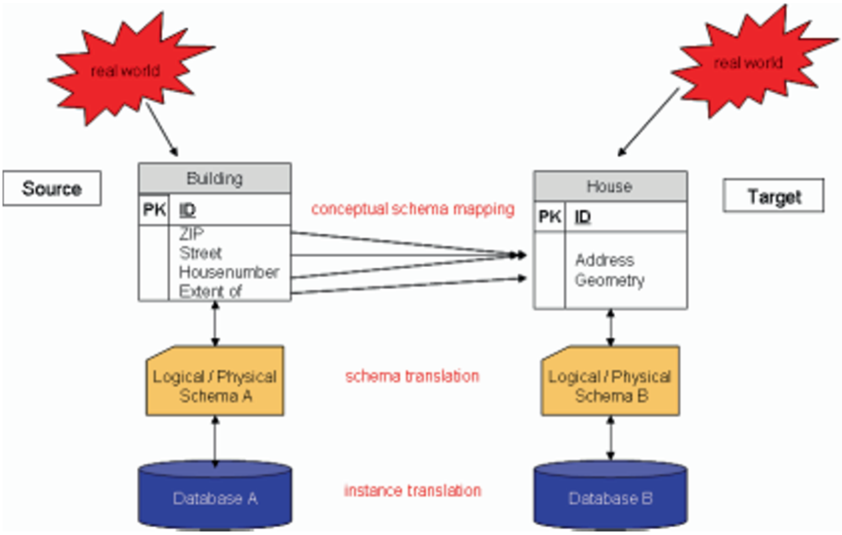

Figure 5. Model driven architecture, abstract view (according to OMG group).

4. Examples for Spatial Data Infrastructures

Several government agencies and organizations around the world have experienced success with solutions. The examples below showcase organizations that have successfully implemented and are enjoying the benefits of spatial data infrastructure technology.

4.1. SITGA – GALICIA, SPAIN

As a result of the demands generated by the District Development Plan of Galicia (PDC), Galicia created a land planning and management tool at the local and district government levels. This, known as the Territorial Information System of Galicia (SITGA), compiles socioeconomic, physical, and infrastructural data from a variety of sources.

SITGA's many responsibilities include developing GIS applications for system users and publishing cartographic maps in different scales. SITGA stores Galicia's geospatial data in a catalog located on different servers, enabling other government municipalities of the region to access this information as needed. Conversely, this process can prove laborious, requiring too much time to push this data to the different servers. SITGA's objective is to provide users with as much geographic information as possible while allowing them to access this information from other servers and applications through the use of international standards.

The main objectives of the project were:

- Create a user-friendly environment to facilitate geospatial data management.
- Make spatial data commonly available, based on international standards.
- Share resources and procedures with other regional government municipalities.
- Introduce GIS functionalities to decision makers.

SITGA decided to implement a Web-based solution with two levels of access: an intranet for technicians of Galicia's regional government and an Internet site for other interested users and communities. Based on their past experience with Intergraph GeoMedia software, SITGA partnered with Intergraph (Spain) to develop the Web solution. Intergraph used GeoMedia WebMap Professional as the basis for the solution. GeoMedia WebMap Professional enables the manipulation of valuable geographic information, allowing SITGA to create custom dynamic, open, and scalable Web mapping applications on the fly.

Figure 6. SITGA's new Web-based solution.

SITGA's new Web-based solution (see Figure 6) allows users to easily retrieve spatial data relating to the Galicia region. Users can access a database with basic and thematic cartography at different scales, as well as an aerial and satellite images stores. The solution also incorporates various services such as CSW, WFS-G, WMS, and WFS.

Through their new Web-based solution, SITGA now has an easy-to-use cartographic server complete with a wide array of services needed to manage a large amount of cartographic information. By promoting the development of online information services in the government of Galicia, this solution is a major step toward creating an entire Galician Spatial Data Infrastructure.

4.2. STATE OF BADEN-WUERTTEMBERG

The Survey Administration of State of Baden-Wuerttemberg is responsible for the collection, update, and dissemination of all geospatial base data, such as cadastre, topographic data, and analogues or digital maps for the whole state, which has about 11 million inhabitants and an area of 36,000 km², making Baden-Württemberg the third largest state in Germany.

The state office has been running a geoportal known as GEODIS for data dissemination since 1998, based on Intergraph GeoMedia WebMap technology for online ordering and selling of their geospatial data. Due to a new German wide standard data and process model on cadastre and topography, the entire structure for production, storage, and dissemination needed to be updated. Additionally, new responsibilities in the field of SDI were granted to the state office. Consequently, it serves as an active node in the national SDI (called GDI-DE) and for the INSPIRE directive of the European commission.

To fulfil these new challenges, updates and extensions of the existing geoportal environment to the new standards and upcoming needs of INSPIRE and GDI-DE wherever necessary. A new database for product generation and Web Services based on a new German wide data model was implemented. This is integrated into the existing SAP-connected e-shop system by a rich set of services. The state office decided to extend their system with several OGC® services for data delivery, including WMS, WFS, and WCS. Additionally, the system provides metadata based on the OGC® Catalogue Service – Web Standard. For local searches, a Gazetteer Service, using OGC® WFS-Gazetteer profile, helps users find the information they need. As official geospatial data in Germany is subject to a charge, the functionality for secured services fulfils a critical task. It protects the data services from unauthorized use and tracks how services are being used by authorized users. It also integrates with a privilege management and SAP-based accounting system.

The resulting new GEODIS geoportal of the Survey Administration of State of Baden-Wuerttemberg serves as an innovative node in the expanding European SDI, and it helps to optimize the processes of data discovery and delivery to Baden-Württemberg, Germany, and Europe.

5. SDI: Brave New World?

While in the beginning the specifications of the Open Geospatial Consortium were far ahead existing solutions and the demands of the customers, situation has changed. A couple of necessary documents are still in the standardization and discussion pipe urgently demanded from the market.

Especially service and content monitoring and protection is to be named. As shown in the example of Baden-Wuerttemberg, there is an urgent demand for higher valued services.

To protect data owner services from illegal usage, secured services with the following protection methods for rights management are necessary:

- User authentication:
    - User name and password (as parameter of HTTP-header)
    - IP address of the caller
- User authorization:
    - Access rights on feature classes/layers
    - Access rights on geographic extent (bbox)
    - Time-based access rights

As part of an SDI, each participating node should have a clear understanding of its serving capabilities. To be a reliable part of an external value chain, these nodes will be "confronted" with Service Level Agreements (SLA), which guarantees a certain level of quality of the services. The service provider must have valid, up-to-date information about its services for this to be successful. Classical operational monitoring tools alone are not sufficient. Furthermore, monitoring the content is also essential, especially whenever these services are connected to a billing system. These monitoring functionalities seem to be very valuable:

- Events logging:
    - No response from resource
    - No connection
    - Incompatible version of request and grounding service
- Performance measurements:
    - Number of calls/s
    - Average service response time
- Content logging:
    - Requested layers
    - Requested spatial extend
    - Requested feature objects

In terms of Enterprise Application Integration (EAI) or Service Oriented Architectures (SOA), the transport protocol is also an issue. OGC® services typically relay on the http post/get paradigm, while EAI and SOA are typically looking for Simple Object Access Protocol (SOAP) bindings.

Last but not least, how many infrastructures there are within the spatial data infrastructure? Today, talking about SDI most often leads to a discussion of software technology aspects. Despite this valuable discussion, hardware and networks and their operation do play an important role in the game too.

6. Conclusions

This chapter clearly highlights the benefit of using SDI technology for collaboration and distribution of geospatial data. In some regions around the world, providing data is enforced by law, and there is a strong demand for sharing geospatial data from business perspective as well. In terms of interoperability, this technology helps to streamline processes and improve efficiency. To summarize, the technology for cooperation and collaboration, denoted as SDI technology brings a lot of opportunities and also challenges. Even with these tools in hand, open issues have to addressed and closed very soon, especially data harmonization and security.

Acknowledgement

I would like to thank Mrs. Breu from Intergraph Germany, for providing the valuable input concerning the data harmonization, as well as the European Commission, which funds the projects Humboldt and GIS4EU.

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TOWARDS INTEROPERABLE ENVIRONMENTAL SECURITY APPLICATIONS – THE ROLE OF OPEN GEOSPATIAL SERVICE PLATFORM

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Abstract. One of the key issues for the analysis and the management of environmental security is the integration of information that is related to environmental security. There is a growing importance towards open geospatial service platforms based on international standards in order to achieve cross-boundary interoperability. The chapter outlines the major technological trends that have determined the design of environmental information systems as kernel components of environmental security applications in the last years following the requirements of the stakeholders. It presents an open architecture for environmental risk management that has achieved best-practices status at the Open Geospatial Consortium (OGC), and it discusses the integration of sensor networks based on OGC® standards. The chapter concludes with the discussion of ongoing research topics such as the exploitation of semantic technologies, emerging Web service paradigms and design methodologies for service-centric computing.

Keywords: Environmental Security Applications, Open Geospatial Service Platform, Service-Oriented Architecture, Open Geospatial Consortium.

1. Introduction

One of the key issues for the analysis and the management of environmental security is the integration of information that is related to environmental security (NATO, 2008). On the one hand, environmental information from various sources, being in-situ, airborne or space borne sensors or environmental

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data bases, is required to protect humans, natural resources or human-made artifacts from environmental hazards, either being subtle effects or sudden environmental events such as Earthquakes, storms or forest fires. On the other hand, information resulting from the continuous monitoring of natural resources is a key factor to assess the short-term or long-term impact of human activities upon the environment. Public safety from environmental dangers, one of the five key elements in Environmental Security, has to be considered "within and across national borders" (Landholm, 1998). As a consequence, environmental security applications shall enable an efficient and flexible exchange of information as well as the remote call and eventually the reuse of their embedded functional components across system boundaries. Thus, there must be an agreement on information models and service interfaces – in the best case based on international standards.

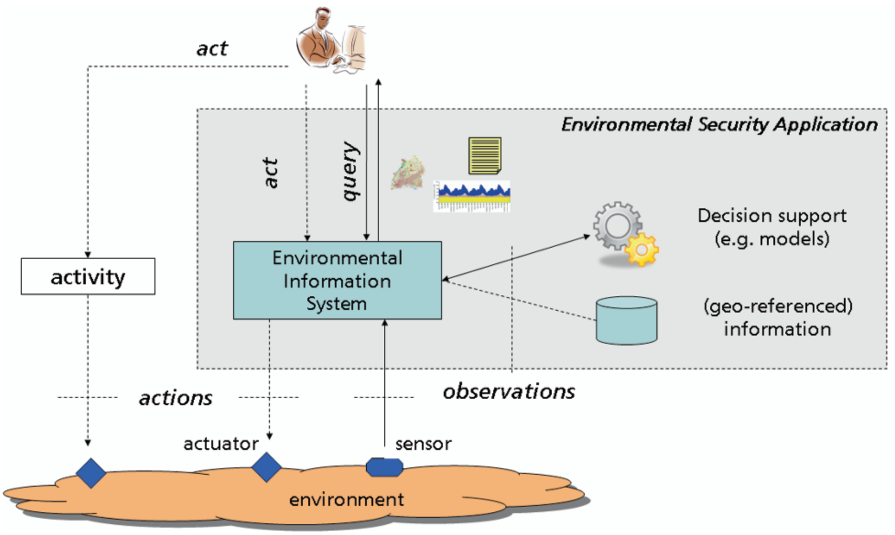

Figure 1. Structure of environmental security applications.

Environmental security applications usually contain Environmental Information Systems (EIS) as kernel components for the gathering, processing and rendering of environmental information (see Figure 1). EIS play a key role in the human's understanding of the past, current and future status of the environment. Usually based on large databases that are indirectly (offline) or directly (online) coupled to environmental sensors, they allow the user to query and process environmental information and visualize it through thematic maps, diagrams and reports. More advanced functions cover, for instance, the estimation of future values of environmental parameters based on simulation or stochastic models as a basis for decision-support or early warning. Resulting actions are performed either by human activities outside of the EIS or through actuators triggered by the EIS. In the last 10–15 years, the design of EIS has undergone fundamental changes following both the requirements of the users and the capabilities of the underlying information and communication technologies (ICT).

This chapter first identifies the major trends that have determined these changes, it deduces the growing importance of open service platforms for the design of EIS and it concludes with an overview about ongoing research topics aiming at establishing the basis for a so-called "Single Information Space for the Environment in Europe" as requested by the European Commission (Coene and Gasser, 2007). The design of such an information space may constitute a blueprint for an analogous objective in the field of environmental security.

2. Trends in Environmental Information Systems

Three major trends resulting from the demands of the stakeholders have determined the design of EIS in the last years (Usländer, 2008):

1. Domain Integration
2. Wider Distribution
3. Functional Enrichment

2.1. DOMAIN INTEGRATION

Domain Integration responded to the demand of enabling the correlation of EIS information and services across various thematic domains, mainly driven by the needs to understand the complex inter-domain relationships in ecological systems. The European Commission (2008) follows this trend in its ambition to conceive a "Shared Environmental Information System" in Europe. End-users are expected to make investments to "render their existing systems interoperable and link them to an integrated system of systems".

From the perspective of open ICT solutions, these demands have resulted in the development of open middleware technologies such as CORBA (Common Object Request Broker Architecture). Although only partially successful as standard for distributed EIS middleware, CORBA laid the basis for thinking in terms of "distributed architectures" based on the notion of "interfaces" specified in a platform-neutral interface definition language. Nowadays, "Web services" have emerged as the middleware of choice also for distributed Web-based EIS applications crossing thematic and organisational boundaries following these initial ideas.

2.2. WIDER DISTRIBUTION

EIS have opened up to a wider spectrum of users (from employees in environmental agencies, over politicians in ministries, up to the citizen) and the design of the functions of an EIS is based on callable units from other applications. Environmental information has to be offered in a variety of formats and aggregation levels to a multitude of users.

The answer, in ICT terms, to these demands has been essentially influenced and pushed forward by the growing acceptance of the World Wide Web as "computing platform" and not only as information medium. The acceptance of "service-oriented architectures (SOA)" also for the design of EIS resulted from the encouraging perspective of deploying an EIS as a set of re-usable components (services) with well-defined interfaces. These services shall be callable from the Intranet/Internet, thus offering environmental information in an "open" manner to an increasing and heterogeneous user community.

2.3. FUNCTIONAL ENRICHMENT

More sophisticated functions such as environmental simulations or geo-processing capabilities shall be made directly available within an EIS in order to reduce purchase, development, user training and maintenance costs. Here, the SOA approach has helped a lot as these functions may also just be loosely-coupled with the EIS as a remote Web service, instead of being provided in stand-alone systems, e.g., a Geographic Information System (GIS). Standardised geospatial Web services (e.g., the Web Map Service) as specified by the Open Geospatial Consortium (OGC) have captured the generic parts of such remote functions.

The emergence of these IT solutions has created a more challenging vision: an "ideal" IT support that would make information available on demand for the end users and would enable service providers to offer high-quality services at considerably lower cost in a plug-and-play manner. As illustrated in Figure 2, EIS applications of various types, running in control or information centres and tailored to the analysis of environmental data or to its visualisation in maps or diagrams, have to be coupled with data of various types. Data Sources encompass geospatial thematic data, documents or information about environmental phenomena observed by monitoring stations, cameras or satellites – a vision formulated by Denzer (2005) of a functionally rich but generic platform as a need to effectively build environmental decision support systems.

3. Open Geospatial Service Platform

An essential element of such an ideal IT support is an "open geospatial service platform" which provides seamless access to resources (information, services and applications) across organisational, technical, cultural and political borders, thus overcoming real-world heterogeneity and assuring a sustainable investment for the support of future, yet unknown requirements. "Open" hereby means that service specifications are published and made freely available to interested vendors and users with a view to widespread adoption. Furthermore, an open service platform makes use of existing standards (e.g., ISO and OGC) where appropriate and otherwise it contributes to the evolution of relevant new standards. In the following two examples open architectures are presented in more detail. Their development has been partly funded by the European Commission in the unit "ICT for the Environment".

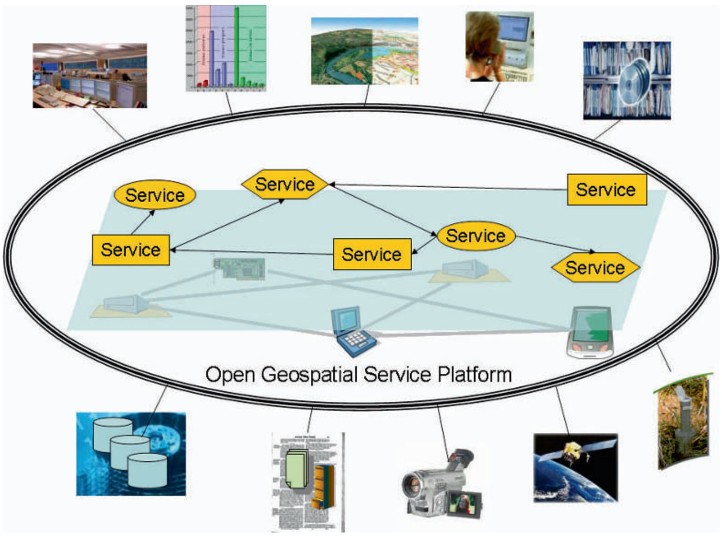

Figure 2. Open geospatial service platform.

3.1. THE ORCHESTRA ARCHITECTURE

Based on a systematic analysis of user and system requirements, the European research project ORCHESTRA (Open Architecture and Spatial Data Infrastructure for Risk management) has specified and implemented a reference model and a series of architecture services that provide the generic and platform-neutral functional grounding of such open geospatial service platforms (Klopfer and Kannellopoulos, 2008). This Reference

Model for the ORCHESTRA Architecture (Usländer, 2007) has been accepted as a best-practices document for architectural design by the OGC.

The reference model is built upon two main pillars: a conceptual model and a process model. The conceptual model provides a uniform meta-model including a set of rules on how to specify information models, interfaces and services. The process model applies an incremental, iterative approach for the analysis and design phases. Usually, a multi-step breakdown process across several abstraction layers is necessary to analyse the functional, informational and non-functional user requirements and map them to the capabilities of a service platform. In practice, the individual process steps are often interlinked. The reference model distinguishes between an abstract service platform, that is specified independently of a given middleware technology, and a concrete service platform, e.g., Web Services based on the Web Service Description Language (WSDL) bound to the SOAP protocol (Figure 3).

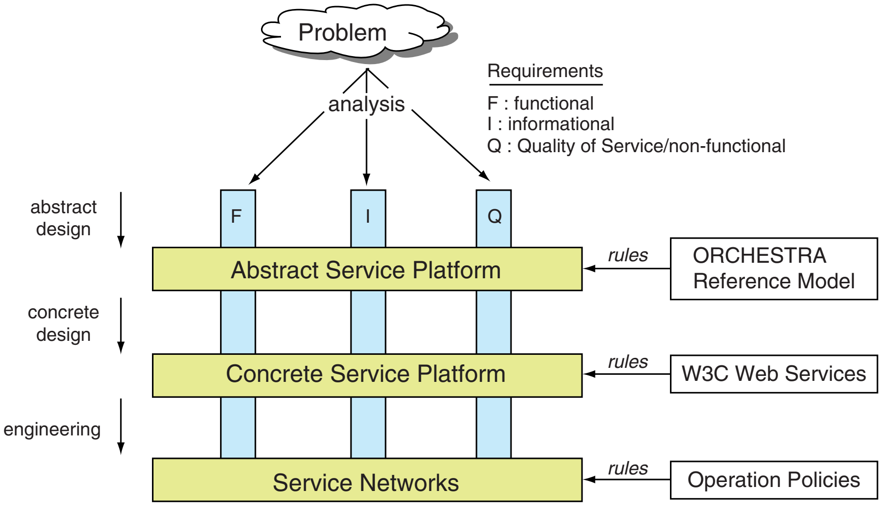

Figure 3. Abstract and concrete service platforms.

The abstract design phase leads to platform-neutral specifications following the rules defined in the conceptual model of the reference model. The concrete design phase maps the abstract specifications to a chosen concrete service platform. In the engineering phase the platform-specific components are organized into service networks taking into account the qualitative requirements and translating them into operational policies.

3.2. INTEGRATION OF SENSORS INTO A SERVICE PLATFORM

The European research project SANY (Sensors Anywhere) (Havlik et al., 2007) extends the ORCHESTRA architecture into a Sensor Service Architecture through the inclusion of sensors and sensor networks based upon the OGC® Sensor Web Enablement architecture (Simonis, 2008). Sensors provide the basic input data for environmental monitoring as well as for risk management of natural and man-made hazards.

As a result, a high percentage of the required functionality of an environmental security application may already be covered by applying and tailoring the generic architecture services of both projects listed in Table 1. They are based upon international standards but extend them where necessary. For illustrative purposes, they are organised in the following functional domains (see Figure 4):

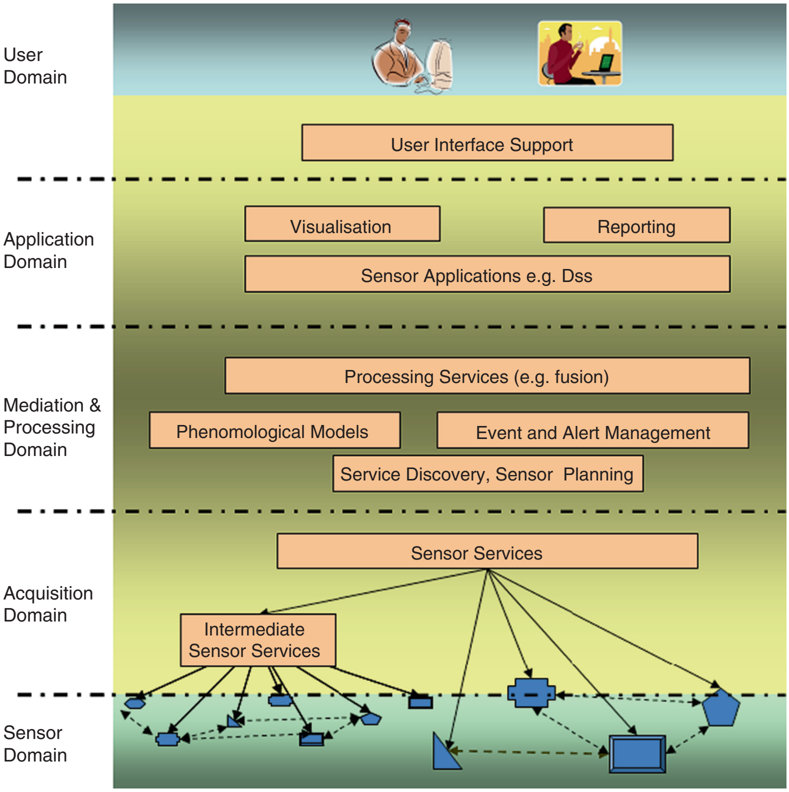

Figure 4. Functional domains of the SANY sensor service architecture.

Services in the Sensor Domain cope with the configuration and the management of individual sensors and their organization into sensor networks. Examples are services that support communication between the sensors

TABLE 1. List of major architecture services and interfaces required for an open geospatial service platform (Usländer, 2007; Schimak et al., 2008; Simonis, 2008).

Name of service and interface type [functional domain]	**Application**
Basic Interface Types [all]	Enable a common architectural approach for all architecture services, e.g., for the capabilities of service instances.
Annotation Service [MP]	Relates textual terms to elements of ontology (e.g., concepts, properties, instances).
Authentication Service [MP]	Proves the genuineness of principals (i.e., the identity of a subject) using a set of given credentials.
Authorisation Service [MP]	Provides an authorisation decision for a given context.
Catalogue Service [MP]	Ability to publish, query and retrieve descriptive information (meta-information) for resources of any type. Extends the OGC® Catalogue Service by additional interfaces for catalogue cascade management and ontology-based query expansion.
Coordinate Operation Service [MP]	Changes coordinates on features from one coordinate reference system to another.
Document Access Service [MP]	Access to documents of any type (e.g., text and images).
Feature Access Service [MP]	Selection, creation, update and deletion of features available in a service network. Corresponds to the OGC® Web Feature Service but is extensible by schema mapping.
Map and Diagram Service [AP]	Enables geographic clients to interactively visualise geographic and statistical data in maps (such as the OGC® Web Map Service) or diagrams.
Ontology Access Interface [MP]	Supports the storage, retrieval, and deletion of ontologies as well as providing a high-level view on ontologies.
Service Monitoring Service [MP]	Provides an overview about service instances currently registered within service network incl. status and loaded.
User Management Service [MP]	Creates and maintains subjects (users or software components) including groups (of principals) as a special kind of subjects.
Sensor Observation Service [A]	Provides access to observations from sensors and sensor systems in a standard way that is consistent for all sensor systems including remote, in-situ, fixed and mobile sensors.

TABLE 1. (Continued)

Name of service and interface type [functional domain]	**Application**
Sensor Alert Service [A]	Provides a means to register for and to receive sensor alert messages.
Sensor Planning Service [A]	Provides a standard interface to task any kind of sensor to retrieve collection assets.
Web Notification Service [all]	Service by which a client may conduct asynchronous dialogues (message interchanges) with one or more other services.

themselves, e.g., a take-over service in case of an impending sensor battery failure. Services in this domain are abstractions from proprietary mechanisms and protocols of sensor networks.

Services in the Acquisition Domain (tagged as “A” in Table 1) deal with access to observations gathered by sensors. This includes other components in a sensor network (e.g., a database or a model) that may offer their information in the same way (as observations) as sensors do. They explicitly deal with the gathering and management of information coming from the source system of type “sensor”. The information acquisition process may be organized in a hierarchical fashion by means of intermediate sensor service instances (e.g., using data loggers).

Services in the Mediation and Processing Domain (tagged as “MP” in Table 1) are specified independently of the fact that the information may stem from a source system of type “sensor”. They mediate access from the application domain (see below) to the underlying information sources. They provide generic or thematic processing capabilities such as fusion of information, the management of models and the access to model results. In addition, support for resource discovery, naming resolution or service chaining is grouped in this domain.

Services in the Application Domain (tagged as “AP” in Table 1) support the rendering of information in the form of maps, diagrams and reports directly to the end-user in the user domain.

The functionality of the user domain is to provide the system interface to the end user. Usually, open generic architectures do not specify dedicated services for this domain. Both projects consider this functionality to be specified in a dedicated implementation architecture that also may take proprietary components and products into account.

4. **Ongoing Research Activities**

In the following sections, those research activities for service-centric distributed applications are shortly presented that are highly relevant for the future design of open geospatial service platforms.

4.1. SEMANTIC WEB SERVICES

There is ongoing research work in the field of semantic extensions of the Web (Semantic Web) which has already led to a series of basic recommendations of the World Wide Web Consortium (W3C) such as the Resource Description Framework (RDF) as a general method of modelling information as statements about resources in the form of subject-predicate-object expressions, and OWL, the W3C Web Ontology Language to define and instantiate ontologies.

Research work on semantic extension of Web Services (Semantic Web Services) has resulted in competing submissions of sophisticated Semantic Web Services frameworks to the W3C. As a first step, the W3C recommends to use "Semantic Annotations for WSDL and XML Schema" (SAWSDL) (Farrell and Lausen, 2007). SAWSDL defines a set of extension attributes for the WSDL and XML Schema definition language as illustrated in Figure 5.

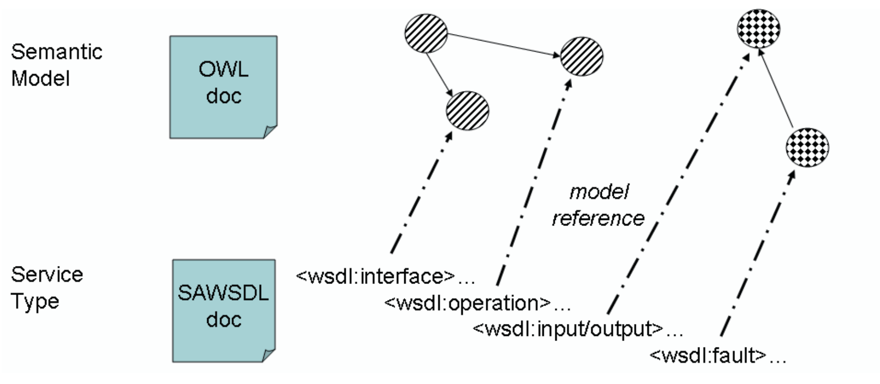

Figure 5. Model references of the semantic annotations for WSDL and XML schema.

The approach is to annotate elements of WSDL documents, in particular interfaces and operations as well as their input, output and fault message structures. This is realized by model references to concepts in semantic models, e.g., ontologies. SAWSDL does not specify a language for representing the semantic models. The annotation mechanism is independent of the ontology expression language.

When applied to open geospatial service platforms, SAWSDL enables service and data matchmaking on semantic level which may increase the degree of interoperability. This benefit, however, has still to be validated in practical use cases.

4.2. WEB SERVICE PARADIGMS

Looking at the technical foundation for the open service platforms, there is an ongoing discussion about the basic Web service paradigm to be used. The OGC® services have been designed before the W3C standards SOAP and WSDL have been accepted. Thus, they are still specified with an http/KVP (key-value pair) binding. Although the OGC® Technical Committee has decided in June 2006 to provide additional WSDL/SOAP bindings for the OGC® service interfaces, they have not yet reached the status of accepted OGC® standards. Furthermore, the mass-market in the Geospatial Web tends towards another paradigm, the RESTful web services (Richardson and Ruby, 2007). RESTful Web services aim at accessing and manipulating uniquely identified resources based on a uniform interface with commonly agreed, well-defined semantics such as the http-protocol of the World Wide Web.

Research is required how to govern this variety of Web service paradigms both in the design but also in the operational phase. In particular, aspects of ICT security (e.g., fine-grained access control) and dependability are not yet sufficiently solved for such open environments.

4.3. SERVICE-ORIENTED ANALYSIS AND DESIGN

Up to now, methods to service-oriented analysis and design are still in an early stage (Chang and Kim, 2007). Existing software development models such as Object-oriented Analysis and Design and Component-based Development need to be enhanced with additional facilities such as service modelling, service interface design and composition.

Lutz (2007) describes a methodology for ontology-based discovery of geo-processing services. However, his methodology aims at supporting the automatic composition of geospatial services rather than helping a human system architect in the design of a SOA where approximate matches are sufficient (Toch et al., 2008). Although he has chosen a lightweight semantic representation for operations (semantic signature), it is still too complicated to be used in the practice of a SOA design where the requirements to be matched are often ambiguous and incomplete.

None of these works describes a SOA design methodology that explicitly takes the side-conditions of open geospatial information systems (e.g., the compliance to the series of international standards) into account.

5. Conclusions

Technologies for service platforms for environmental security applications have continuously changed in the past and are expected to change in the future. The ORCHESTRA and the SANY projects provide a sustainable open service architecture with a series of generic architecture services that have been systematically derived from user requirements. They favour an efficient development of geospatial applications and may cope with the pluralism of Web service paradigms. Although this architecture provides a specification framework, there is a lack of model-driven design methodologies for such open geospatial service platforms starting from formalised user requirements. Semantic technologies will emerge but have to be validated and taken up step-by-step into the series of OGC® standards.

Today, open geospatial service platforms still have some essential technological gaps to be closed by research activities. However, an "open" approach based upon standards and supported by functionally rich geospatial service platforms is indispensable when aiming at providing interoperable solutions for environmental security applications.

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SIGNAL AND DATA PROCESSING

SORTING SPATIAL DATA BY SPATIAL OCCUPANCY

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Abstract. The increasing popularity of web-based mapping services such as Microsoft Virtual Earth and Google Maps/Earth has led to a dramatic increase in awareness of the importance of location as a component of data for the purposes of further processing as a means of enhancing the value of the nonspatial data and of visualization. Both of these purposes inevitably involve searching. The efficiency of searching is dependent on the extent to which the underlying data is sorted. The sorting is encapsulated by the data structure known as an index that is used to represent the spatial data thereby making it more accessible. The traditional role of the indexes is to sort the data, which means that they order the data. However, since generally no ordering exists in dimensions greater than 1 without a transformation of the data to one dimension, the role of the sort process is one of differentiating between the data and what is usually done is to sort the spatial objects with respect to the space that they occupy. The resulting ordering should be implicit rather than explicit so that the data need not be resorted (i.e., the index need not be rebuilt) when the queries change. The indexes are said to order the space and the characteristics of such indexes are explored further.

Keywords: Spatial Indexing, Sorting, Geometric Data Structures.

1. Introduction

The increasing popularity of web-based mapping services such as Microsoft Virtual Earth and Google Maps/Earth has led to a dramatic increase in

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awareness of the importance of location as a component of data for the purposes of further processing as a means of enhancing the value of the nonspatial data and of visualization. Both of these purposes inevitably involve searching. The efficiency of searching is dependent on the extent to which the underlying data is sorted. The conventional definition of the term *sort* is that it is a verb meaning:

- To put in a certain place or rank according to kind, class, or nature
- To arrange according to characteristics.

The sorting is encapsulated by the data structure that is used to represent the spatial data thereby making it more accessible. In fact, the term *access structure* or *index* is often used as an alternative to the term *data structure* in order to emphasize the importance of the connection to sorting. The notion of sorting is not new to visualization applications. One of the earliest examples is the work of Warnock who, in a pair of reports that serve as landmarks in the computer graphics literature (Warnock, 1968, 1969), described the implementation of hidden-line and hidden-surface elimination algorithms using a recursive decomposition of the picture area. The picture area is repeatedly subdivided into rectangles that are successively smaller while it is searched for areas that are sufficiently simple to be displayed. It should be clear that the determination of what part of the picture area is hidden or not is equivalent to sorting the picture area with respect to the position of the viewer. This distinction is also present in back-to-front and front-to-back display algorithms. These algorithms form the rationale for the BSP tree representation (Fuchs et al., 1980, 1983) which facilitates visibility calculations of scenes with respect to a viewer as an alternative to the z-buffer algorithm which makes use of a frame buffer and a z buffer to keep track of the objects that it has already processed. The advantage of using a visibility ordering over the z-buffer algorithm is that there is no need to compute or compare the z values. Sorting is also used to accelerate ray tracing by speeding up the process of finding ray-object intersections (e.g., Glassner, 1984; Samet, 1989a,b). Notwithstanding the above definition, sorting usually implies the existence of an ordering. Orderings are fine for one-dimensional data. For example, in the case of individuals we can sort them by their weight, and given an individual such as Bill, we can use the ordering to find the person closest in weight to Bill. Similarly, we can use the same ordering to also find the person closest in weight to John. Unfortunately, in two dimensions and higher, such a solution does not always work. In particular, suppose we sort all of the cities in the US by their distance from Chicago. This is fine for finding the closest city to Chicago, say with population greater than 200,000. However, we cannot use the same ordering to find the closest city to New York, say with population greater than 200,000, without resorting the cities.

The problem is that for two dimensions and higher, the notion of an ordering does not exist unless a dominance relation holds (e.g., Preparata and Shamos, 1985) – that is, a point $a = \{a_i|1 : i : d\}$ is said to dominate a point $b = \{b_i|1 : i : d\}$ if $a_i : b_i$, $1 : i : d$. Thus the only way to ensure the existence of an ordering is to linearize the data as can be done, for example, using a space-filling curve (e.g., Sagan, 1994; Samet, 2006). The problem with such an approach is that the ordering is explicit. Instead, what is needed is an implicit ordering so that we do not need to resort the data when, for example in our sample query, the reference point for the query changes (e.g., from Chicago to New York). Such an ordering is a natural byproduct when we sort objects by spatial occupancy, and is the subject of the remainder of this chapter.

2. Methods Based on Spatial Occupancy

The indexing methods that are based on sorting the spatial objects by spatial occupancy essentially decompose the underlying space from which the data is drawn into regions called *buckets* in the spirit of classical hashing methods with the difference that the spatial indexing methods preserve order. In other words, objects in close proximity should be placed in the same bucket or at least in buckets that are close to each other in the sense of the order in which they would be accessed (i.e., retrieved from secondary storage in case of a false hit, etc.).

There are two principal methods of representing spatial data. The first is to use an object hierarchy that initially aggregates objects into groups based on their spatial proximity and then uses proximity to further aggregate the groups thereby forming a hierarchy. Note that the object hierarchy is not unique as it depends on the manner in which the objects were aggregated to form the hierarchy. Queries are facilitated by also associating a minimum bounding box with each object and group of objects as this enables a quick way to test if a point can possibly lie within the area spanned by the object or group of objects. A negative answer means that no further processing is required for the object or group, while a positive answer means that further tests must be performed. Thus the minimum bounding box serves to avoid wasting work. Data structures such as the R-tree (Guttman, 1984) and the R*-tree (Beckmann et al., 1990) illustrate the use of this method.

As an example of an R-tree, consider the collection of straight line segment objects given in Figure 1(a) shown embedded in a 4 × 4 grid. Figure 1(b) is an example of the object hierarchy induced by an R-tree for this collection. Figure 1(c) shows the spatial extent of the bounding rectangles of the nodes in Figure 1(a), with heavy lines denoting the bounding rectangles corresponding to the leaf nodes, and broken lines denoting the bounding rectangles corresponding to the subtrees rooted at the nonleaf nodes.

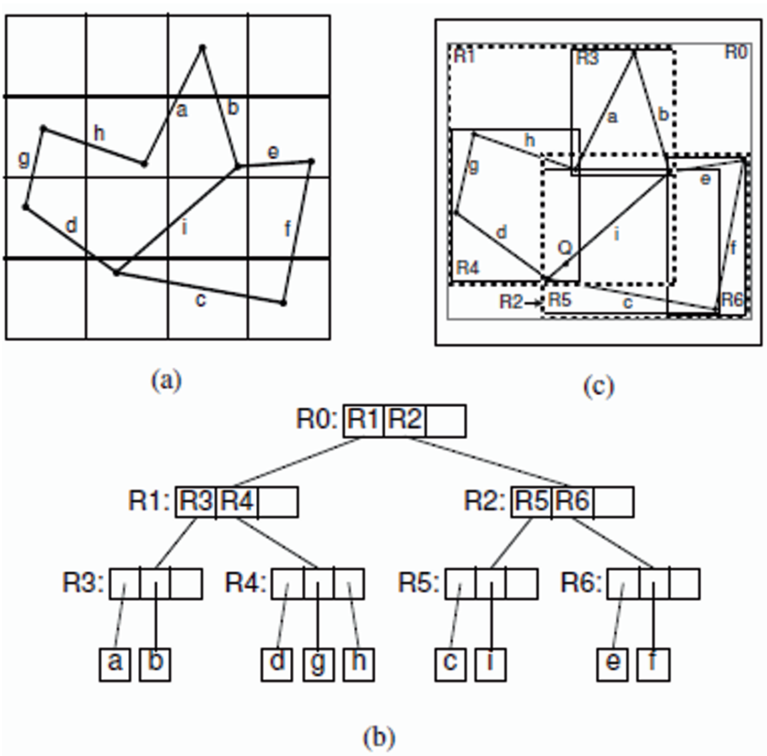

Figure 1. (a) Example collection of straight line segments embedded in a 4 × 4 grid, (b) the object hierarchy for the R-tree corresponding to the objects in (a), and (c) the spatial extent of the minimum bounding rectangles corresponding to the object hierarchy in (b). Notice that the leaf nodes in the (c) also store bounding rectangles although this is only shown for the nonleaf nodes.

The drawback of the object hierarchy approach is that from the perspective of a space decomposition method, the resulting hierarchy of bounding boxes leads to a non-disjoint decomposition of the underlying space. This means that if a search fails to find an object in one path starting at the root, then it is not necessarily the case that the object will not be found in another path starting at the root. This is the case in Figure 1(c) when we search for the line segment object that contains Q. In particular, we first visit nodes R1 and R4 unsuccessfully, and thus need to visit nodes R2 and R5 in order to find the correct line segment object i.

The second method is based on a recursive decomposition of the underlying space into disjoint blocks so that a subset of the objects are associated with each block. There are several ways to proceed. The first is to simply redefine the decomposition and aggregation associated with the object hierarchy method so that the minimum bounding rectangles are decomposed into disjoint rectangles, thereby also implicitly partitioning the underlying objects that they bound. In this case, the partition of the underlying space is heavily dependent on the data and is said to be at arbitrary positions. The k-d-Btree (Robinson, 1981) and the R^+-tree (Sellis et al., 1987) are examples of such an approach.

The second way is to partition the underlying space at fixed positions so that all resulting cells are of uniform size, which is the case when using the uniform grid (e.g., Knuth, 1998), also the standard indexing method for maps. Figure 1(a) is an example of a 4 × 4 uniform grid in which a collection of straight line segments has been embedded. The drawback of the uniform grid is the possibility of a large number of empty or sparsely-filled cells when the objects are not uniformly distributed. This is resolved by making use of a variable resolution representation such as one of the quadtree variants (e.g., Samet, 2006) where the subset of the objects that are associated with the blocks are defined by placing an upper bound on the number of objects that can be associated with each block (termed a *stopping condition* for the recursive decomposition process). An alternative, as exemplified by the PK-tree (Samet, 2004; Wang et al., 1998), makes use of a lower bound on the number of objects that can be associated with each block (termed an *instantiation* or *aggregation* threshold).

Quadtrees (Hunter and Steiglitz, 1979; Klinger, 1971) and their three-dimensional octree analogs (Hunter, 1978; Meagher, 1982) have also been used widely for representing and operating on region data in two and three dimensions, respectively (e.g., Samet, 1988). In particular, algorithms have been devised for converting between them and numerous representations such as binary arrays (Samet, 1980a), boundary codes (Dyer et al., 1980; Samet, 1980b), rasters (Samet, 1981a, 1984; Shaffer and Samet, 1987), medial axis transforms (Samet, 1983, 1985), terrain models (Sivan and Samet, 1992), boundary models (Tamminen and Samet, 1984), constructive solid geometry (CSG) (Samet and Tamminen, 1985), as well as for many standard operations such as connected component labeling (Samet, 1981c), perimeters (Samet, 1981b), distance (Samet, 1982), image dilation (Ang et al., 1990), and computing Euler numbers (Dyer, 1980). Quadtrees and their variants are to be distinguished from pyramids (e.g., Aref and Samet, 1990; Tanimoto and Pavlidis, 1975) which are multiresolution data structures.

The PM1 quadtree (Hoel and Samet, 1991; Samet and Webber, 1985) (see also the related PMR quadtree (Nelson and Samet, 1986, 1987)) is an example of a variable resolution representation for a collection of straight line segment objects such as the polygonal subdivision given in Figure 1(a).

In this case, the stopping condition of its decomposition rule stipulates that partitioning occurs as long as a block contains more than one line segment unless the line segments are all incident at the same vertex which is also in the same block (e.g., Figure 2). A similar representation has been devised for three-dimensional images (e.g., Ayala et al., 1985) and the references cited in Samet (2006). The decomposition criteria are such that no node contains more than one face, edge, or vertex unless the faces all meet at the same vertex or are adjacent to the same edge.

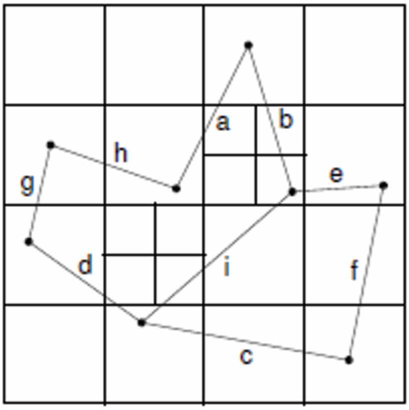

Figure 2. PM1 quadtree for the collection of straight line segment objects of Figure 1(a).

The principal drawback of the disjoint method is that when the objects have extent (e.g., line segments, rectangles, and any other non-point objects), then an object may be associated with more than one block. This means that queries such as those that seek the length of all objects in a particular spatial region will have to remove duplicate objects before reporting the total length. Nevertheless, methods have been developed that avoid these duplicates by making use of the geometry of the type of the data that is being represented (e.g., Aref and Samet, 1992, 1994; Dittrich and Seeger, 2000). Note that the result of constraining the positions of the partitions means that there is a limit on the possible sizes of the resulting cells (e.g., a power of 2 in the case of a quadtree variant). However, this means that the underlying representation is good for operations between two different data sets (e.g., a spatial join (Hoel and Samet, 1995; Jacox and Samet, 2007)) as their representations are in registration (i.e., it is easy to correlate occupied and unoccupied space in the two data sets, which is not easy when the positions of the partitions are not constrained as is the case with methods rooted in representations based an object hierarchy even though the resulting decomposition of the underlying space is disjoint). For a recent empirical comparison of these representations with respect to multidimensional point data (see Kim and Patel, 2007).

3. Example of the Utility of Sorting

As an example of the utility of sorting spatial data suppose that we want to determine the nearest object to a given point (i.e., a "pick" operation in computer graphics). In order to see how the search is facilitated by sorting the underlying data, consider the set of point objects A–F in Figure 3 which are stored in a PR quadtree (Orenstein, 1982; Samet, 1990b). The PR quadtree recursively decomposes the space in which a set of point objects lie into four equal-sized squares until each cell is empty or contains just one object (i.e., the objects are sorted into the cells which act like bins). The PR quadtree represents the underlying decomposition as a tree although our figure only illustrates the resulting decomposition of the underlying space into blocks (i.e., the leaf nodes/blocks of the PR quadtree).

The search must first determine the leaf that contains the location/object whose nearest neighboring object is sought (i.e., P in our example). Assuming a tree-based index, this is achieved by a top-down recursive algorithm. Initially, at each level of the recursion, we explore the subtree that contains P. Once the leaf node containing P has been found (i.e., 1), the distance from P to the nearest object in the leaf node is calculated (empty leaf nodes have a value of infinity). Next, we unwind the recursion so that at each level, we search the subtrees that represent regions overlapping a circle centred at P whose radius is the distance to the closest object that has been found so far. When more than one subtree must be searched, the subtrees representing regions nearer to P are searched before the subtrees that are farther away (since it is possible that an object in them might make it unnecessary to search the subtrees that are farther away).

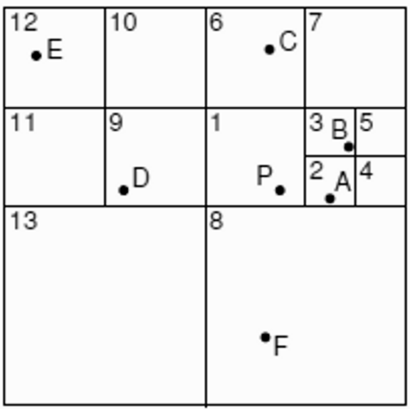

Figure 3. Example illustrating the neighboring object problem. P is the query object and the nearest object is represented by point A in node 2.

In our example, the order in which the nodes are visited is given by their labels. We visit the brothers of the node 1 containing the query point P (and all remaining nodes at each level) in the order of the minimum distance from P to their borders (i.e., SE, NW, and NE for node 1). Therefore, as we unwind for the first time, we visit the eastern brother of node 1 and its subtrees (nodes 2 and 3 followed by nodes 4 and 5), node 6, and node 7. Note that once we have visited node 2, there is no need to visit node 4 since node 2 contains A. However, we must still visit node 3 containing point B (closer than A), but now there is no need to visit node 5. Similarly, there is no need to visit nodes 6 and 7 as they are too far away given our knowledge of A. Unwinding one more level reveals that due to the distance between P and A, we must visit node 8 as it could contain a point that is closer to P than A; however, there is no need to visit nodes 9, 10, 11, 12, and 13.

4. Concluding Remarks

An overview has been given of the rationale for sorting spatial objects in order to be able to index them thereby facilitating a number of operations involving search in the multidimensional domain. A distinction has been made between spatial objects that could be represented by traditional methods that have been applied to point data and those that have extent thereby rendering the traditional methods inapplicable. In our examples, the sorting supported operations that involve proximity measured in terms of as "the crow flies". However, these representations can also be used to support proximity in a graph such as a road network (e.g., Samet et al., 2008; Sankaranarayanan et al., 2005).

The functioning of these various spatial sorting methods can be experienced by trying VASCO (Brabec and Samet, 1998a,b, 2000; Brabec et al., 2003), a system for Visualizing and Animating Spatial Constructs and Operations. VASCO consists of a set of spatial index JAVATM (e.g., Arnold and Gosling, 1996) applets that enable users on the worldwide web to experiment with a number of hierarchical representations (e.g., Samet, 1990a,b, 2006) for different spatial data types, and see animations of how they support a number of search queries (e.g., nearest neighbor and range queries). The VASCO system can be found at http://www.cs.umd.edu/˜hjs/quadtree/. For an example of their use in a spatial database/geographic information system (GIS), see the SAND Spatial Browser (Brabec and Samet, 2007; Esperança and Samet, 2002; Samet et al., 2003) and the QUILT system (Shaffer et al., 1990). Such systems find use in a number of alternative application domains (e.g., digital government (Marchionini et al., 2003)).

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GIS MODEL APPLICATIONS FOR SUSTAINABLE DEVELOPMENT AND ENVIRONMENTAL PLANNING AT THE REGIONAL LEVEL

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Abstract. A 5-year cooperation between the Universities of Munich (Germany) and Redlands (USA) has resulted in the development of GIS processing tools and models to support regional environmental planning and management. Large spatial databases were structured and modern geoprocessing technologies such as ESRI's *ModelBuilder* were used to develop frameworks of GIS models and decision support tools. The results include a Decision Support System in the form of a complete database and models that can be easily adjusted to different planning goals or regions and allow identification of land use conflicts, sensitivity analysis, assessment of development scenarios and their impacts, besides graphical representation of the processing workflows and high quality output maps. Actual planning projects were the bases for application examples in the Munich Region: the Landscape Development Concept, and the urban growth model framework.

Keywords: Regional and Environmental Planning, Natural Resource Management, Decision Support System, Modelling, GIS, *ModelBuilder*, Urban Growth, Munich.

1. Introduction – Models and GIS for Regional Planning

Regional planning is a complex and multidisciplinary task performed by various institutions and government sectors. It is the practice of spatial planning for the sustainable use of physical, biological and cultural resources of a region (Ahern, 1999). Its purpose is to protect unique and rare resources,

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control the use of limited resources, avoid hazards, manage processes of landscape change, and place human development in adequate locations (Ahern, 1999). Regional planning is also a task of coordination of contradictory social, economic and ecological interests; it is an attempt to develop and order the space in a way that considers as much as possible all public and private needs, but also solves and avoids conflicts.

Regional planning methods and instruments vary depending on the planning goals and objectives, time frame and physical scale considered, availability of data and knowledge, political support, level of participation and driving issues (Ahern, 1999). Many technologies and tools, such as Spatial Decision Support Systems (sDSS), may be used to help the decision making process in regional planning; models are particularly useful.

A model is a representation of one or more processes of the real world, an abstraction and simplification of complex systems (ESRI, 2007). Nowadays, a model is usually a computer program that takes a digital representation of one or more aspects of the real world and transforms them (Goodchild, 2005). Models may be simple representations of real processes or tools for prediction and forecasting, used to assess scenarios and reduce uncertainties about the future. Models may be repositories of knowledge, which may be used to assess scenarios and answer policy questions; models can also contribute to generation of knowledge, when the execution of a model reveals something previously unknown (Goodchild, 2005).

The GIS (Geographic Information System) technology has made it easier to create and implement models for problems of spatial nature. GIS tools help not only to process, analyze, and combine spatial data, but also to organize and integrate spatial processes into larger systems that model the real world (ESRI, 2000). Some GIS products, such as ArcGIS from ESRI use graphical representations of models (diagrams), making it easy to create, edit and execute geoprocessing workflows.

For the past 5 years, the GIS & CAD Laboratory of the Technical University of Munich (TUM, Germany) and the Chair of GIS Science of the University of Redlands (USA) have been working on the development of new GIS software processing tools and models to support environmental planning and management at the regional level.

The research cooperation involves the development of new applications of ESRI's *ModelBuilder* software for planning support, and is based on the two institutions' previous experience with both GIS technologies and environmental management and planning. It focuses on the development of GIS-based environmental modelling technology to provide new applications in the field of regional environmental planning and assessment.

This chapter presents an overview of the results of this successful cooperation, including the generation of the related geodatabases, the GIS processing model structures created with *ModelBuilder* technology, and two examples of geoprocessing applications for real regional planning projects in the Region of Munich, Germany – the regional Landscape Development Concept (LDC) and the urban growth model framework.

2. GIS Modelling Technology

GIS technology is often used to support complex environmental and planning issues. In a real regional planning, intensive spatial data processing is usually required, using geoprocessing tools to produce output datasets. During a usual GIS work for regional planning, GIS analysts use specific geoprocessing tools to perform a logical sequence of tasks (a geoprocessing workflow). They must keep track of the work steps performed and a good documentation of all input/output data; if something changes (e.g., a land use change), most of the work has to be repeated.

A GIS spatial model makes this easier – it automates the workflows by connecting tasks and processes together. It allows performing a workflow, modifying it, and repeating it with one click of the mouse, making it easier to manage the workflow and increasing the efficiency of geoprocessing.

2.1. THE “MODELBUILDER”

In the specific case of ESRI’s *ModelBuilder* GIS technology, the GIS model is graphically represented by a diagram that facilitates to create, visualize, edit and execute geoprocessing workflows, to use and reuse them, share and to apply to different geographic areas. The *ModelBuilder* innovation allows complex processes to be displayed in the form of flowcharts in a graphic user interface. The user can plan the work to be carried out, which tasks to perform and in which sequence, and then automate the workflow by easily stringing processes and tools together in the model diagram. Thanks to the diagram, every step of the process can be traced and documented on the fly. Datasets (inputs and outputs) and geoprocessing tools can be selected by drag-and-drop into the model window and connected graphically with arrows according to the processing sequence.

Planners with no GIS expertise are able to run *ModelBuilder* models because they are intuitive to use. The models also make it easier to share the planning process with other planners, decision-makers, and the public. The models may be stored and used as a template for different applications or for planning other regions with similar planning requirements.

2.2. CREATING MODELS WITH "MODELBUILDER"

The *ModelBuilder* allows to edit the structure of a model by adding and deleting processes or changing the relationships between processes, to alter inputs or outputs, to change values for the parameters of tools, and then to re-run the model to test different results. The model is dynamically updated when a change is made and the geoprocessing workflow is automated. The model may be fully documented, including descriptions, help pages, comments, and Web links in order to make it clear and easy for anybody to use it. Features also include wizards to automate the creation or change of processes, layout configuration and drag-and-drop tools, property sheets to quickly modify the properties of model components, and the possibility to save the entire model (except input data) in one XML file (ESRI, 2000).

The *ModelBuilder* window consists of a display window where the user builds the model diagram, a main menu, and a toolbar that the user can use to interact with elements in the diagram (Figure 1).

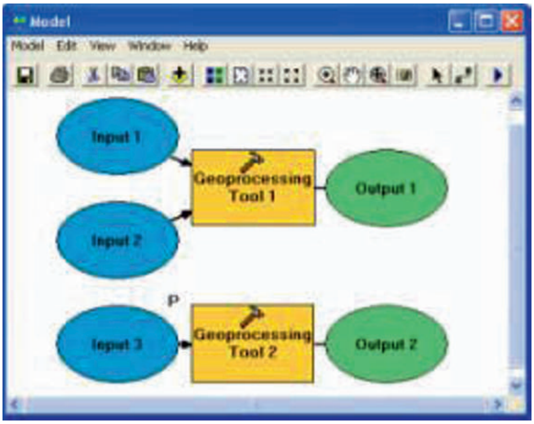

Figure 1. ModelBuilder interface: model processes and elements.

In *ModelBuilder*, a spatial model is a graphical representation of a geoprocessing workflow, i.e., one or usually multiple processes strung together. A process consists of a tool (which may be a system tool, a model or a script) and its parameter values (e.g., input and output data, a reclassification table). The components of this model graphical representation are called elements, and may be of three types (Figure 1):

- Inputs (blue ovals): are the geographic data (vector or raster) that exist before the model runs, used as input parameter values for tools in the model. Inputs may also be values (i.e., non-geographic data parameter values such as a cluster tolerance) or an SQL expression.

- Processes or tools (orange rectangles): are the operations to be performed on input data. A process may be one of the numerous ready-to-use system tools available in ArcGIS, which can be easily dragged from the *ArcToolbox* and dropped onto the *ModelBuilder* window. It may also be a script created with Python or other COM-compliant language, or even an embedded model – when an operation is complex and requires several processes it is better to arrange these processes in a separated model and to embed it into the main model. The whole embedded model appears in the main model as one single rectangle.
- Outputs (green ovals): are data generated when the model runs, created by the tools or scripts and that don't exist until the process is executed. Once created, they may be input to another process. Derived elements may also be values (non-geographic data) created by running a tool.

Input and output elements may be defined as "parameters" of a model, i.e., information that must be specified by the user. Parameters are labelled with a 'P' next to the oval symbol and are defined in the model's dialog box (Figure 2). This is the first interface that opens up when instruction is given to run a model; it has all the model parameters, some description and help.

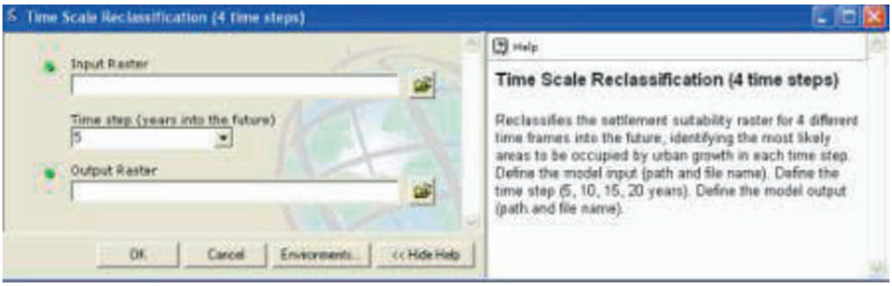

Figure 2. Example of model dialog box with parameters defined by the user and help section.

3. Application Examples – Munich Region

The greater Munich Region (or planning Region 14), with over 2.5 million inhabitants in an area of 5.503 km^2, comprised by the city of Munich and 186 municipalities in Southern Germany, is one of the fastest growing regions in Europe. The dynamic growth observed in the past 150 years, and the consequent development of infrastructure, commercial and residential areas have brought about pressures to the region's natural and cultural resources, landscape changes, intensification of land use, and threats to the quality of life. The inhabitants of the region are particularly concerned with maintaining the existing outstanding quality of rural landscapes and the open spaces for recreation purposes. Furthermore, recent and expected future developments at the national and European levels increase the uncertainties regarding the sustainability of this region.

Regional and local authorities are faced with the challenge of planning future developments for the Munich Region that guarantee a sustainable balance between use and protection of existing resources, taking into consideration the social, economic, cultural and ecological interests, public and private needs, and avoiding as much as possible impacts and conflicts.

Planners and decision-makers in the Munich Region have used environmental planning methods and modelling technologies to help planning and implementing measures for the sustainable regional development. The following sections describe two examples of practical applications of GIS models and tools developed at the regional level, which demonstrate the benefits of GIS-based modelling for decision support and scenario analysis in face of this region's complex planning issues and goals (Schaller et al., 2008).

3.1. URBAN GROWTH MODEL FRAMEWORK

The first application example is related to just one aspect of the Munich Region planning – urban development.

Most of the changes observed in this region in the past 150 years have been driven by population growth and movements, and consequent settlement development. In order to assess settlement suitability and potential future settlement development scenarios in the region, an urban growth model framework was developed, updating and upgrading existing preliminary models, testing GIS technologies and methodological approaches that could contribute to the regional planning (Mattos, 2007).

The work was divided into four consecutive phases: region characterization and segmentation; identification of development goals, principles and objectives; models design and GIS-implementation; scenarios implementtation and analysis.

In a first step, existing GIS and statistical data were collected and processed in order to provide a better understanding of the Munich Region in terms of population, socio-economy, nature protection and other relevant aspects and to identify eventual intra-regional differences and tendencies.

Cluster analysis and GIS display of statistical data showed that the region is not homogenous, having at least four groups of municipalities with distinct characteristics, development trends and requirements: (1) the densely populated city of Munich and its surroundings; (2) the dynamic area under influence of the Munich International Airport, an important source of employment and driver of urban growth; (3) the wealthy and touristic southern area, with predominance of forests and water-rich landscape; and (4) the other municipalities. Additionally, time series analysis of municipal population data provided forecasts of future population development until 2025, which corroborated those intra-regional differences.

In a second step, a review of the current Regional Plan and the local plans of four selected municipalities (one from each of the intra-regional groups previously identified), complemented by interviews with local planning authorities, provided an understanding of the planning process, the main development goals and principles at regional and local levels. The main spatial aspects related to settlement development that could be used as basis for GIS modelling were identified in these plans.

Ten settlement development models were then designed based on the Munich Region's characteristics and on the identified regional and local developments goals and principles:

- Eight "partial" suitability models (or sub-models) addressed relevant criteria and identified the favourable locations for settlement development: (1) exclusions, or forbidden areas for settlement, such as protected areas; (2) restrictions to settlement development set by plans and laws; (3) physical environment suitability, based on soil types and slope; (4) land cover/land use suitability; (5) socio-economic suitability, based on employment and education; (6) proximity to infrastructure; (7) proximity to recreation; (8) scenery beauty.
- One main suitability model combined and weighted the outputs of sub-models, adjusting them to the four intra-regional groups, and generated a settlement suitability map for the entire Munich Region (Figure 3).
- A final dynamic model added a time scale to the main model to assess potential future settlement developments in the region based on the suitability mapping and on prognoses of population and urban growth, and was used to assess potential scenarios of future development.

The models were implemented in a GIS environment with ESRI's *ModelBuilder*, using the available system tools in *ArcToolbox* and additional functionalities implemented through Python scripts (see an example in Figure 4). Various elements of the models (input/output data, suitability values and relative weights of model criteria) were set as parameters so they could be defined by the user.

The models' dialog boxes were customized and all models documented, including explanations about their purpose, constrains and limitations of use, and instructions. A qualitative sensitivity analysis was used to adjust model variables (relative weights of model criteria and suitability values).

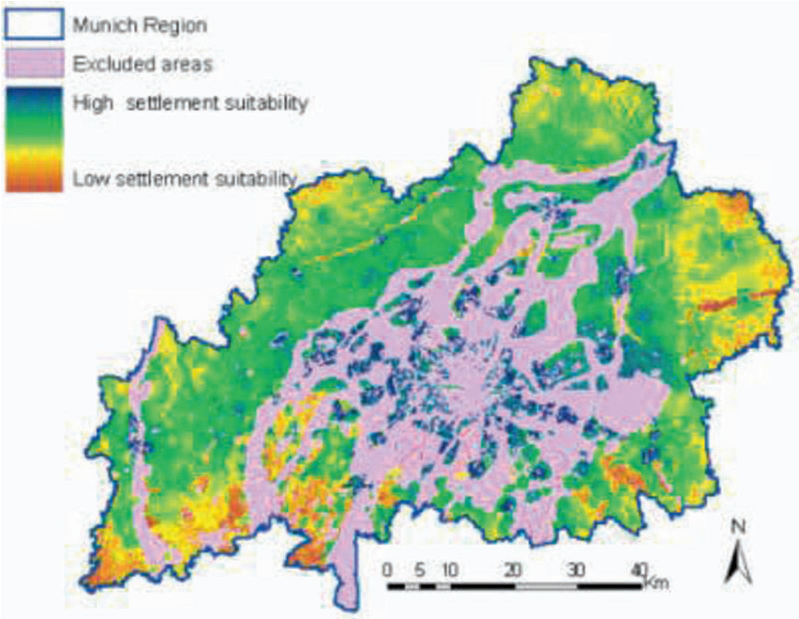

Figure 3. Output of the main suitability model for settlement development.

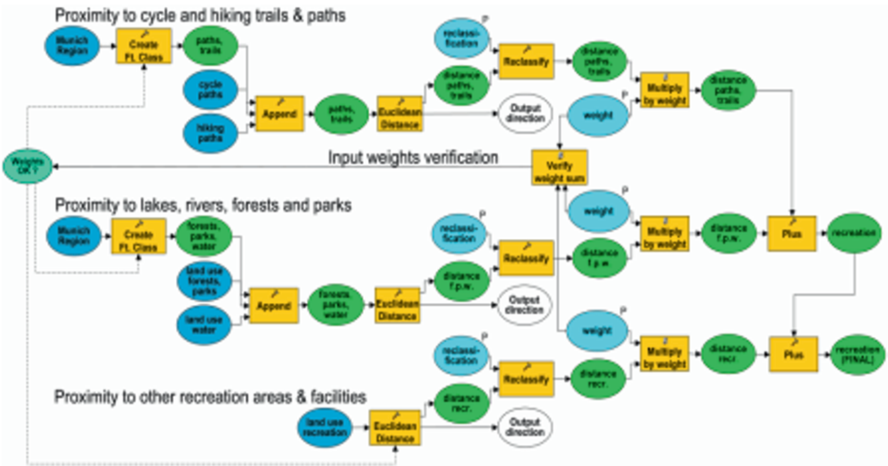

Figure 4. Graphical representation of the proximity to recreation suitability model.

Three development scenarios developed by local and state governments were implemented using the dynamic time model and their consequences were analyzed: (1) high migration scenario, resulting in 11% population growth and 13,652 ha of new settlements until 2023; (2) stagnation scenario with 6.6% population growth and 6,865 ha of new settlements until 2023;

(3) airport expansion scenario (construction of a third runway) with 2,271 ha of new settlements until 2020 in 62 municipalities near the airport.

3.2. LANDSCAPE DEVELOPMENT CONCEPT (LDC)

Contrary to the previous example, this GIS modelling application is related not only to settlement, but to all aspects of the Munich Region planning.

In face of the Munich Region's characteristics, potentials and limitations, past and future development trends, existing development guidelines and norms, values and desires of the population, and many complex planning challenges, a *Landscape Development Concept* (LDC) was developed by request of the Regional Government of Upper Bavaria.

The LCD is a planning concept for the sustainable development of the region that serves as a basis for decision makers in the fields of nature protection, ecology and landscape development. It is a comprehensive regional landscape development concept for nature protection and landscape management, which also includes suggestions for the Regional Plan and measures for areas beyond the regional borders, so as to ensure the sustainable development of the Munich Region (Schaller and Schober, 2007).

But the LDC is more than just a document with goals and proposals. Based on GIS and environmental planning methods and on advanced modelling technologies that allow constant updating to follow up the impacts of growth and the results of planning measures, the LDC is a decision support system that makes an important contribution to the regional sustainable development, natural resources management, conservation and visual landscape quality. The latest GIS technologies were used for its development, including automated processing and documentation of geoprocessing workflows with the *ModelBuilder* tool.

Some of the main issues and questions faced by the planners in the Munich Region included:

- The quality and sensitivity of natural resources.
- Environmental impacts of development on population.
- Nature and landscape scenery.
- Potential development scenarios.
- Which qualitative and quantitative changes are caused by these developments and how can this be compensated by planning measures.
- How can complex issues be communicated efficiently to the decision makers and to the public?

The LCD addressed these issues and questions, having as goals:

- Maintenance, protection, and development of nature and landscape as compensation for intensively used urban areas.
- Protection and sustainable use of natural resources.
- Development of open-space and green-belt concepts as a foundation for the maintenance of the living quality.
- Development of proposals for sustainable land use and land use development, especially for commercial, residential, transportation, and water management uses, besides agriculture, forestry, and recreation.

The first step was the creation of an issue-based database structure containing all necessary spatial information to solve these planning issues, including abiotic and biotic resources, land-use data, and planning data (e.g., master plans and landscape plans, regional resource plans, infrastructure, protected areas, biotope conservation concept, regional water management plans, etc.). The data was structured in an ArcGIS geodatabase and documented with the software VISIO.

The next step was the assessment of the natural resources, their function, quality and development potential. Biotic and abiotic resources were analyzed; their actual state, functions (e.g., groundwater recharge, energy exchange, ventilation, species diversity and biotope network, recreation) and main risks (e.g., erosion, flooding, noise, deforestation, etc.) were documented and mapped.

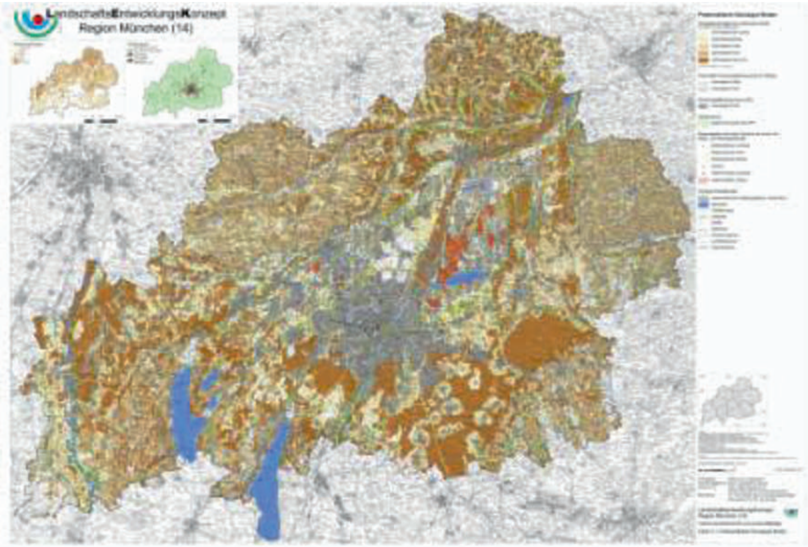

Figure 5. Example of resource map – soils that require protection.

Resource assessment maps or function maps were created: soils and potential agricultural yield map, current land use map, ground and surface water map, protection species and habitats map (Figure 5).

The following step was the assessment of the potential impacts (and impact intensity) of actual and planned land uses on the natural resources, as well as impacts on human requirements (e.g., recreation). The impacts and conflicts were modelled and mapped using GIS geoprocessing and modelling tools and the *ModelBuilder*. In a first design phase, very simple conceptual models were developed to describe the relationships between resource potentials and sensitivity of impacts. In a second design phase, each conceptual model was further detailed, including direct relationships to the existing geodatabase and scientific assessment criteria from literature and expert ratings. Examples are groundwater recharge, flooding risk, soil erosion hazard, and soil potential models (Figure 6).

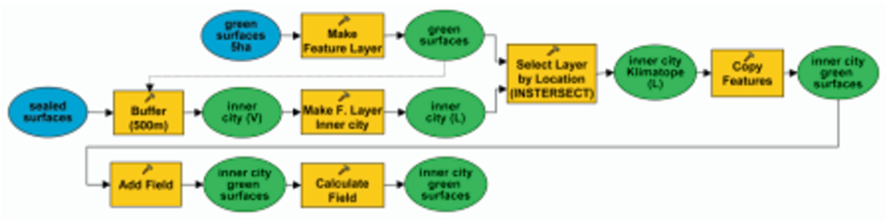

Figure 6. Example of LDC model – open spaces connection.

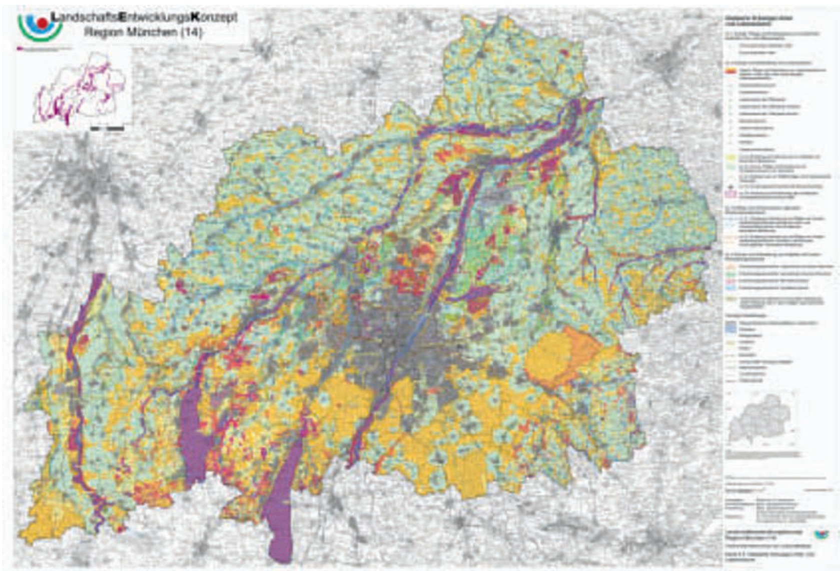

Figure 7. Example of a goals map – protection of species and wildlife habitats.

In order to assess potential impacts and formulate general and specific goals for sustainable land use and resource protection, the resource and land use maps were overlaid in a processing model to show the actual conflicts between land use and resource functions. Based on the intensity of conflicts in relation to the protection and sustainable development goals, general goal maps were produced and displayed as thematic maps (Figure 7).

Based on the results obtained, an overall landscape concept was developed for the Munich Region and landscape safeguard instruments derived from the Regional Plan. Suggestions were also made on how to implement the goals through actions.

Finally, the Decision Support System for planning and decision making was delivered in the form of a complete database containing geodata and *ModelBuilder* models, which can be edited, updated and used for assessment of different land use-based development alternatives.

4. Conclusions

The results of the two applications described in this chapter exemplify the benefits of using modelling and scenarios assessment in a GIS environment to help regional planners visualize suitable areas for desired developments, to locate and quantify the consequences of alternative scenarios, and to reduce uncertainties about the future. These applications show the potential of GIS-based modelling and particularly *ModelBuilder* to help optimize and speed up planning procedures, to support decision-making, and to provide new possibilities of documenting planning procedures and decisions.

The GIS-based models allowed integrating a lot of information in a systemic way, to produce quantified, georeferenced, and visual outputs. Despite limitations of GIS as a modelling platform, particularly for dynamic time models, the implementation of models for the Munich Region was facilitated by the *ModelBuilder*, where geoprocessing workflows were automated in a graphical environment that facilitates creating, changing, and executing models.

The graphical workflow diagrams and model output maps made it easier to communicate the complex planning and assessment steps that had been carried out to decision makers and also to the public, facilitating participation, efficient teamwork and acceptance of the decisions taken.

Furthermore, these models developed for the Munich Region can potentially be replicated and adapted to other areas, development goals, and scales. The urban growth model framework, for instance, has already been successfully adapted and tested for the region of Redlands, California.

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APPLICATION OF NEURAL NETWORKS IN IMAGE PROCESSING AND VISUALIZATION

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Abstract. Artificial Neural Networks (ANNs) are supporting tools for image processing, even if currently they are no longer considered as the default best solution to any classification or regression problem. ANNs conserve their role as non-parametric classifiers, non-linear regression operators, or (un)supervised feature extractors. The chapter reviews the applications of ANN methodology in all the steps of the image processing chain, starting from data preprocessing and reduction, image segmentation, up to object recognition and scene understanding.

Keywords: Artificial Neural Networks (ANN), Image Processing.

1. The Connectionist Paradigm

The Artificial Neural Networks (ANNs) emerged more than 60 years ago as biologically inspired tools for learning complex mappings from a set of examples. The most important architectural feature that distinguishes an ANN from other computing systems is that the computing power and memory are not concentrated in its processing units, the artificial neurons, but in the network interconnecting these neurons. On the other hand, the most important functional feature of an ANN is its capacity to learn, i.e., to define the action to take for each pattern applied at its input in the execution mode, based on the examples presented to the system in the training mode. The learning occurs at the level of the network interconnecting the neurons and typically is ends when the system is in the execution mode. Traditional

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Turing-like computing machines typically process data by using a fixed program, prepared in advance.

The mimicking of the brain makes the ANN very attractive for many soft-computing tasks, but the history of ANNs was certainly not smooth. Periods of spectacular developments and oversized expectations alternated with periods of bitter disappointments and relative stagnation.

The first models of artificial neurons were introduced by McCulloch and Pitts (1943) and the first physiological learning rule was formulated by Hebb (1949). Hebb's postulate simply states that the effectiveness of a synapse between two neurons is increased by the repeated activation of one neuron by the other across the synapse.

The way towards solving engineering and real-life problems was opened by Rosenblatt (1958) who designed the perceptron. This approach allowed applying ANNs for pattern-recognition and classification problems, the basic tasks that define their specific capabilities even today. As a linear version of the perceptron, Widrow and Hoff (1960) introduced ADALINE (Adaptive linear element) based on the least mean square (LMS) algorithm.

A wave of optimism followed the development of these ANN models, which seemed to be able compute everything. The full understanding of the real state of the art occurred at the end of the sixties, when Minsky and Papert (1969) published their famous monograph, which did not encourage further work on perceptrons, demonstrating their limitations and restrictions. At the time, only algorithms for training ANNs with one layer of mutually independent neurons were known. Unfortunately, these single layer perceptrons were inherently not able to solve problems that were not linearly separable. On the other hand, no algorithm was then known for the training of multilayer perceptrons, the ANNs that were in theory able to handle problems of real-life complexity.

Therefore, the interest in ANNs decreased dramatically and, for almost a decade, only a few pioneers continued their efforts to overcome the drawbacks. Grossberg (1980) established the principle of self-organization that provided a basis for ART (Adaptive Resonance Theory) networks, Hopfield (1982) published his seminal paper on recursive networks, the forerunners of modern ANNs, Kohonen (1982) developed the concept of Self Organizing Maps (SOMs) and Kirkpatrick et al. (1983) introduced the concept of simulated annealing.

The long waited for major breakthrough came when the Parallel Distributed Processing Group at the University of California-San Diego, led by Rumelhart and McClelland (1986), proposed the Back Propagation (BP) algorithm. BP allowed the training of multilayer ANNs, overpassing the limitations of linear separability. Ironically, the BP algorithm was in fact published 12 years earlier by Werbos (1974), in his PhD thesis, but went un-noticed. This essential development greatly stimulated the research in the field of ANNs, as it became feasible to train not only single layer perceptrons, but also ANNs having one or more hidden layers. Such ANNs can, in theory, be trained to perform virtually any regression or discrimination task. Moreover, no assumptions are made as with respect to the type of the input variables, which may be nominal, ordinal, real or any combination hereof.

Broomhead and Lowe (1988) designed a new feedforward network based on Radial Basis Functions, as an alternative to the multilayer perceptron. Several modalities for the implementation of the connectionist paradigm and for training the networks (Moller, 1993) became available. The newly considered neuron activation functions were able to generate any analogue or discrete output values, by operating on a weighted sum of the inputs (first order), a weighted sum of products (second order) or polynomials (higher order) of the inputs.

It has been proven that feedforward ANNs, with only one hidden layer, are universal approximators for analogue input and analogue output, as well as for other combinations of inputs and outputs. On every compact support, compact range function can be approximated as well as desired with regard to uniform convergence, i.e., to the L_∞ norm.

ANNs can be seen as elements of autonomous agents, featuring the three basic features of intelligence: the potential to learn, to communicate and to establish complex, yet flexible organizational structures (Fletcher et al., 1998). Systems consisting of a population (or more) of agents adapting their behaviour to the environment through evolution have a better capability to handle tasks in a non-stationary environment involving chaos, randomness and complex nonlinear dynamics (Fogel, 2000). This naturally leads to the concept of Evolutionary Intelligent Agent (EIA), merging the agent-based and the evolutionary computation approaches (Cristea, 2000; Cristea et al., 2000). The EIA approach brings together the two main forces of adaptation: learning, which occurs at the level of each agent, and evolution, which takes place at the level of the population of agents and unfolds at the time scale of successive generations. The EIA has the potential to efficiently address complex real-life problems, describing systems in non-stationary environments, that cannot be handled by traditional algorithms. This approach moves from the resources and capabilities of individual ANNs, to the evolving ANN populations. Applications of the EIA concept include multiresolution conceptual learning (Meystel, 2000), information retrieval (Pereira and Costa, 2000), personalized web learning/teaching (Cristea, 2000), authoring models for adaptive hypermedia (Cristea, 2005), cluster optimization (Pereira et al., 2007), etc.

2. ANNs in Image Processing and Visualization

The connectionist paradigm has generated a great deal of excitement in using ANNs for tasks ranging from pattern recognition to identification and control of dynamical systems with unknown nonlinearities or randomness. This range includes the ANN application to image processing. Due to their approximation capabilities, as well as their inherent adaptability, ANNs present a potentially appealing alternative for all image processing steps, from the low level pixel processing, up to the level of image understanding. Furthermore, from a practical perspective, the massive parallelism and fast adaptability of neural networks holds the promise of efficient implementation of algorithms mimicking tasks performed by the visual and central nervous systems of living organisms.

In most applications ANNs are used as classifiers and the main difficulty is the poor transferability of classifiers, especially when used in critical applications, such as medical or military. A classifier trained on patterns with a specific class distribution, can have a poor or even unacceptably performance when working on patterns with another class distribution. The solution has been to use an ensemble of classifiers and to exploit the differences of their individual behaviour, based on the hypothesis that classifiers will not fail simultaneously. Two of the most popular ensemble algorithms are *bagging* (Breiman, 1996) and *boosting* (Schapire, 1990; Freund, 1995; Freund and Schapire, 1996). Boosting changes adaptively the distribution of the training set based on the performance of previously created classifiers, whereas *bagging* changes stochastically the distribution of the training set. Boosting uses a weight for voting determined by the performance of each classifier, whereas bagging uses equal weight voting (Kotsiantis and Pintelas, 2004). Ensemble algorithms outperform individual classifier systems in all problems of practical interest.

Classification and regression problems tend to involve large input dimensions, especially when the algorithms operate at the level of pixels. Some modalities, such as confocal microscopy or CT/MR medical imaging are 3D and require either feature-based pattern recognition or sparse sampling of the images to provide a good computing efficiency (Candès et al., 2006; Donoho, 2006).

A lot of interest has been shown recently in using ANNs, frequently SOMs, for the automatic classification of land surface forms based on morphometric features obtained from DEM – digital elevation models compiled from contour lines or from other sources like SRTM – the Shuttle Radar Topography Mission, combined with spectral information from remotely sensed data. SOMs are unsupervised ANNs which cluster high dimensional input vectors into a two dimensional output space revealing regularities and correlations in data (Kohonen, 2001; Li and Eastman, 2006). SOMs have been used in a wide variety of areas such as classification of remote sensing data (Duda and Canty, 2002 ; Jianwen and Bagan, 2005), information visualization and knowledge discovery (Koua, 2003) or class modelling (Marini et al., 2005).

The main tasks in an image processing chain are shown in Table 1 and are briefly discussed in the following.

TABLE 1. Basic tasks in the image processing chain.

Task	**Operation**	**Input**	**Function**	**Output**
Preprocessing	Construction of image from sensor data/filtering	Input (raw) data (pixel or local)	Image construction/restoration/debluring/enhancement Contrast enhancement Noise reduction	Restored or enhanced image (pixel)
Data reduction	Windowing to extract relevant parts of the image or to transform the image	Image (pixel)	Feature or structure extraction, compression, DCT, gabor and wavelet transformations	Local features (image structure), reduced size image (pixels) transformed image (pixels)
Segmentation	Decomposition of the image in accordance to certain criteria	Image or feature sets (pixel, local structure)	Pixel segmentation (coherent partition, colour recognition) Feature segmentation (segregation of textures, clustering)	Partitioned image (list of segments and clusters)
Object recognition	Identifying, describing and classifying objects in the image	Image, feature sets and/or Segments (pixel, image structure)	Pixel-based object recognition (template matching) Feature-based object recognition (position, orientation, scale)	Partitioned and labeled scene (list of objects)
Scene understanding	Eliciting of high level information from the image	Feature-, segment-, or object-sets (image structure, list of objects), lighting, context	Image analysis	Meaningful object arrangement (semantic knowledge)

The abbreviations listed at the end of this chapter will be used to specify the types of ANNs mostly used for each specific task (after the comprehensive review by Egmont-Petersen et al., 2002).

2.1. ANN DATA PREPROCESSING

Preprocessing is an essential step comprising a variety of tasks necessary to make data adequate for the intended visualization and the subsequent steps of image processing. This step can consist in preparing raw data from a system of sensors, or use data received from external sources or retrieved from data bases. Preprocessing ensures the coherence of input data, allowing to be submitted to similar further processing. Preprocessing might restore wrong or missing data, before being used to built the primary image. The generated image can be morphological, i.e., describing the structure of an object or scene, such as a photo, or functional, giving the spatial distribution of the values of certain parameters of interest. The separation between the two types of images is not a clear cut. In many applications a fusion of data from various sensors (multimodal images) can be used. The filtering task is a component of the same step, consisting in a change of the primary image from the point of view of some selected features, usually without changing the dimensions of the original image. Such operations include image deblurring, contrast enhancement and noise reduction, which are usually performed on a pixel or local basis. The fast parallel operation and the ease with which ANNs can be embedded in hardware make neural implementation attractive for image preprocessing. ANNs such as FF(R), FF(C), HP, CNN, GANF, ART, ADA, NF, and O are mostly used.

2.2. ANN DATA REDUCTION AND FEATURE EXTRACTION

The *data reduction/feature extraction* step consists of operations that extract components representing the image, an object, an area or some characteristic of the image. The two most important operations belonging to this processing step are image compression and feature extraction. The image compression is important for image transmission and storage, and it is directly related to the coding/decoding of images. The recent success of compressive sensing and coding has shown the effectiveness of ℓ_1 minimization for recovering sparse signals from a limited number of measurements, apparently contradicting Shannon's theorem (Candès et al., 2006, Donoho, 2006). The feature extraction can focus on particular geometric or perceptual characteristics of the image, such as edges, corners and junctions, or on an application dependent characteristic, such as facial features. The number of extracted features is usually significantly smaller than the number of pixels in the input window, which facilitates subsequent image segmentation or object recognition.

ANNs such as FF(RG), FF(AA), FF(P), RBF, SOM, LVQ, HP, NF, O are currently used for this processing step.

2.3. ANN IMAGE SEGMENTATION

The *segmentation* step comprises the operations that partition an image into regions that are coherent with respect to some criterion. One example is the segregation of different textures. However segmentation can be based on more complex combinations of texture, shape and other application dependent features. The spectacular development of mobile devices has generated stringent requirements for efficient memory and computing power management, to allow further miniaturization, increased functionality and reduced power consumption. Hence, segmentation is a major concern, to allow various parts of an image to be processed differently, in accordance to their specific role. Segmentation performed at pixel level is a classification task that simply assigns labels to individual pixels or voxels. In another approach, segmentation is a clustering, based on image local features. A large variety of ANNs, comprising FF(RG), FF(CL), FF(RC), RBF, SOM, LVQ, HP, CNN, AM, P, CP, NF, and O, are used for image segmentation.

2.4. ANN OBJECT RECOGNITION

The *object detection and recognition* is an important step towards image understanding, but also towards an efficient tracking of the elements of interest in an image. Determining the position and, possibly, the orientation and scale of specific objects in an image, and classifying these objects, is currently performed with FF(AA), FF(CL), FF(SW), FF(RC), SOM, HP, ART, AM, NEO, HO, NF, and other ANNs. This step is can be essential in medical applications (Bobo and Lee, 2000, Cenci et al., 2000), and for a better use of computing and bandwidth resources (Wang et al., 2005)

2.5. ANN IMAGE UNDERSTANDING

Image understanding is the ultimate goal of automatic image handling, allowing to extract meaningful results from the vast and ever increasing amount of continuously collected data and information. Progress in obtaining high level (semantic) knowledge of what an image shows has been attempted by using various approaches, using ANNs such as FF(CL), SOM, AM, DT, BN and O. Unfortunately, image understanding remains a difficult and even a controversial ANN application, because of the ANNs' black-box character and because of the need for a large number of images for the training and testing sets.

3. Neural Networks in Geographic Information Systems

In 2003, NASA released SRTM data that can be freely downloaded at http://seamless.usgs.gov (Falorni et al., 2005; Miliaresis and Paraschou, 2005). Consequently, landform information recorded in a DEM, as a regularly spaced elevation matrix, became widely available and could be combined with land cover information derived from multi-spectral satellite data (e.g., Landsat ETM+). This wealthy source of information stimulated many studies that address a large range of applications such as topography and terrain characteristics (Rabus et al., 2003; Gorokhovich and Voustianiouk, 2006), volcano morphology (Wright et al., 2006), vegetation studies (Kellndorfer et al., 2004), analysis of large aeolian bedforms (Blumberg, 2006), hydrologic modelling (Hancock et al., 2006; Ludwig and Schneider, 2006), glacier flowing (Kääb, 2005) and topography classification (Iwahashi and Pike, 2006).

Figure 1 shows schematically how a landscape can be described in terms of its morphology (geometric shape), land cover (what lies upon it) and land use (what it is used for).

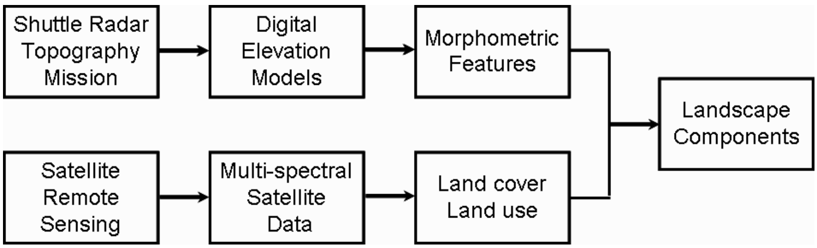

Figure 1. Landscape component extraction.

The analysis of GIS images involves either supervised or unsupervised classification. ANNs are increasingly used for the purpose of determining spatial patterns. Unsupervised classification is based on pixel level analysis, with the purposes of classifying image objects and entities, by using tone, texture and hue (Ehsani, 2007). Supervised classification involves referencing the pixels to actual site conditions and the colour balancing of the images. Landscape patterns, important in the area of landscape ecology, can also be ascertained through the analysis of pixels, i.e., their shape, colour, connectivity, direction, edges and patchiness. The weighting of pixels and their inter-relatedness provides clues about the relationships of objects on the landscape.

In transportation problems (Miller, 1999), a dynamic approach is used. The variations of the vehicular traffic through a city with respect to the time in the day, road network capacity and weather has to be taken into account. In the case of an accident or some other event causing the flow of traffic to change, ANNs can be used to input all variables describing the event, and to output the optimum re-routing until the traffic flow is stabilized. In such a case, GIS mapping is used and spatial data acts as one of the input variables into the ANN. A map server can be updated with the latest conditions and transfer those to vehicles, allowing individual drivers to follow the best selected re-routing. Such an approach is obviously useful for emergency vehicle access purposes.

At another time scale, a Land Transformation Model (LTM) based on ANNs and GIS has been developed to simulate land use change and urban development (Pijanowski et al., 2001). LTM uses population growth, transportation factors, proximity or density of important landscape features such as rivers, lakes, recreational sites, and high-quality vantage points as inputs to the model and tries to predict future developments in a transferable approach. Information derived from an historical analysis of land use change has been used to train such systems and conduct forecasting studies. The results can be used by planners and resource managers to reach better decisions affecting both the environment and local and regional economies.

4. Conclusions

The last decade has brought a change of attitude towards ANNs. On one hand, ANNs are no longer considered as the default best solution to any classification or regression problem. On the other hand, a large scale use of ANNs to solve GIS related problems can be observed. In many cases, ANNs are now combined with genetic algorithms and with other Artificial Intelligence methodologies, to generate new complex approaches. In fact, only the basic bio-inspired features including the massive parallelism, the distributed functionality, the avoidance of a predetermined program in favor of the use of a set of examples are essential and are successfully used in all applications. ANNs are interesting as tools in cases when there is a real need for an adaptive approach or for a fast, parallel solution. The relatively new approaches, such as the support vector machines (Vapnik, 1998), provide valuable alternatives.

ANNs conserve their role as non-parametric classifiers, non-linear regression operators, or (un)supervised feature extractors.

Abbreviations and Symbols

AA	Auto-association	HO	Higher order network
ADA	ADALINE	HP	Hopfield
AM	Associative memories	LVQ	Learning vector quantization
ART	Adaptive resonance theory	NEO	Neocognitron
BN	Neural belief network	NF	Neuro-fuzzy
CL	Classification	O	Other
CNN	Cellular	P	Perceptron
CP	Counterpropagation network	RBF	Radial basis function
DT	Neural decision tree	RG	Regression
FF	Feed-forward	SOM	Self-organizing feature map
GANF	Generalized adaptive neural filters	SW	Shared weights

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DATA PROCESSING FOR HEAVY METALS ACCUMULATION IN URBAN AREAS

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Abstract. Industrial activities, coal burning, and automobile exhausts are mainly responsible for the increasing emissions of heavy metals into the atmosphere. Heavy metals are easily dissolved in rainwater and deposited over local, regional, and global scale making a major ecological and health problem. In the urban area of Belgrade the ambient air concentration of Zn in the PM10 and PM2.5 was the highest but the limit values of toxic trace elements according to WHO and EC Air quality guidelines were not exceeded with regards to Ni. In some surface waters of Serbia presence of harmful substances Cr^{6+} and Hg was also confirmed. Depleted Depleted Uranium (DU) is toxic for living organisms as a heavy metal. An investing-ation of the contents of DU in the soil of targeted locations on West Balkan countries shows that mobile phases are in the range 50–90% which is indicated strong affinity for DU mobilization through the soils and potential dangerous for underground waters.

Keywords: Heavy Metals Accumulation, Urban Area.

1. Introduction

Heavy metals in the atmosphere are derived from a variety of sources including natural phenomena (i.e., the Earth's crust, the oceans, volcanic activities, the biosphere), and a number of anthropogenic processes (i.e., fossil fuel burning, waste incinerators, various industrial activities, traffic,

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etc.). Once in the atmosphere, heavy metals are easily dissolved in rainwater and deposited over local, regional, and global scale making the perturbation of biogeochemical cycles of trace elements a major ecological and health problem. The two principal sources of toxic metals in soils, in addition to contributions from the atmosphere, are the disposal of ash residues from coal combustion and disposal of commercial products on land (Nriagu and Pacyna, 1988). Roadway dust receives varying inputs of anthropogenic metals from a variety of mobile or stationary sources, such as vehicular traffic, industrial plants, power generation facilities, residential oil burning, waste incineration, construction and demolition activities and resuspension of surrounding contaminated soils. The presence of these potentially toxic contaminants in particulate matter is traditionally characterized in terms of total metal concentration, although it has been recognized that the environmental significance of a metallic element depends, besides other factors, on its specific partitioning within or on solid matrices.

Emissions into aquatic ecosystems stem mainly from the atmosphere, metal smelters, coal burning and the dumping of sewage sludge. Due to mobilization of metals into the biosphere, their circulation through soil, water and air has greatly increased (Nriagu and Pacyna, 1988).

Recruitment of elements in evolution has not only been governed by chemical properties but also by abundance in the Earth's crust. There are higher order elements that most likely have not become essential only because of their lower abundance as compared to a lighter element of the same group (Clemens, 2006). Therefore, heavy metals are entering in the environment and sharing with natural cycles. For example, heavy metals emitted in atmosphere are removing by atmospheric deposition. The contribution of atmospheric deposition to heavy metal accumulation has been evidenced for forest and other types of vegetation (Berthelsen et al., 1995). Plant leaves are used as indicators of heavy metal pollution. In industrial and urban areas, higher plants can give better quantifications for pollutant concentrations and atmospheric deposition than non-biological samples. Therefore, using plant leaves primarily as accumulative biomonitors of heavy metals pollution has a great ecological importance (Tomašević et al., 2004; Clemens, 2006). Relevant for plants and algae are mostly soil and water metal content (Clemens, 2006). Of major concern, with respect to plant exposure as well as human food-chain accumulation, are the metalloids arsenic (As) and selenium (Se), and the metals cadmium (Cd), mercury (Hg), and lead (Pb) (McLaughlin et al., 1999).

2. Presence of Heavy Metals in Local Urban Areas

2.1. HEAVY METALS IN BELGRADE'S ATMOSPHERE

2.1.1. Atmospheric heavy metals deposition at urban locations in Belgrade

Direct collection of atmospheric deposition using bulk sampling devices offers a practical approach to monitor atmospheric heavy metals deposition providing valuable information on the influences of atmospheric inputs of heavy metals on the surface environment. Samples of atmospheric deposits were collected from June 2002 to August 2003 at the three urban locations in Belgrade using bulk deposition samplers, and were analyzed for heavy metal concentrations. Average values of daily atmospheric deposition of heavy metals in the Belgrade urban area are given in Table 1.

TABLE 1. Average daily atmospheric deposition of heavy metals (μgm^{-2} day^{-1}) in the Belgrade urban area.

	Cd	Cr	As	Ni	V	Zn	Cu	Pb
Student square	0.55	0.62	1.15	4.51	10.49	65.09	249.00	44.37
Botanic garden	0.62	1.69	4.52	7.01	14.82	109.83	71.81	83.21
Autokomanda	0.63	2.59	12.95	19.70	72.11	180.39	66.35	107.85

Based upon these results, the study attempted to examine elemental associations in atmospheric deposition and to indicate the potential sources of heavy metal contaminants in the region. Various sources were identified by a principal component analysis as resuspended soil particles oil combustion, emissions from industrial activities and traffic (Tasić et al., 2004).

2.1.2. Heavy metals contents in PM10 and PM2.5 airborne of urban air in Belgrade

An assessment of air quality of Belgrade was performed by determining the trace content in airborne PM10 and PM2.5 in 2 years period. Samples were collected at two locations in a heavy polluted area. The total mean concentrations of individual metals detected are shown in Tables 2 and 3.

TABLE 2. Heavy metal concentrations in PM10 (ng m^{-3}).

	Pb	Cu	Zn	Mn	Fe	Cd	Ni	V	Al	Cr
Mean	46.5	71.3	1389.2	20.8	1462.9	1.4	17.7	36.6	873.8	10.2
σ	128.5	118.7	2313.4	15.9	1911.9	2.2	17.7	48.8	914.1	11.4

Results indicated that the ambient air concentration of Zn in the PM10 and PM2.5 was the highest. Also, the highest Enrichment Factor (EF) value was obtained for Zn, following with high EF for Cd and Pb in PM10, reflecting importance of anthropogenic inputs. The limit values of toxic trace elements from WHO and EC Air quality guidelines were not exceeded with expect to Ni (Rajšić et al., 2006).

TABLE 3. Heavy metal concentrations in PM2.5 (ng m^{-3}).

	Pb	Cu	Zn	Mn	Fe	Cd	Ni	V	Al	Cr
Mean	21.0	20.8	1998.0	15.2	1081.2	0.9	28.4	59.8	1180.3	6.2
σ	27.0	19.2	1846.4	13.7	1360.3	1.2	43.1	56.3	1657.4	3.8

The significant primary source of heavy metal emission in the air in Belgrade region is Coal Fired Power Plants (CFPP) Nikola Tesla A and Nikola Tesla B located at south west direction about 50 km away in Obrenovac that are using low caloric lignite. Lignite combustion produces huge amounts of ash, approximately 20% of the amount of lignite which enters the process. Level of emitted toxic elements in the particles, oxides and the gaseous phase depends on their contents in coal. To this day the investigation did not include determination of toxical elements in flying ash particles that are going into atmosphere. One of the investigations shows that 1 t of Kolubara lignite during combustion is releasing 1.4 g As and 0.4 g Hg (Vukmirović et al., 1997). It is important to mention that daily lignite consumption in these plants is 90,000 t/day.

2.2. HEAVY METALS ACCUMULATION IN BELGRADE'S TREE LEAVES

The results of the measurements of heavy metal concentrations in tree leaves from city parks showed the accumulation of Cu, Pb, Zn and Cd, reflecting atmospheric concentrations and soil contamination. The influence of atmospheric deposition, wet and dry, was significant, and the soil contamination was mostly the result of it. Horse chestnut and linden could be a good choice for Belgrade urban areas, where they are very abundant species. Especially high heavy metal contents were measured in horse chestnut leaves, indicating a better response to atmospheric heavy metal pollution. Leaves of deciduous tree species horse chestnut (*Aesculus hippocastanum* L.) and Turkish hazel (*Corylus colurna* L.) were used as accumulative biomonitors of trace metal pollution in urban area of Belgrade. Two successive experimental years (1996 and 1997) with remarkably different atmospheric trace metal concentrations were analyzed. Trace metal concentrations of Pb, Cd, Zn and Cu were analyzed on a single leaf level. An increase of trace metal concentrations in leaves of *A. Hippocastanum* reflected a higher trace metal atmospheric pollution. The contents of Pb and Zn in soil for the same period also followed this trend. As accumulation of trace metals was more pointed out in *A. Hippocastanum* than in *C. Colurna*, the former may be suggested as a suitable biomonitor (Tomašević et al., 2005, 2006).

We evaluated the reliability of biomonitoring heavy metal pollution by horse chestnut and linden leaves, common species found in Belgrade city parks. The results show that the highest concentrations of heavy metals were found in horse chestnut leaves at Studentski Park site, amounting to 110.2, 20.3 and 4.9 mg g^{-1} dry weight for Cu, Pb and Cd, respectively, which are considered above toxic levels for plants (Tomašević et al., 2004).

Analyses of Pb, Cu, Zn and Cd contents in single leaves pointed to a high correspondence with the level of atmospheric pollution. The significant concentration variability is a consequence of different trace metal concentrations in each single leaf. Leaf water status is correlated with the level of plant resistance to trace element effects and leaf damage. The response of *A. hippocastanum* to the change in concentrations of trace metals in the atmosphere corroborates our choice of this plant species as a suitable biomonitor of air pollution in urban areas (Tomašević et al., 2008).

2.3. HEAVY METALS IN SURFACE WATERS OF SERBIA

The total water inflow in Republic Serbia is around 162.5 billion m^3 per year; the total runoff from our territory is about 178.5 billion m^3 of water per year; the total domicile water is around 16 billion m^3 per year; the total precipitation is around 65 billion m^3 per year and the total evaporation is around 49 billion m^3 per year. From the territory of the Republic Serbia waters run in to Black Sea (approximately 176 billion m^3 water or 93% through Danube and its tributaries), to Adriatic Sea (around 2 billion m^3 through Drim and Plavska River) and to the Aegean See (around 0.5 billion m^3 through Pčinja, Dragovištica and Lepenac).

Hydrometeorological service of the Republic of Serbia permanent controls surface water quality. Frequency of water sampling depends to the program for investigation of water quality including comprehensive daily, weekly, half monthly and monthly investigations.

Beside standard parameters that are defining surface water quality (like total organic carbon, soluble O_2, pH, Electroconductivity, Suspended matter, etc.) monitoring has revealed traces of following elements: Zn, Cd, Pb, Cu, Fe, Mn, Hg, Ni, As, Cr, Al, Se, Sn, Ca, Mg, Na and K.

According to the results of 2003–2004, the presence of dangerous and toxic heavy metals is evident. Presence of Cr^{6+} was confirmed in rivers such as Danube, Brzava, Topčiderska, Velika Morava and Veliki Lug as well as in the network of channels Danube-Tisa-Danube. The presence of Hg was confirmed in Stari Begej River and in the network of channels Danube-Tisa-Danube. In all surface waters it was found a high content of Fe and Mn as well as S^{2-}.

2.4. PRESENCE OF DEPLETED URANIUM AT BOMBED LOCATIONS IN WEST BALKAN COUNTRIES

2.4.1. Depleted uranium (DU) in the soil

During the war of the 1990s, more than 10 t of Depleted Uranium (DU) were dropped onto the territory of former Yugoslavia (Assimakopolos, 2003). Depleted Uranium is chemically similar to natural uranium, thus it is toxic for living organisms as a heavy metal, but it is also harmful due to its radioactivity (Radenković et al., 2003). To assess the environmental impact of Depleted Uranium ammunition used in West Balkan countries, a comprehensive study was carried on investigating Depleted Uranium physical/chemical behaviour and its status in contaminated soil a few years after the appearance. Here will present results related to the soil samples collected in 2002, at contaminated locations. After the γ spectrometric based investigation on Depleted Uranium in soil, some samples are subjected to a modified five step Tessier's (Tessier et al., 1979) sequential extraction procedure and further radiochemical treatment and isotopic analysis to determine Depleted Uranium distribution in obtained extracts. The soil samples were collected in Serbia, Montenegro and Bosnia and Herzegovina. The specific activities of ^{238}U in topsoil samples taken at the projectiles entrance spot and path through the soil were of 10^4 Bq/kg magnitude order, and in the nearest soil layer it was 10^5 Bq/kg. The naturally occurring uranium concentration is within 20–60 Bq/kg in investigated soils. Radiochemical characterization of the projectile confirmed presence of the ^{237}Np, $^{239,240}Pu$ and ^{236}U traces indicating irradiated fuel origin of Depleted Uranium material but there are no these isotopes in investigated soil samples. The potential present forms of uranium are investigated also in the soil samples taken at the end of 2003, near the "hot spots" marked as contaminated areas. The results are only preliminary and indicate that a detailed analysis is needed and that a cleanup of contaminated areas is advisable. In all samples, the $^{235/238}U$ activity ratio was about 2×10^{-3}, which is characteristic of Depleted Uranium and it is an indicator for their presence in the contaminated soils.

Non-selectively bonded uranium (both poorly soluble and U(IV) and soluble U(VI) forms) within various substrates in soil is extracted in the first phase of the five-step Tessier's procedure. In the second step, dissolution of carbonates and manganese hydroxides is provoked where the soluble uranyl-ion (VI) maybe expected. The presence of uranium in a high excesses in these two phases of extraction in anthropogenic influenced and related to contamination. Low clay and humus content in the most of the samples indicated hydrous (crystalline) oxides of the iron and manganese as prevailing substrates for uranium extracted in the third phase. Only in the surface soil samples uranium shares are significant in the organic phase extracts.

A strong dependence of the fractionation on the contamination levels was evident resulting with weakly bonded exchangeable uranium in high contaminated soils, no matter the soil geochemical structure. The results indicate that uranium is mostly extracted in the first (extremely mobile) and second (mobile) phases. From the eco-chemical aspect, high uranium contents in the first two phases and its mobility are most relevant. The contents of Depleted Uranium in the first two phases are in the range 50–90%; in the first phase contents are between 30% and 80% which is indicated strong affinity for DU mobilization through the soils and potential dangerous for underground waters (Radenković et al., 2003, 2006).

The present results indicate that a few years after use of DU ammunition a considerable amount of uranium is still weakly adsorbed in the soil, probably on the edaphic carbonates. Although the relationship between uranium speciation and its bioavailability is still a matter of debate, it would be reasonable to claim that the major forms of U (VI) are available to living organisms, and their complexes with inorganic ligands apparently reduce its bioavailability by attenuating the activity of UO_2^{2+} and UO_2OH^+ ions. The content of DU should regularly be monitored and controlled as it presents possible risk of underground water pollution. Since the polluted water may enter the food cycle in the area of targeted sites, it raises a potential risk to human health, due to both chemical and radiological toxicity of uranium (Radenković et al., 2006, 2007).

2.4.2. An evidenced consequence on the air pollution during attacking by DU ammunition

Besides influences on soil and potential dangerous for underground waters some influence on ambient air pollution has been detected. 24-h samples of total suspended particles (TSP) were measured in Hreceg Novi, 5 km away from Cape Arza, located on the Luštica Peninsula, which was bombed with Depleted Uranium (DU) on 30 May 1999. The radioactivity level in the surface soil at Cape Arza was found to be 7–350 times higher than the background level. This level was determined after the end of the NATO campaign on 10 June 1999. In the meantime there has been no evidence of how much radioactive material from the surface soil had been transported by wind to a wider environment. In the sample of the total suspended particles (TSP) taken in Hreceg Novi between 31st May and 1st June the pulverous material was found. The TSP concentration was moderately increased to 46.2 $\mu g\ m^{-3}$ but the SEM microphotograph indicated an extremely pulverous material (see Figure 1d), completely different from typical aerosols well known in literature (Figure 1 a–c).

The concentrations of trace metals in this sample, in ng m^{-3} were: 0.2 of Cd, 0.5 of Co, 0.7 of Cr, 7.6 of Cu, 1 of Ni, 6 of Pb, 2.7 of Hg, 10 of Ti, 202.5 of Fe and 6.4 of Mn (Đorđević et al., 2004). US EPA initiated a study of developing emission factors of PM10 for propellants and explosives as a function of energetic material (Mitchell and Suggs, 1998). There are no reliable data on aerosol emission for open detonation of Depleted Uranium ammunition. In every case, this emission depends on the obstacle that was hit. It may be supposed that the maximum was reached when the rocks of Cape Arza were targeted. Trajectory calculations were implemented in the Eta model for the episode (Đorđević et al., 2004).

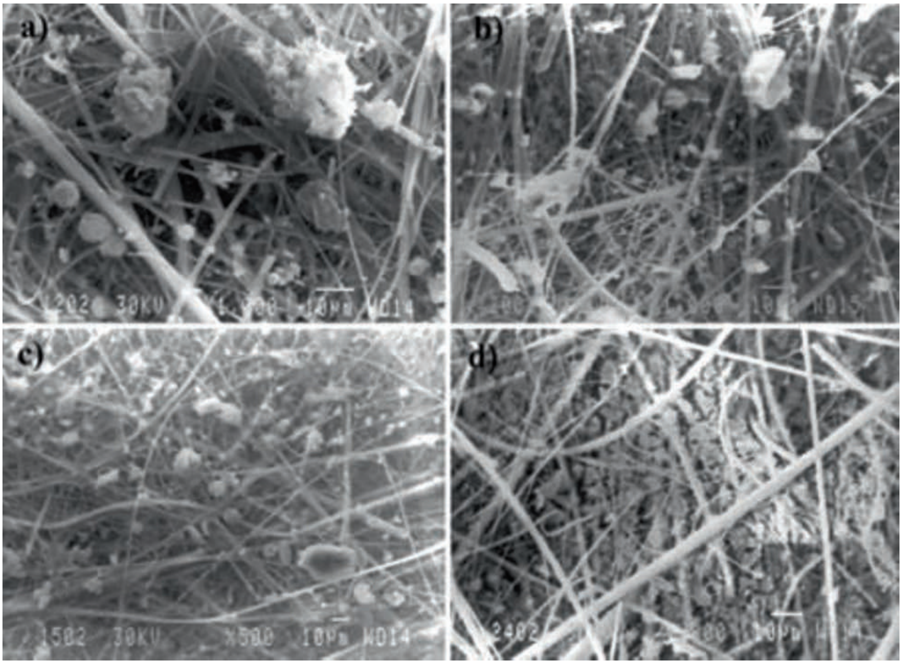

Figure 1. SEM microphotograph of (a–c) typical aerosols known in literature and of (d) sampled material.

Numerical simulations by the Eta model are initialized at 0000 UTC on 30 May for the forward trajectory calculation and at 0000 + 42 h for the backward trajectory using the European Center for Medium-Range Weather Forecasts (ECMWF) analysis as the initial conditions.

This part addresses the simulation of local air pollution originating from Cape Arza at the seaside of Montenegro and its properties as reflected on typical trajectories.

The air pollutants along trajectories below 1,000 m moved slowly over Montenegro and northern Albania towards eastern Serbia in the first 30 h, where they stayed up to 48 h. The pollutants along trajectories about 1,500 m moved over Montenegro in the first 8 h, and then, they moved over Serbia towards Romania. Air pollutants below 1,000 m moved slowly in anticyclonic circulation towards Herceg-Novi, over Cape Arza in the last few hours. Similarly, air along trajectory of about 1,500 m in anticyclonic circulation arrived at Herceg-Novi.

The prevailing weather conditions during 30–31 May 1999 were stable. Under such circumstances pollutant levels in the atmosphere may be increased. In the observed case, transport of dust released during the attack on the Cape Arza area was expected on the regional scale. A possible Depleted Uranium deposition could be determined on local (0.1–5 km) and short-regional scales (5–100 km) due to its aerosol size and high density. However, DU resuspension with dust and surface soil particles from bombed terrain is possible in the days after bombing. The backward trajectories below 1,000 m, as well as the chemical and physical properties of the collected particles (Figure 1d), indicated transport of an amorphous material from Cape Arza to Herceg-Novi did take place on 31 May. It is difficult to distinguish what happened subsequently. In September, 2001 Zarić et al. (2002) announced decontamination of the ground on Cape Arza as current and future activities, underlining that a part of the location should be decontaminated. In any case, a fugitive source of particles with DU traces existed a long time after the bombing. The later resuspension processes may be less intense than on the day after the bombing, so that other, more intense, processes might cover their contribution. Only one concentration belonging to the highest range, appeared on 11/12 August 1999 from the Cape Arza direction (Đorđević, Unpublished data).

Resuspension of dust and surface soil particles appears to be a major contributor to increased TSP levels (Đorđević et al., 2005) particularly in the day after the intense bombing of Cape Arza, which is situated 5 km south of the sampling site. The Eta trajectory analysis confirmed dust transport from Cape Arza to Herceg-Novi during the day after the bombing. This was to be expected because the surface soil of the Adriatic Coast is poorly covered by plants, especially by dense grass which plays the role of a particle sink. There is no evidence concerning how long the contaminated surface soil was a fugitive source of airborne particulate matter in the surrounding areas.

3. Conclusion

Through data processing of heavy metals accumulation in urban areas of Serbia including air, water, urban tree lives and soil it can be summarized that some parts of environment of urban areas are affected by specific heavy metals. The limit value of Ni was exceeded in the urban air of Belgrade. Presence of Cr^{6+} and Hg was confirmed in some rivers and Danube-Tisza-Danube channel. In all surface waters of Serbia higher contents of Fe and Mn as well as S^{2-} were found. Some consequences of presence of Depleted Uranium in environment are also confirmed. The present results indicate that a few years after use of DU ammunition a considerable amount of uranium is still weakly adsorbed in the soil. The content of DU should be regularly monitored and controlled as it presents possible risks of underground water pollution.

The recognizing of concrete problems of heavy metals presence in urban areas and recognizing mechanisms that are responsible for their distribution in environment is key for proper management and processing of environment-related data as well as the importance of harmonized IT infrastructures designed to better monitor and manages the environment.

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A MULTI-CRITERIA DECISION MAKING CONCEPTUAL APPROACH TO OPTIMAL LANDFILL MONITORING

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Abstract. In this chapter, we introduce a novel conceptual approach to determining an optimal landfill monitoring procedure by using the Multi Criteria Decision Making (MCDM). Selecting an optimal landfill monitoring procedure is identified as a complex and multifold problem encompassing parameters related to conflicting demands. It should result in identifying possible landfill monitoring alternatives that have to comply with predefined relevant criteria and offer landfill operators a powerful tool when raised in front of the problem of selecting the most appropriate monitoring alternative for their particular landfill. A decision having to be delivered in such a multidimensional and complex environment, seeks the utilization of the MCDM theory, in particular when the problem is new and complex, existing experience is insufficient, economic implications are significant. It is justified to define an algorithm due to frequent incidence of the problem and intuition is not an option, all of which is the case for the herein defined problem: determining optimal landfill monitoring procedure.

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Keywords: Landfill Monitoring, Multi-Criteria Decision Making (MCDM), Environmental Pollution Prevention, Modelling.

1. Introduction

Anthropogenic modern society activities, interpreted primarily through an economical prism and human comfort, implicate multifold irreversible environmental impact – soil, water and air pollution – (IPCC, 2001, 2007), integrally and adversely affecting the natural ecosystems. One of the sectors contributing to environmental pollution is the Solid Waste Management (SWM), inter alia the solid waste landfills.

In accordance with modern guidelines relating to SWM, landfills should be *well-engineered facilities*, located, designed, operated and monitored in such a manner to *ensure compliance* with prescribed laws and regulations (Reinhart and Townsend, 1998, Haarstrick, 2005). They must be designed to protect the environment from contaminants present in the solid waste stream. Further, proper landfills' management *should provide minimum environmental impact* and *minimum potential risk*. Such design, management and operation of landfill sites, requires *well designed* and *reliable on-site monitoring systems*, which monitor for any sign of groundwater contamination and landfill gas (LFG) emissions. Moreover, following the integrated SWM concept, in line with greenhouse gases (GHGs) emission reductions, appropriate monitoring procedures could indicate and assess justification of installing an LFG collecting system and if possible electricity and/or thermal energy production installations, hence avoiding the release of LFG emissions into the atmosphere.

In this chapter, we address the problem of determining optimal landfill monitoring by using the Multi-Criteria Decision Making (MCDM) theory. We introduce a novel conceptual approach that throws light to possible landfill monitoring alternatives and offers landfill operators a powerful tool when raised in front of the problem of selecting the most appropriate monitoring alternative for their particular landfill. Landfill monitoring includes numerous aspects depending on the monitoring goal and it is a function of numerous parameters to be taken into account in order to design and conduct a reliable monitoring procedure. Identified as a multifold problem which incorporates various aspects and conflicting opinions, landfill monitoring seeks the quantitative and comprehensible MCDM conceptual approach for identifying, understanding and addressing the related conflicts and provide options for their solution and trade-offs.

2. Background, State-of-the-Art of the Problem

Landfill monitoring procedures and requirements are stipulated in corresponding laws, regulations, guidelines which vary from country to country, e.g., EPA QP&WS (2001), EPA Ireland (2000, 2006), US EPA (2008), WDNRWMM (2007). However, an integrated approach to how a monitoring procedure should be designed and selected in order to minimize environmental impact and risk on one hand, and to minimize costs on the other hand, while maintaining maximised reliability and taking into account all influential parameters and variables, has not yet been regarded and analysed systematically.

3. MCDM Theory and Background

A solution to be delivered in a multidimensional and complex environment should indicate an optimal decision under given circumstances in *precisely defined temporal* and *space limits*. It implies tackling with conflicting situations, solving derived problems, whereby seeking to choose the one best answer (Dixon, 1966). In order to cope with such a structured problem, the decision making theory adopts complex mathematical models, methods and techniques, some using qualitative, others quantitative approach. The quantitative approach, in particular the MCDM (Hwang and Masud, 1979, Keeney and Raiffa, 1993, Hamalainen et al., 2000, Belton and Stewart, 2002), which we propose for addressing the problem of determining an optimal landfill monitoring procedure, has shown to be the most favourable instrument when:

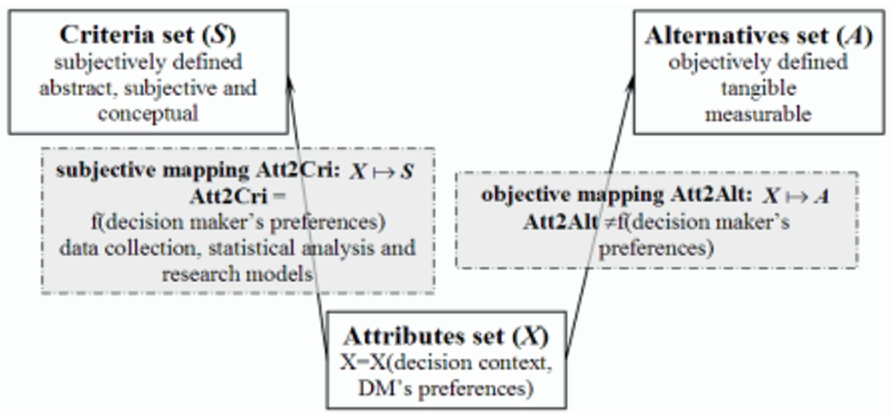

Figure 1. Relations between components of the multi-criteria decision making process.

- The problem is vague, new or complex.
- Economic implications are significant.
- Existing experience (objective and/or subjective) is insufficient.
- Intuition is not an option.
- It is justified to define an algorithm due to the frequent incidence of the problem.

3.1. COMPONENTS OF THE MCDM PROCESS

The main components of a MCDM process are the resources (attributes, alternatives, criteria), the process of transformation (operators, mappings) and the final state (decision) (Figure 1). The amount of existing knowledge related to each component defines the rank of a well or a bad defined decision making problem.

3.2. STEPS OF THE MCDM PROCESS

The steps in a MCDM process (Figure 2) include:

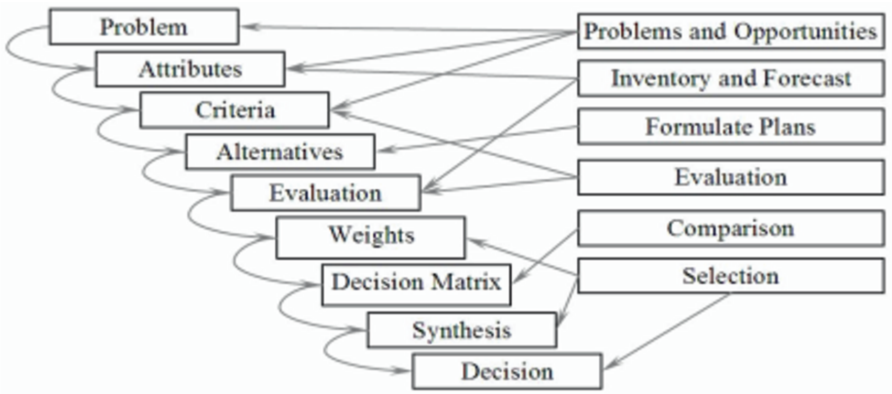

Figure 2. Steps of the multi-criteria decision making process.

1. Problem identification and research
2. Defining the problem relevant attributes (e.g., for the problem analyzed here, all relevant attributes related to landfills and their monitoring)
3. Extracting relevant criteria (build the problem hierarchy, e.g., Figure 3)
4. Discussing and proposing alternatives (e.g., based on Table 1)
5. Recognizing alternatives and eliminating the infeasible ones

6. Making judgments: defining the criteria-related preferences
7. Building the decision matrix
8. Synthesizing and ranking alternatives
9. Examining, verifying and documenting the decision

3.3. MATHEMATICAL DEFNITION

Mathematical formulation to solving a MCDM problem is shortly presented here. Further details are elaborated in Hwang and Masud (1979), Keeney and Raiffa (1993), Belton (1999), Belton and Stewart (2002). The decision matrix (step 7, Figure 2) aggregates the complete problem related information and is a basis for the problem solution.

$$[x_{ij} = f_j(A_i)]_{MxN}, i = 1, M, j = 1, N \tag{1}$$

where, M, N are the number of alternatives and criteria, respectively; $x_{ij}= f_j(A_i)$ indicates the value of criterion X_j with respect to alternative A_i; $S = \{f_1, f_2,..., f_N\}$ is the set of criteria, defined as

$$(\forall \mathbf{x} \in X)(\exists \mathbf{f(x)} \in S) : X \mapsto S = \{\mathbf{f(x)} \mid \mathbf{x} \in X\}; \tag{2}$$

$X = \{\mathbf{x} \mid \mathbf{g(x)} \leq 0\}$ and $\mathbf{g(x)}\leq 0$ are the problem related set of attributes and the corresponding vector of constraints, respectively; and $A = \{A_1, A_2,..., A_M\}$ is the set of the identified feasible alternatives. A weighting factor, w_j, can be associated to each criterion indicating its importance.

Then, the "best" solution to a MCDM problem is defined as

$$\max_x / \min U(\mathbf{f}) = \sum_{i=1}^{N} w_i \cdot u_i(f_j(\mathbf{x})) \tag{3}$$

where, $U(\mathbf{f})$ is the overall utility function, w_i and u_i are the weighting factor and the utility related to a particular criteria and the corresponding alternative.

4. Definition of the Multi-Criteria Decision Making Conceptual Approach for Optimal Landfill Monitoring

In this chapter, we focus on defining a general MCDM conceptual approach seeking optimal landfill monitoring. Delivering a final decision related to a particular landfill determined by corresponding sets of attributes, monitoring alternatives and criteria can be completed when the proposed MCDM concept is applied on a selected landfill. As a further step, this concept shall be applied on a selected set of landfills belonging to a particular landfill type (e.g., MSW). The obtained results will be used for comparison and standardization of landfill monitoring procedures.

As mentioned in Sections 1 and 2, landfill monitoring is an open, not yet strictly categorised problem, important not only from an operating and design perspective (Reinhart and Townsend, 1998), but as well from a regulatory point of view.

Properly designed landfill monitoring should provide:

- Determination of whether or not a landfill is operating as designed.
- Determination of whether or not the surrounding environment is being adversely impacted.
- Early warning of environmental problems that could be corrected before adverse impacts occur.
- An indication of any breach of environmental protection legislation.

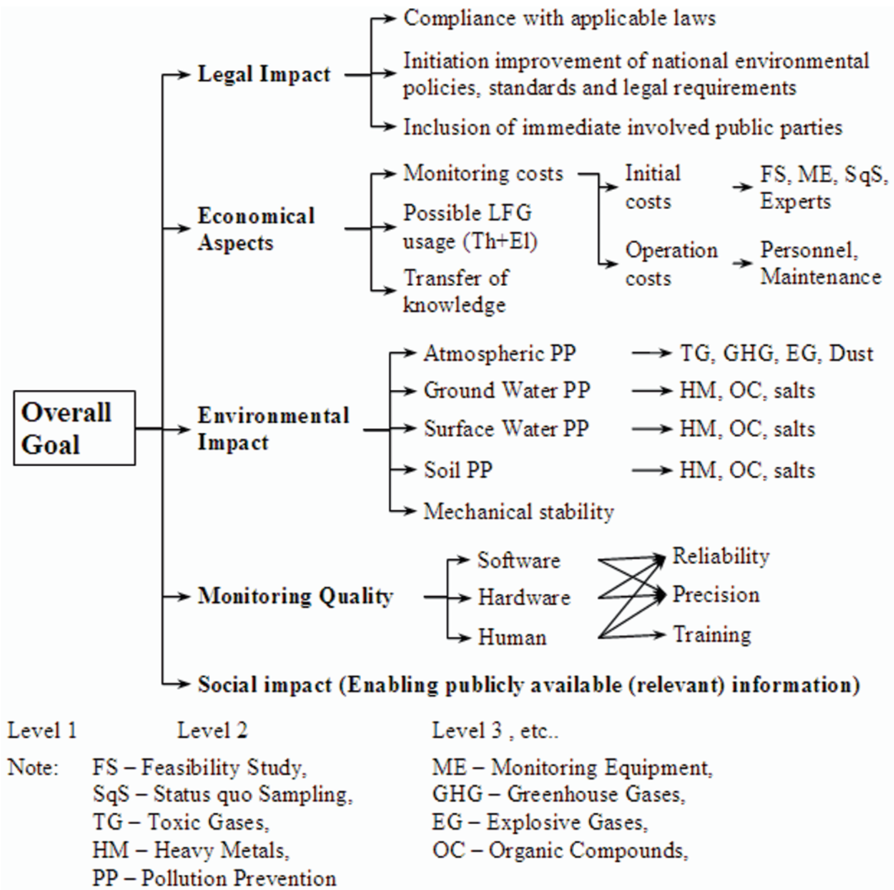

Figure 3. Attributes generating (mapping into) criteria.

Thus, we speak of (1) *detection monitoring*; (2) *assessment monitoring* and under some circumstances (3) *remediation monitoring*, assessing the effectiveness of remediation measures implemented to address a contaminant release detected during (1) and characterized during (2).

4.1. ATTRIBUTES GENERATING CRITERIA AND ALTERNATIVES

Here, we focus on steps 1 through 4: problem identification, determining related attributes, criteria and alternatives as per Figure 2, and partially on step 5. Accordingly to analyzed available literature data and parameters (OECD, 1993, Petts, 2000, Hamalainen et al., 2000, DESA, 2001, Yan, 2002, Haarstrick, 2005, Reichel et al., 2007), and in line with the general MCDM approach (Figure 1), two sets of attributes were identified:

- First set of attributes, mapping into criteria (Figure 3) and defining the problem hierarchy, whereby, every criterion was proven whether answering on the following question: "*Could the attribute X be used as a criterion for assessing the monitoring alternative A*".
- Second set of attributes, mapping into monitoring alternatives (Table 1).

TABLE 1. Attributes generating (mapping into) alternatives.

Attributes	**Sub-attributes**	**Sub-sub-attributes**
General site specifics	Climatic conditions (ambient)	Precipitation, temperature, humidity, evaporation
	Hydro-geological properties	Natural soil permeability distance to the highest level of the aquifer
Landfill specifics	State of operation	In operation/closed
	LF age	young/mature/old
	LF size	LF area, LF volume, maximum waste height
	LF positioning in the landscape (topography)	Vertical positioning (above/below, below, above) positioning on a slope
Applied "system(s)" on site	Artificial base liner system	Material (geomembrane, mineral), permeability
	Cover liner system	Material (soil, geomembrane), permeability
	Daily cover system	Existent/nonexistent
	Existing installations	GCS/AS, LCS/LRS

TABLE 1. (Continued)

Attributes	Sub-attributes	Sub-sub-attributes
Waste properties	Composition	Municipal, industrial, animal, sludge, mixed, other hazardous (toxic, medical, heavy metals, etc.)
	Reactions	Biological, chemical, physical
Gas phase	CH_4, CO_2, H_2S, NH_3	Temperature, pressure, quantity/volume/flow rate
Leachate	pH, electrical conductivity, alkalinity, temperature, quantity/volume/flow rate TOC, DOC, BOD, COD, AOX, DO, etc., cations (As, Fe, Cd, Cu, Pb, Hg, Cr, Zn, Mg, Mn) $SO4^{2-}$, NH_4^+, NO_3^-	
Soluble fraction In MSW (eluate)	Parameters as in the leachate	
Surface run-off	Parameters as in the leachate	
Ground water	Parameters as in the leachate	
Soil	pH, temperature, El. conductivity (measured in the field), TOC Cl^-, Na^+, NH_4^+, NO_3^- cations (Zn, Mg, Fe, Cd, Cu, Pb, Hg, Cr, Mn, Mg)	
Solid fraction (municipal) waste composition	TOC, biodegradable organics, gas potential Fe, Cd, Cu, Pb, Hg, Zn, Cr, Mn $SO4^{2-}$, NH_4^+, NO_3^-, S_2^-, OH^- compounds	
Derived parameters	COD/TOC, stabilization factor, models, additional calculated/simulated factors, etc.	

4.2. DETERMINING WEIGHTS

For the purpose of determining corresponding weights to the selected criteria (step 5, Figure 2) a pool of experts and stakeholders is identified (Table 2) and questionnaires are distributed among them. The Analytical Hierarchy Approach (Saaty, 1986) is utilised to calculate the weights, i.e., they correspond to the elements of the normalized principle eigenvector of a matrix A_i, derived by aggregating stakeholders opinions/judgements,

$$A_i = \begin{bmatrix} 1 & \dots & a_{1n_i} \\ \dots & 1 & \dots \\ 1/a_{1n_i} & \dots & 1 \end{bmatrix}, i = 0, l-1, \; l = \sum_L l_L \tag{4}$$

where L denotes the number of the hierarchy levels (Figure 3), whereby

$$\sum_{j=1,n_i} w_j = 1 \cdot \quad (5)$$

Preliminary derived results are aggregated and presented in Figure 4. It has to be emphasized that the survey is continued and the ongoing research should cover the model refinement and adaptability to different landfills.

TABLE 2. Identified pool of experts and stakeholders for determining criteria related weights.

Institution	No. of experts (approx.)
Selected pool of Landfill experts: universities/consultancies	Preferably 20–25
Representatives from landfill operators	Preferably 10–15
Representatives from NGOs	up to 10–15
Bank representatives	up to 10
Regulatory bodies	up to 10
Representatives from relevant Gov'l authorities (national/local)	Up to 10–15
Total	Up to 90

5. Conclusion

The herein presented MCDM conceptual approach to optimal landfill monitoring represents the first step of defining an integrated procedure for determining an optimal monitoring procedure referring to a particular landfill. The parameters which are to be taken into account in order to describe a particular landfill in an optimal way, vary for different landfills. Therefore, this overall MCDM concept aims at encompassing as much as possible existing and known landfill types, as well as disposed waste types, with a focus on municipal landfills. The importance of such a classified and built-in-a-hierarchy approach can be comprehended through the following parallel: while a mathematical representation of a physical model can be completed, e.g., through a set of differential equations, boundary and initial conditions and its solving will result in a corresponding set of solutions, the definition of a particular MCDM model for optimal landfill monitoring is performed by identifying the corresponding attributes (pendant to the differential equations), criteria (pendant to the initial and boundary conditions) and alternatives (pendant to the solutions set) sets. The one optimal monitoring solution, meeting the selected set of criteria, will be found among the set of the pre-selected monitoring alternatives.

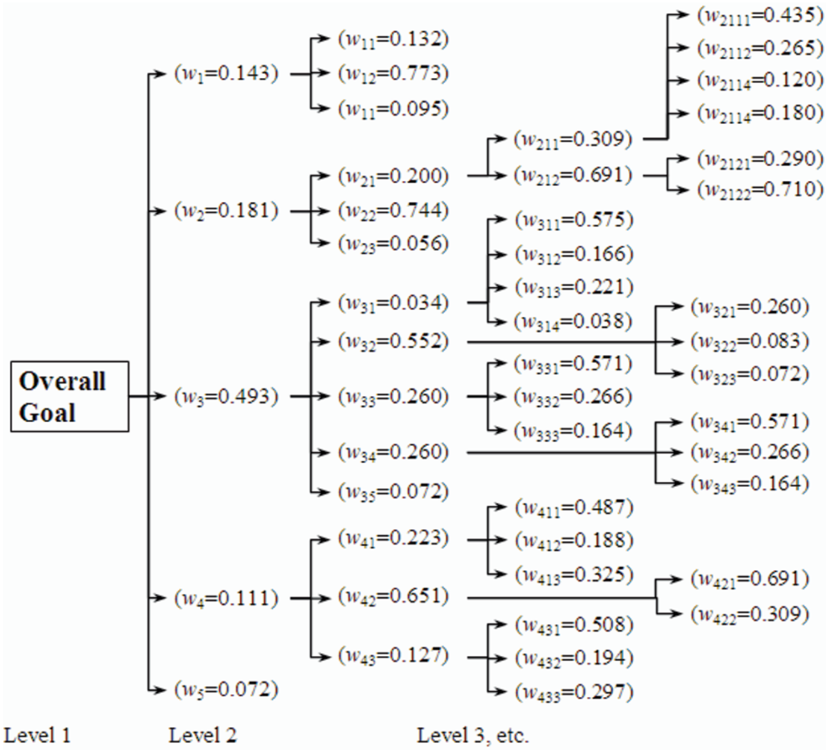

Figure 4. Aggregated criteria related weights from the preliminary survey. Hierarchical structure in compliance with Figure 3.

The verification of the behaviour of the herein proposed MCDM conceptual approach will be based on experimental investigations implemented in a scope of a relevant case study which will be presented as an example in the oral presentation, whereby structuring the corresponding MCDM model for determining the optimal landfill monitoring alternative will be based on this conceptual approach. Consequently, if proven adequate and easy to implement, this MCDM conceptual approach can be recommended for wider utilization, with appropriate modifications and corrections in accordance to landfill, local or country specific circumstances. Due to the proposed hierarchical structure, the herein proposed MCDM conceptual approach can also be used as a sound basis in terms of future (1) risk assessment of landfills, since it is the key to selecting an appropriate level of environmental monitoring required at a particular landfill and (2) sustainability assessment. Furthermore, (3) coupling of the herein proposed MCDM concept with GIS could be a future challenge, especially since such an approach has already been used for land management and spatial planning (Joerin and Musy, 2000).

Aknowledgement

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Abbreviations and Symbols

AOX	Absorbable halogen organic compounds
AOX	Absorbable halogen organic compounds
AS	Aeration system
BOD	Biological oxygen demand
BOD	Biochemical oxygen demand
BOD5	BOD within 5 days
COD	Chemical oxygen demand
COD	Chemical oxygen demand
DESA	Department of economic and social affairs
DO	Dissolved oxygen
EE	Energy efficiency
EPA	Environmental protection agency
GB21	Gas formation within 21 days
GCS	Gas collection system
GHGs	Green-house gases:
GIS	Geographic information system
IPPC	Integrated pollution prevention control
LCS/LRS	Leachate collection/recirculation system
LF	Landfill
LFG	Landfill gas
MCDM	Multi-criteria decision making
TOC	Total organic carbon
TOC	Total organic carbon
UN	United Nations
UNCSD	UN commission for SD
UNEP	UN environment programme
UNFCCC	UN framework convention on climate change
UNSD	UN statistics division
VOC	Volatile organic compounds

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ENVIRONMENTAL PROTECTION AND INDUSTRY: PARAMETERS NECESSARY FOR ENVIRONMENTALLY RELATED DECISION MAKING

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Abstract. Industry, as one of the economy pillars, is to be accounted for the development and improvement of a certain country's well-being. Unfortunately, the prosperity has and still is accompanied with direct and/or indirect negative environmental impact, especially in the Western Balkans countries with economies in transition. In this chapter, we focus on the parameters necessary to identify, describe, parameterize, monitor and prevent pollution deriving from industry for the purpose of alleviating the process of decision making relevant to environmental protection. Illustrated are examples from several industrial sectors including energy generation, public transportation, cement industry and ferrous metallurgy.

Keywords: Environmental Pollution Prevention, Industry, Monitoring, Modelling, Multi Criteria Decision Making.

1. Introduction: Problem Background and Definition

The proper implementation of the introduced environmental laws, depends on the quality and reliability of the monitoring referring to operation and functioning of the industrial facilities that are mandatory to comply with the existing laws and regulations. Identifying pollution sources and indicators for their monitoring, as well as their accessibility to the regulatory bodies, is a prerequisite for delivering a reliable decision addressing to resolving and preventing potential environmental pollution deriving from the industrial capacities.

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1.1. ECONOMY AND INDUSTRY VS. ENVIRONMENTAL POLLUTION

Based on the level of public awareness for the environment impact of the pollution, various stages in the global industrial development define and practice corresponding approaches to environmental protection (McCann, 1998). Substantial portion of the industry activities, are related to energy generation and consumption and they are interpreted solely through an economical prism, whereby the fact that the energy has an irreversible impact on the environment is very often disregarded (Ciconkov, 2002).

The Third (2001) and the Fourth (2007) Assessment Report of the Inter-governmental Panel for Climate Change (IPCC) provide a firm proof of the anthropogenic origin to the accelerated dynamics in the climatic changes and their adverse return-effects on the natural ecosystems and humankind. Further, as elaborated by United Nations Environment Programme (UNEP) and the United Nations Framework Convention on Climate Change (UNFCCC) (2001), these processes are associated with a substantial increase in the average atmospheric temperature on a global scale, induced by the increase in the atmospheric concentrations of the green-house-gases (GHGs), i.e., the so called green-house-effect.

In one of the latest publications of the International Energy Agency, it is stated that the Western Balkans region currently and in the forthcoming period will be facing significant economy and energy challenges. The origins for these challenges could be identified in the following:

- The conflicts over the break-up of the former Yugoslavia damaged much of the energy infrastructure and compounded the challenge of providing reliable energy supply.
- The political, economical and social turmoil and instability, followed by a transitional period in the newly established states, led to a period of stagnation in any substantial investments in the industrial sectors, not only due to lack of financial measures, but as well due to lack of interest and discouragement of the foreign investors.
- The improper maintenance of the existing energy capacities and installations, reduced the reliability of the energy supply, causing unplanned breaks in the production process.
- The constant growth of the oil prices in the past couple of years, accompanied with the rising awareness for environmental protection.
- The general strategy of the countries in the region, which have already started the processes of accession in the European Union, requiring transposing the country legislative to comply with the European Union.

Therefore, a priority list across the region of Western Balkans, as well as in other countries with developing and transitional economies, is to be defined,

- *Firstly*, on the infrastructure and policies that can support the provision of reliable, affordable and sustainable industry and energy supply.
- *Secondly*, on the institutions that can support establishing, generating and enforcing related legislation in compliance with the European Community, providing minimum industry impact on the environment.
- *Thirdly*, on the research and educational institutions, which are expected to focus their research on using (a) Best Available Techniques (BAT) in the industry,[1] (b) alternative energy sources, preferably renewable and environmentally friendly.

1.2. CLASSIFICATION OF ECONOMY SECTORS

Industry, as part of the economy, is classified in accordance with numerous general categorization models, developed by various international organizations and associations. Those models, are usually further annexed and refined in accordance with the country specific circumstances, and used as basis for developing national categorizations of industry sectors. In this section, an overview of several categorization systems is presented.

- *Classical Categorization Approach*. In accordance with the general classical categorization approach, industries are classified customarily, whereby three major industrial sectors are identified: (1) *primary sector*, raw material extraction industries (e.g., mining and farming); (2) *secondary sector*, refining and manufacturing, further classified as heavy and light; and (3) *tertiary sector*, dealing with services (e.g., law and medicine) and distribution of manufactured goods. A fourth category, referring to the new type of industry, relating to technological research, design and development (e.g., computer programming and biochemistry), has been introduced as *quaternary sector*. A general presentation of the development in time and employment correlations in those four major industrial sectors is given on Figure 1.
- *The International Standard Industrial Classification (ISIC)*. The most complete and systematic industrial classification of all economic activities has been prepared by the United Nations Statistics Division and structured into the so-called International Standard Industrial

[1] For example, in accordance to the Integrated Pollution Prevention Control (IPPC) Directive.

Classification (ISIC). ISIC is arranged so that entities can be classified in accordance to the activity they carry out (Table 1).

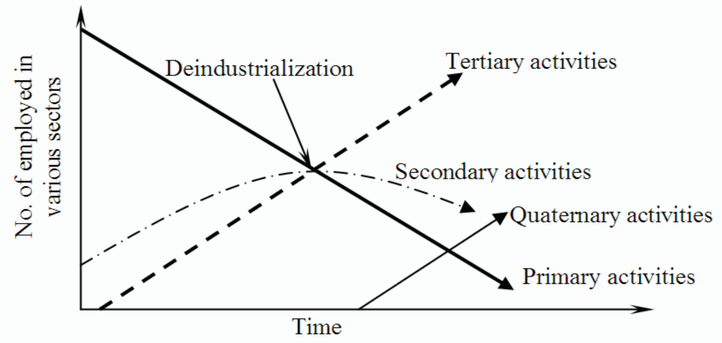

Figure 1. Clark's sector model (Clark, 1957).

- *Other Industry Classification Systems*. The North American Industry Classification System (NAICS) (Table 1) has replaced the US Standard Industrial Classification system. It was developed jointly by the US, Canada, and Mexico to provide new comparability in statistics about business activity across North America. Other categorization systems are used by various countries, such as the Global Industry Classification Standard (e.g., in Macedonia).

1.3. CRITERIA FOR DETERMINING PARAMETERS RELEVANT FOR ENVIRONMENTAL PROTECTION

In order to identify critical industrial sectors, to further canalize and focus the research activities and to respectively identify parameters related to environmental protection, the following relevant criteria are proposed in this chapter. These criteria derive, fulfil and comply with the following:

- Sectors categorize in a first instance as primary and secondary activities (see Section 1.2), and in a second instance as tertiary and quarterly.
- Pollution deriving from the considered activities represent significant part of the overall pollution in all sectors.
- Pollution reduction potential in the considered sectors is assessed as significant.
- Potential for increasing energy efficiency is assessed as significant, thus necessary/planned measures (could) lead not only to reduction in energy consumption, but consequently to reduction in environmental pollution.

TABLE 1. Standardized categorization methods of the industrial sectors.

Sub-sector	Categorization method
Agriculture, forestry and fishing	ISIC[2] (A), NAICS[3] (11)
Mining and quarrying	ISIC (B), NAICS (12)
Manufacturing	ISIC (C), NAICS (31–33)
Electricity, gas, steam and air conditioning supply	ISIC (D), NAICS (22)
Water supply; sewerage, waste management and remediation activities	ISIC (E), NAICS (22,56)
Construction	ISIC (F), NAICS (23)
Wholesale and retail trade; repair of motor vehicles and motorcycles	ISIC (G), NAICS (42,44,45)
Transportation and storage	ISIC (H), NAICS (48,49)
Accommodation and food service activities	ISIC (I), NAICS (72)
Information and communication	ISIC (J), NAICS (51)
Financial and insurance activities	ISIC (K), NAICS (52)
Real estate activities	ISIC (L), NAICS (53)
Professional, scientific and technical activities	ISIC (M), NAICS (54)
Administrative and support service activities	ISIC (N), NAICS (56)
Public administration and defence; compulsory social security	ISIC (O), NAICS (92)
Education	ISIC (P), NAICS (61)
Human health and social work activities	ISIC (Q), NAICS (62)
Arts, entertainment and recreation	ISIC (R), NAICS (71)
Other service activities	ISIC (S), NAICS (81)
Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	ISIC (T), NAICS (22,81)
Activities of extraterritorial organizations and bodies	ISIC (U), NAICS (22,81)

- Availability of data is sufficient for inception assessment and analyses.
- Previous experiences and knowledge is significant.
- Sectors where investment opportunities are expected, especially in developing countries and countries with economies in transition.
- Limitations from the enterprises for obtaining data due to data uncertainty and unavailability.

[2] ISIC – International Standard Industrial Classification.
[3] NAICS – North American Industry Classification System.

- Reluctance to publicly dispose/disclose proper data concerning environmental pollution, due to non-compliance with existing country-specific regulations and laws.

As defined by the Ad Hoc Expert Group on biodiversity indicators (UNEP, 2003), "Indicators serve four basic functions: simplification, quantification, standardization and communication. They summarize complex and often disparate sets of data and thereby simplify information. They usually assess trends with respect to policy goals. They should provide a clear message that can be communicated to, and used by, decision makers and the general public". Figure 2 gives an overview of the relations between the amount of information and the involved stakeholders described by the information pyramid, and the corresponding theories, methods, techniques and environmentally related regulations and policies in practice.

In accordance with the above listed criteria, whereby following the ISIC categorization and the indicators' definition, the focus in this chapter is set on parameters and indicators significant for environmental protection, elaborated through selected examples:

- *Primarily* in the following industrial (sub)sectors: (1) selected subsectors of manufacturing; (2) electricity, gas, steam and air conditioning supply; (3) water supply; sewerage, waste management and remediation activities; (4) transportation (without storage).
- *Secondarily* on the following (sub)sectors: (1) agriculture (without fishing/forestry); (2) construction; (3) accommodation and food service activities; (4) Professional, scientific and technical activities; (5) Education.

The order in the listing is not by priority, but in line with the original categorisation.

2. Theories, Methods and Techniques

2.1. VARIOUS ASPECTS AND APPROACHES IN DETERMINING ENVIRONMENTAL PARAMETERS

Different rules, aspects, approaches and languages move the world of scientists, the world of policymakers and politicians and the world of economics, industry and profit.

- Scientists are concerned with detail, reliability, replicability, accuracy, etc. (Figure 2).
- Economy experts focus on the dimension of the potential profit to be expected from the foreseen investments in industry and economy.

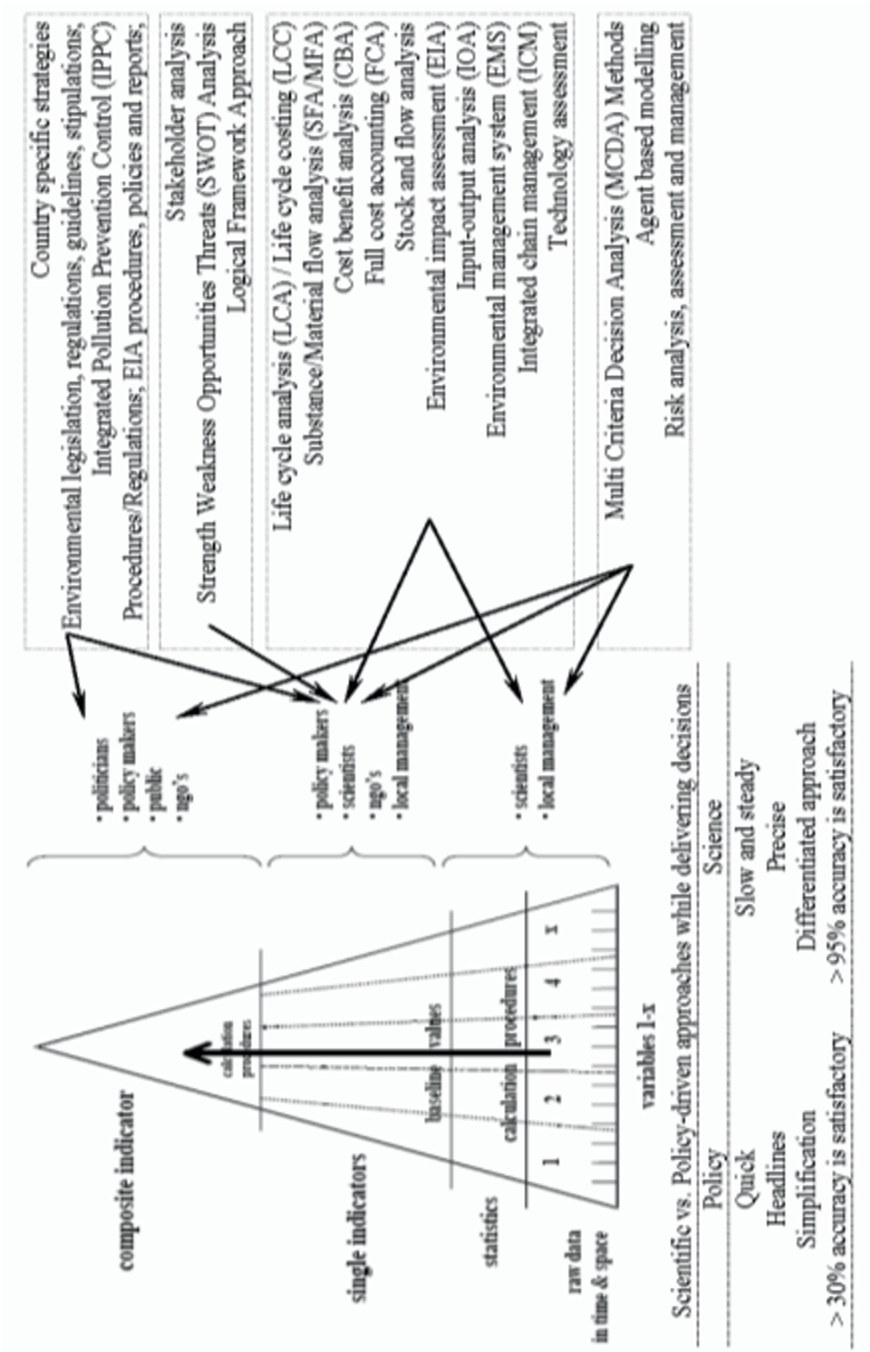

Figure 2. Information pyramid vs. theories, methods, techniques and legislation used to analyse, assess and reduce environmental pollution (Guitouni and Martel, 1998), annexed by the authors.

- High-level politicians are interested in the broad picture, the key message, preferably a value condensed in one figure on a scale from 0 to 10.

The profit-driven approach is, most probably, the origin of the successfulness of the economy experts in establishing information systems and defining procedures related to aggregating industry parameters and indicators into indices in nearly all countries. On the other hand, ecologists and environmentalists failed in nearly all countries (Azar et al., 1996). This is not due to the fact that the economy is less difficult and complex than ecosystems to describe and assess. On the contrary, the laws driving the environment and nature are on the same level of complexity, sometimes even more complex.

Figure 2 gives a general overview of the theories, techniques and methods used to analyse, assess and reduce environmental pollution and related risks, categorised by the field and aspects of utilization. As presented, the underlined problem is multifold and complex, thus seeks the characteristics and performances of a theory offering a holistic approach, observing and consideration.

The multidisciplinary field known as Industrial Ecology (IE) deals with this complex, holistic and sustainable combination of *environment, economy, social aspects* and *technology* systems, which implies difficulties to understand the system's behaviour and may lead to rebound effects. Clearly, identifying, defining and utilising cross-section and combined criteria, parameters and indicators is limited under such circumstances (Robeyns and van der Veen, 2007). This chapter aims to help this process of identifying parameters related to delivering decisions in this complex environment.

2.2. MULTI CRITERIA DECISION MAKING (MCDM): THEORY AND BACKGROUND

Living, planning and realizing actions in the human multidimensional and complex reality implies coping and tackling with conflicting situations, i.e., solving derived problems and making decisions on different levels and on a daily basis, seeking to choose *the one best answer* (Dixon, 1966; Belton, 1999). An optimal decision can be delivered only under given circumstances in *precisely defined time* and *space limits* and *quality measures*. Decisions are rarely unanimous and even more rarely universally supported, hence it is essential that they are transparent and reflect compromise.

Decision making theories adopt complex mathematical models, methods and techniques, some using *qualitative*, others *quantitative* approach (Martinsons and Maris, 2001; Bell et al., 2002). The quantitative approach is an optimal instrument when a problem is vague, new or complex, economic implications are extreme, existing experience (objective and/or subjective) is insufficient, intuition is not an option, and it is justified to define an algorithm due to the frequent incidence of the problem.

2.2.1. Steps and components of the MCDM process

As elaborated by Hwang and Masud (1979), Kereskenyi (2004), Lazarevska (2007), a MCDM problem is defined by three basic sets: *attributes*, *criteria* and *alternatives*, whereby defined are two mappings, the *first*, from the attributes set to the criteria set, and *second* from the attributes set to the alternatives set.

In this chapter, the *attributes* are derived and defined from the definition of the industry (see Section 1, e.g., sectorial categorisation, policies, etc.), including the environmental impact.

The corresponding environmentally related global set of *criteria* (constraints) is presented in Figure 3 (see. examples in Section 3).

The set of identified feasible *alternatives* can be determined from the identified environmental problem which has to be resolved for the particular type of pollution deriving from the corresponding industrial facility (e.g., transport, electricity generation, cement industry, ferrous metallurgy, etc.).

Delivering the final decision related to the particular MCDM problem is carried out through the following steps (Zeleny, 1982; Ortega, 2002): (1) Problem identification and research; (2) Defining the problem relevant objectives for the MCDM model; (3) Defining criteria, while preserving the concept of Driving Force/State/Response (DF/S/R) (UN CSD, 2001) and the (OECD, 1993); (4) Making judgments; (5) Discussing and proposing alternatives; (6) Recognizing alternatives and eliminating the infeasible; (7) Building the decision matrix for the MCDM model; (8) Synthesizing and ranking alternatives; (9) Examining, verifying the decision; and (10) Documenting the decision.

2.2.2. Mathematical formulation

The mathematical formulation of a MCDM problem is shortly presented in this chapter. Details are given in (Hwang and Masud, 1979; Keeney and Raiffa, 1993; Lazarevska, 2008). This formulation is based on defining a K-dimensional vector, **x**, of design variables (attributes) the criteria and constraints depend on. The vector of constraints is $\mathbf{g(x)} \le 0$. Then a feasible set of attributes $X = \{\mathbf{x} \mid \mathbf{g(x)} \le 0\}$ exists. Further, let the set of criteria $S = \{f_1, f_2, ..., f_N\}$ be defined as

$$(\forall \mathbf{x} \in X)(\exists \mathbf{f(x)} \in S) : X \mapsto S = \{\mathbf{f(x)} \mid \mathbf{x} \in X\} \tag{1}$$

i.e., X is mapped into the criteria space S. If the set of the alternatives is $A = \{A_1, A_2, ..., A_M\}$, where every alternative is described through a set of

N attributes, the MCDM problem can be described by Eq. (2) and subject to a set of constraints Eq. (3), i.e.,

$$\max_{\mathbf{x}}\{f_1(\mathbf{x}), f_2(\mathbf{x}),..., f_N(\mathbf{x}) \mid \mathbf{x} \in A, \dim \mathbf{x} = K\} \tag{2}$$

$$g_r(\mathbf{x}) \leq 0, r = 1, L \tag{3}$$

The decision matrix (Eq. 4) aggregates the complete related information.

$$[x_{ij} = f_j(A_i)]_{MxN}, i = 1, M, j = 1, N \tag{4}$$

where, M, N are the number of alternatives and criteria, respectively, $x_{ij}= f_j(A_i)$ indicates the value of the criterion X_j with respect to the alternative A_i. A weighting factor w_j can be associated to every criterion indicating the importance of that criterion. In problems where weighting is applied (Keeney and Raiffa, 1993), the "best" solution to a MCDM problem can be obtained by

$$\max_x / \min U(\mathbf{f}) = \sum_{i=1}^{N} w_i \cdot u_i(f_i(\mathbf{x})) \tag{5}$$

where $U(\mathbf{f})$ is the overall utility function, u_i, w_i are the utility and weight related to particular alternatives and criteria. If proven appropriate, use of other forms of the utility function is justified.

3. Examples

Using the above shortly presented mathematical formulation, in accordance with the listed criteria in Section 1.3, and the guidelines from OECD (1993), UNCSD (2001), and UNEP (2003), in this chapter, an overall hierarchy to a decision making procedure in relation to environmental pollution deriving from industry is provided as presented on Figure 3. The number of environmental criteria clusters in the second hierarchical level is N = 13, while the number of indicators on the lower levels 3 and 4 is further defined on a case-by-case basis.

Relevant environmental parameters for the following examples are identified, and proposed as relevant for observation and monitoring: (1) improvement of the public transportation concept; (2) initial project assessment in the sector electricity generation; (3) environmental impact in the cement industry; and (4) energy efficiency measures in ferrous metallurgy.

3.1. IMPROVEMENT OF THE PUBLIC TRANSPORTATION CONCEPT

As elaborated by Lazarevska (2007, 2008), whereby preserving the hierarchy categorisation from Figure 3, while analysing a potential project that addresses the multifold problem identified as "*improvement of the public transportation concept in the city of Skopje*", parameters relevant (1) to assess the project's environmental impact and (2) to monitor and prevent possible environmental pollution, and (3) to integrate the environmental impact into the assessment of the project's contribution to sustainable development (SD), are as presented in Figure 4.

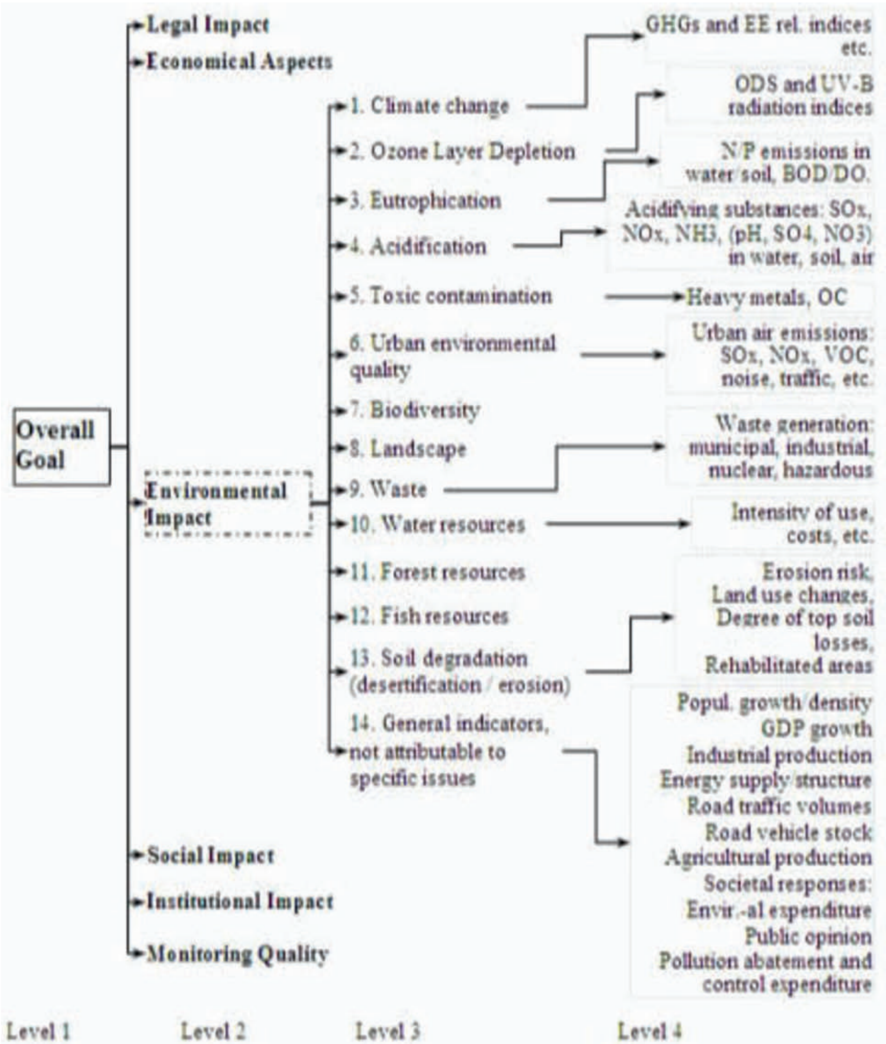

Figure 3. Overall hierarchy to a decision making processes related to preventing industry related environmental pollution. Selected indices are given per given category.

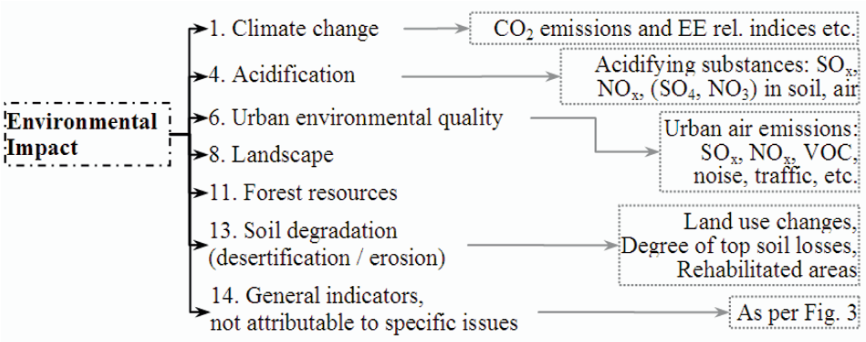

Figure 4. Environmental parameters for the problem identified as "improvement of the public transportation concept in the city of Skopje".

3.2. INITIAL PROJECT ASSESSMENT IN THE SECTOR ELECTRICITY GENERATION

Depending on whether the electricity generation process derives from fossil fuel fired plants or hydro (renewable) resources, the pollution risks and prevention differ significantly, e.g., the indicators associated with categories such as climate change have an opposite meaning. While in fossil-fuel fired plants due to the unavoidable CO_2 emissions the indicator indicates negative environmental impact, in the case of renewable energy sources the indicator points out the displaced CO_2 emissions through the generated green electricity (MoESP, BES, 2007).

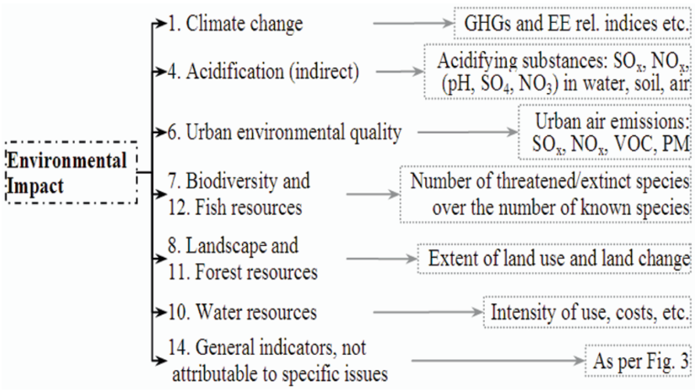

Figure 5. Environmental parameters related to initial project assessment in the sector electricity generation – hydro-power plant.

The hierarchy on Figure 5 refers to an *initial project assessment in the sector electricity generation from renewable (hydro) sources*. The hierarchy referring to the environmental parameters is constructed how it could be later integrated into a more general MDCM model for assessing project's contribution to SD. Thereby, the environmental impact will be complementing the remaining conceptual pillars of the SD concept: economical, social and institutional.

Similar hierarchy can be prepared for a fossil fuel fired power plant taking into account the specifics of the thermal environmental pollution as a separate indicator.

3.3. ENVIRONMENTAL IMPACT OF THE CEMENT INDUSTRY

According to the documentation for requesting an A-Adjustment Permit with an Adjustment Plan (Usje, 2007), under the current Law of environment, the cement factory Titan Usje has registered 49 emission sources classified as major (11) and smaller (38). Based on previous and present studies (Nošpal et al., 2003a,b, 2004), the hierarchy for assessing environmental impact of the cement industry is given as in Figure 6.

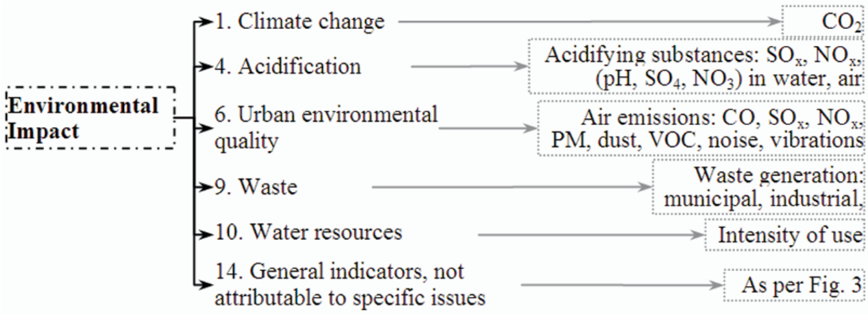

Figure 6. Environmental parameters related to the cement industry Titan Usje, Skopje.

3.4. ENERGY EFFICIENCY MEASURES IN FERROUS METALLURGY

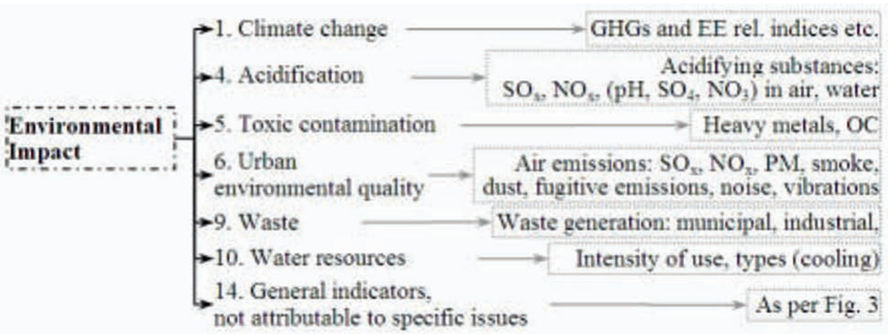

Figure 7. Environmental parameters related to the ferrous metallurgy, Makstil, Skopje.

According to the documentation for requesting an A-Adjustment Permit with an Adjustment Plan (Makstil, 2007) under the current Law of environment, the following hierarchy for assessing environmental impact of the ferrous metallurgy is given as in Figure 7.

4. Conclusions

The presented MCDM model allows defining and determination of the three basic sets: attributes, criteria and alternatives.

In this chapter we determine the sets of attributes and criteria, and the mapping between them. An overview of some parameters and their categorisation in view of delivering reliable decisions towards environmental pollution prevention are given as concrete examples. The set of corresponding feasible alternatives remains to be determined on a case-by-case basis for the presented examples.

Continuous monitoring of environmental parameters and the indicators of the environmental impact of the industrial processes is defined and integrated in the existing and newly introduced environmental laws, laws under revision and submission. Thus, establishing a polluters' register, integrated within a geographic information system is the first step towards alleviating potential pollution accountable to the industry and defining, predicting and preventing related risks. Moreover, such an integrated system can be easily modified for further utilization in assessing the contribution of the industrial facilities to the (non) sustainable development of the region they operate in.

Abbreviations and Symbols

PM	Particulate matter
BAT	Best available techniques
CFCs	Chlorofluorocarbons
DESA	Department of economic and social affairs
EE	Energy efficiency
GHGs	Green-house gases
IPPC	Integrated pollution prevention control
ISIC	International standard industrial classification
NAICS	North American industry classification system
ODS	Ozone-depleting substances
SD	Sustainable development
UN	United Nations
UNCSD	UN Commission for SD
UNEP	UN Environment Programme
UNFCCC	UN framework convention on climate change
UNSD	UN Statistics Division
VOC	Volatile organic compounds
TOC	Toxic organic compounds

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TIME-FREQUENCY ANALYSIS FOR SAR AND ISAR IMAGING

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Abstract. In the past 10 years the Time-Frequency (TF) techniques have found significant importance for improvement and refinement of radar images (both SAR and ISAR) and in extraction of objects' features from radar images. The main contributions in this direction are given by V. Chen (Chen and Ling, 2002). Here, we will concentrate our attention on the radar imaging and two novel strategies: S-Method (SM) imaging and Local Polynomial Fourier Transform (LPFT) imaging. The application of these ideas to radar imaging, as well as a procedure for setting design parameter of the algorithms, will be presented. Transformations will be compared in terms of calculation complexity and quality of the resulted radar images. Moreover, it will be demonstrated that the LPFT-based algorithm has better robustness to additive noise than the SM or the adaptive SM.

Keywords: Time-Frequency Signal Analysis, SAR/ISAR, Moving Targets.

1. Introduction

When radar transmits an electromagnetic signal to an object, the signal reflects from it and returns to the radar. The reflected signal, as compared to the transmitted signal, is delayed, changed in amplitude, and possibly shifted in frequency. The parameters of the received signal contain information

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about the object's characteristics. For example, delay is related to the object's distance from the radar. The Synthetic Aperture Radar (SAR) and the Inverse Synthetic Aperture Radar (ISAR) are systems for obtaining high resolution image of an object based on the change in viewing angle of the illuminated object with respect to the radar. Relative motion between radar and object produces these viewing angle changes. In the case of ISAR, radar is fixed while the object is moving, while in the SAR case radar is carried on an aircraft or spacecraft platform, moving at uniform speed and constant altitude. Details related to the radar imaging and feature extraction using obtained radar images can be found in excellent publications: Raney (1971), Carrara et al. (1995), DeGraaf (1998), Lieu et al. (1999), Chen and Miceli (2001), Chen and Ling (2002), Kirscht (2003), Chen et al. (2003) and Sparr and Krane (2003).

SAR and ISAR imaging is commonly achieved by 2D Fourier Transform (FT) of received pre-processed signal. However, SAR images of moving objects can be defocused as well as ISAR images of fast manoeuvring objects and objects with 3D motion. Thus, some more sophisticated techniques are required for focusing these radar images.

TF representations offer several important advantages over other techniques for motion-effects compensation in SAR and ISAR images:

- They are computationally simple, requiring just minor additional processing with respect to the standard 2D FT imaging.
- They can be designed in such a manner that geometry of observed objects or model of object motion does not have to be known in advance.
- They can be designed in such a manner that contains a small number of relatively easily adjusted parameters.

In this chapter we consider two TF representations: S-Method (SM) (Stanković et al., 2008; Thayaparan et al., 2008a,b) and Local Polynomial Fourier Transform (LPFT) (Djurović et al., 2006) and their applications to the imaging of point scatterers data. The SM is a post-processing technique. It improves imaging results by auto-correlating the standard image, having, at the same time, possibility to control corresponding parameter in a relatively simple manner. In the case when objects on radar image are very close to each other SM is unable to separate them. Then the linear LPFT technique can be used to improve radar images. The improvement is obtained at the expense of increased computational burden. In addition, in the case of radar signals embedded in noise, the procedure for adaptive threshold selection used for the SM calculation can failed to accomplish a good concentration of fast moving objects. As a result, these objects can be almost invisible compared to other highly focused objects. LPFT will produce a high concentration of these objects, reducing, in the same time, the level of noise.

The manuscript is organized as follows. In Section 2, signal model is reviewed for point scatterers data in both SAR and ISAR imaging. Two novel techniques for radar imaging are considered in Sections 3. The first technique is based on the SM, while the other is inspired by LPFT. Comparison of the proposed techniques with potential drawbacks is given in Section 4. Application examples and comparison with standard imaging technique are presented in Section 5. Conclusions are given in Section 6.

2. Signal Model

In this chapter we assume that received radar signal from illuminated object can be modelled using point scatterer model (Chen and Miceli, 2001; Chen and Ling, 2002). Therefore received signal can be written as a sum of the frequency modulated (FM) signals (Stanković et al., 2008):

$$q(m,n)=\sum_i \sigma_i \exp(j\phi_i(m,n)), \tag{1}$$

where σ_i is reflection coefficient of the corresponding scatterer, while m and n, respectively, correspond to the signal number transmitted toward a target (so called slow time coordinate) and to the sample number within one chirp (so called fast time coordinate). The form of the phase functions $\phi_i(m,n)$ depends on the type of the corresponding radar scatterer. Typical phase function models for both SAR and ISAR systems are given in Table 1.

In all considered cases, the phase functions can be written as: $\phi_i(m,n)=a_i^{(1)}m+b_i^{(1)}n+\psi_i(m,n)$, where $\psi_i(m,n)$ represents higher-order terms in the signal phase, while parameters ($a_i^{(1)}$, $b_i^{(1)}$) correspond to the position of scatterers. Other introduced parameters $a_i^{(p)}$, $d_i^{(p,k)}$, c_i, α_i, β_i and φ_i depend on the position of the observed objects, relative motion, radar systems parameters, parameters of the object motion and some other effects.

The radar image can be obtained by using the 2D FT as:

$$Q(m',n')=\sum_m\sum_n q(m,n)w(m,n)\exp(-j2\pi m'm/M-j2\pi n'n/N), \tag{2}$$

where M is the number of pulses in one revisit, N is the number of samples within one pulse, while $w(m,n)$ is a window function used to reduce spectral leakage effects in the FT domain. For a single scatterer return that corresponds to non-moving objects in the SAR systems and rigid body parts in the ISAR systems (second row of Table 1) the 2D FT is:

$$Q_i(m',n')=\sigma_i W(m'-Ma_i^{(1)}/2\pi, n'-Nb_i^{(1)}/2\pi), \tag{3}$$

where $W()$ is the 2D FT of the window function. Since a window is commonly designed to be highly concentrated in the FT domain, we can assume that, for stationary objects, radar image is highly concentrated around position that is proportional to ($a_i^{(1)}$, $b_i^{(1)}$), and these parameters are proportional to the position of the scatterer point in the cross-range/range domain.

TABLE 1. Phase functions for SAR and ISAR systems and different setups.

Phase function	SAR systems	ISAR systems
$a_i^{(1)} m + b_i^{(1)} n$	Non-moving objects	Rigid body parts
$a_i^{(2)} m^2 / 2 + a_i^{(1)} m + b_i^{(1)} n$	Moving objects	Objects with uniform acceleration
$\sum_{p=1}^{P} a_i^{(p)} m^p / p! + b_i^{(1)} n$	Objects with non-uniform motion	
$a_i^{(1)} m + b_i^{(1)} n + \sum_{p=1}^{P} \sum_{k=1}^{K} d_i^{(p,k)} (m^p / p!)(n^k / k!)$	Objects with complicated motion patterns	
$a_i^{(1)} m + b_i^{(1)} n + c_i \sin(\alpha_i m + \beta_i n + \varphi_i)$	Objects with vibrations and rotations	

For other forms of the phase function the 2D FT can be represented in the following form:

$$Q_i(m', n') = \sigma_i W(m' - Ma_i^{(1)} / 2\pi, n' - Nb_i^{(1)} / 2\pi) *_{m'} *_{n'} FT\{\exp(j\psi_i(m, n))\} \quad (4)$$

where $*_{m'} *_{n'}$ represents the 2D convolution, while the term $FT\{\exp(j\psi_i(m, n))\}$ causes spreading and possible dislocating component from the proper position. The motion compensation techniques compensate this term based on the estimation of motion parameters of the objects. Alternatively, the motion compensation can be performed by estimating higher-order coefficients in the signal phase (Djurović et al., 2006). However, these techniques are computationally demanding. The TF representations are another approach that will be considered in the next section where two novel techniques for radar imaging based on the TF representation are presented. The algorithms for realization are given as well as brief comparison of these techniques.

3. TF Representations in Radar Imaging

3.1. BACKGROUND

In order to avoid complex valued nature of the 2D FT, its squared magnitude $|Q(m',n')|^2$ is commonly used for imaging, which is equivalent to the periodogram in spectral analysis (or to the spectrogram in the TF analysis). The mechanism of defocusing in the radar images is equivalent to the spreading of components in the case of the spectrogram in the TF analysis. Thus, well developed techniques for sharpening components in the TF analysis can be applied here with some modifications.

The TF analysis developed numerous tools for sharpening the signal from the spectrogram toward the ideal concentration. However, these tools introduce different kind of drawbacks: cross-terms and inner interferences, significantly increased complexity and memory demands, etc. Cross-terms and inner interferences correspond to fake (ghost) objects in radar images. Here, we will demonstrate two novel techniques in the field. The first technique is based on the SM. This representation is bilinear that combines some favourable properties of the periodogram representation and Wigner Distribution (WD). Its application to the radar imaging is quite simple and it includes just one additional software or hardware component for realization (Ivanović et al., 2006). The SM has free parameter that can be selected adaptively based on some suitable criterion. Alternative imaging is based on LPFT. This transform is linear. Therefore, it is quite suitable since it can be used for development of high quality strategy for focusing radar images without introducing spurious components. However, determination of the free parameter of this transform is not straightforward and we need some sophisticated procedure to obtain it. In addition, sometimes it is important to have LPFT with different adaptive parameters for various components. This can significantly increase calculation burden of LPFT. We will define these two transforms and describe corresponding radar imaging approaches.

3.2. S-METHOD (SM)

The 2D WD can be defined in the following form:

$$\begin{aligned} WD(m,n;m',n') = \sum_{m_1}\sum_{n_1} q(m+m_1,n+n_1)q^*(m-m_1,n-n_1) \\ \times w(m_1,n_1)\exp(-j4\pi m_1 m'/M - j4\pi n_1 n'/N). \end{aligned} \tag{5}$$

In radar imaging applications this can be written in an alternative form using the standard radar image $Q(m',n')$ as:

$$WD(m',n') = \sum_{k}\sum_{l} Q(m'+k,n'+l)Q^*(m'-k,n'-l) .$$

Therefore, the WD can be considered as a sum of periodogram $|Q(m',n')|^2$ and terms $Q(m'+k,n'+l)Q^*(m'-k,n'-l)$ for $k \neq 0$ and $l \neq 0$. However, it can be proved that even a small number of these terms (for small $|k|$ and $|l|$) improves concentration, i.e., helps in focusing radar image. What is more important, large values of $|k|$ and $|l|$ do not improve concentration significantly, but they can introduce the cross-terms and inner interferences (Stanković, 1994; Stanković et al., 1996). In radar imaging these components correspond to fake objects in images. Then, as a natural tool for imaging, the SM can be used (Stanković et al., 2006):

$$SM(m',n') = \sum_k \sum_l \Pi(k,l) Q(m'+k,n'+l) Q^*(m'-k,n'-l) . \tag{6}$$

Frequency window function $\Pi(k,l)$ can be defined as:

$$\Pi(k,l) = 1 \text{ for } |k| \leq K \text{ and } |l| \leq L \text{ and } \Pi(k,l) = 0 \text{ elsewhere} . \tag{7}$$

However, quite often the SM is calculated along a single coordinate, for example along fixed range cell for $L = 0$ or along single cross-range cell for $K = 0$. Selection of the parameter K and/or L is straightforward since we can take relatively small values for these parameters (for example between 1 and 10) for obtaining relatively good results. These results are expected to significantly improve concentration of components without introducing spurious terms. When objects are moving in different manners or when objects are very close to each other we need some technique to adaptively select window width. Here, we will describe the adaptive selection of the parameter K in the SM calculated only along the cross-range component (for $L = 0$). This can be extended in similar manner for other forms of the SM including 2D SM with both $K \neq 0$ and $L \neq 0$.

The adaptive 1D SM for radar images can be defined as:

$$SM(m',n') = |Q(m',n')|^2 + 2\,\mathrm{Re}\left\{ \sum_{k=1}^{K(m',n')} Q(m'+k,n') Q^*(m'-k,n') \right\} . \tag{8}$$

$K(m',n')$ can be simply obtained as a maximal value of k for which the term $\mathrm{Re}\{Q(m'+k,n')Q^*(m'-k,n')\}$ used for SM calculation is greater than a specific threshold $R(m',n')$, and where all terms $\mathrm{Re}\{Q(m'+k',n')Q^*(m'-k',n')\}$ for $|k'| < |k|$ are greater than the threshold. This can be written as:

$$K(m',n') = \arg\max_k \bigwedge_{k'=1}^{k} \left(\mathrm{Re}\left\{ Q(m'+k',n') Q^*(m'-k',n') \right\} \geq R(m',n') \right) . \tag{9}$$

The remaining problem is threshold $R(m',n')$ selection. There are various approaches for threshold determination, but in this manuscript we will use a quite simple technique that follows the Otsu algorithm for threshold selection in digital image processing (Stanković et al., 2008). STEP 1: Set the initial value of threshold to the half of the pixels intensity maximum:

$$\rho = \max_{m',n'} |Q(m',n')|/2 . \tag{10}$$

STEP 2: Calculate S_1 as a sum of intensity values of the pixels whose intensity is arger than ρ and S_2 as a sum of intensity values of the pixels smaller than ρ:

$$S_1 = \sum_{m',n'} |Q(m',n')|, \ \left(\forall(m',n'), \ |Q(m',n')| > \rho\right) \tag{11}$$

$$S_2 = \sum_{m',n'} |Q(m',n')|, \ \left(\forall(m',n'), \ |Q(m',n')| < \rho\right) \tag{12}$$

STEP 3: Calculate ρ_1 and ρ_2 as:

$$\rho_1 = S_1 / N_1, \ \rho_2 = S_2 / N_2 , \tag{13}$$

where N_1 and N_2 are number of elements summed in (11) and (12) respectively. STEP 4: Compute a new threshold value as:

$$\rho = (\rho_1 + \rho_2)/2 . \tag{14}$$

STEP 5: Repeat steps 2 through 4 until the difference in ρ in successive iterations is smaller than a predefined parameter, or for a specified number of iteration.

It is interesting that this quite simple thresholding strategy gives very good results in numerous experiments we performed on point scatterer data, nevertheless alternative forms of threshold determination could also be employed. The threshold obtained after five iterations is used in our simulations.

3.3. LOCAL POLYNOMIAL FOURIER TRANSFORM (LPFT)

The local polynomial form of the radar image can be obtained as:

$$Q_P(m',n') = \sum_m \sum_n q(m,n) w(m,n) e^{-j2\pi mm'/M - j2\pi nn'/N} \exp\left(-j\sum_k \sum_l \alpha_{kl} m^k n^l\right),$$

where α_{kl} are polynomial coefficients and $k+l \geq 2$. It can be seen that the standard imaging is changed by adding polynomial phase term $\exp(-j\sum_k \sum_l \alpha_{kl} m^k n^l)$. This term is introduced for compensation of the higher-order terms that are described in Table 1.

Commonly, spreading occurs only in one direction (range or cross-range domain). Therefore, we are performing autofocusing operations only in this domain. In addition, we can assume that the most of defocusing can be eliminate with second order (chirp) parameter and that we can take that

$\alpha_{20} = \alpha \neq 0$ and all other $\alpha_{kl} = 0$ (or, as an alternative, $\alpha_{02} \neq 0$ and $\alpha_{kl} = 0$). Then this simplified LPFT form of radar image can be written as:

$$Q_\alpha(m',n') = \sum_m \sum_n q(m,n) w(m,n) e^{-j2\pi mm'/M - j2\pi nn'/N} e^{-j\alpha m^2},$$

for focusing only in the cross-range domain. The problem is how to determine the chirp-rate parameter α in such a manner to obtain the best possible auto-focused radar image. Unfortunately, this cannot be performed simply. Namely, radar image can contain numerous objects, some of them moving with various motion parameters. Then different chirp-rate values are required for focusing various components. Here, we will demonstrate the adaptive LPFT determination along cross-range direction concentrating attention on the single received chirp components. In the description of the algorithm we will fix chirp $s(n) = q(m,n)$, but it should be kept in mind that this procedure is repeated for each chirp.

Algorithm

Calculate $R(n') = \sum_n s(n) \exp(-j2\pi nn'/N)$, set $I = 0$ and $s_I(n) = s(n)$.

WHILE $s_I(n)$ has significant energy, i.e., $\sum_n |s_I(n)|^2 \geq \varepsilon'$.

Calculate $S_I(n') = R(n')$ if frequency (n') represents well focused component and $S_I(n') = 0$ otherwise. Update non-focused components as: $R(n') \leftarrow R(n') - S_I(n')$. Calculate $s_I(n) = IFT\{R(n') \exp(j\hat{\alpha}_i n^2)\}$.

We assume that component is highly concentrated when the considered pixel $|S_I(n')|$ is above the threshold $|\mathrm{S_I(n')}| \geq \varepsilon''$. Furthermore, we set that $S_I''(n')$ should be local maximum (greater than neighbour samples) and, what is more important, we want that this maximum is significantly larger than neighbour samples $\left|S_I''(n')\right| \geq \kappa_r \left|S_I''(n' \pm r)\right|$, $\kappa_r \geq 1$.

Set $\mathrm{I} \leftarrow \mathrm{I}+1$.

FOR $\alpha \in \Lambda$ (for various chirp-rates from the considered set Λ)

Calculate

$$R_\alpha(n') = \sum_n s_I(n) \exp(-j2\pi nn'/N - j\alpha n^2). \tag{15}$$

ENDFOR

Estimate the chirp-rate of the radar returns as:

$$(\hat{\alpha}_I, \hat{n}') = \arg\max_{(\alpha,n')} |R_\alpha(n')|, \qquad R(n') = R_{\hat{\alpha}_I}(n'). \tag{16}$$

ENDWHILE

If $s_I(n)$ has still significant energy but we cannot detect highly concentrated components we can assume that signal has higher-order terms in the phase (higher than 2) and we can perform search for the next order in the signal phase (third order) in the same manner as we did for the second order. Details on the adaptive order search procedure can be found in Stanković and Djukanović (2005).

The most interesting question is related to the design parameters of the algorithm ε', ε'', κ_r. Global threshold under which we assume that there are no more components can be determined by using the same or similar procedure as in the case of the SM and the Otsu algorithm. Alternatively, we can set this threshold to be several percentage of entire input signal energy. In our experiments, we obtained accurate results for threshold within [0.2, 2]% of entire signal energy for noiseless case. In order to perform optimization procedure for a small number of chirps, in the case of the signal corrupted by additive white Gaussian noise, the threshold ε' is set to: $kN\sigma^2$, where N is the number of samples within one chirp, σ^2 is estimation of the variance obtained as in Djurović et al. (2008), while $k = 1.8$ is used in our simulations. For determination of the second threshold ε'' we can assume that maximum in the corresponding chirp is always candidate for the highly concentrated component. In addition, all components that have comparable magnitude to the maximal for corresponding chirp are candidates for highly concentrated component. Hence, we adopted conservative value for threshold $\varepsilon'' = 0.1 \max |R(n')|$. Finally, we want to select only sharp local maximum and we want that this component is significantly stronger than components on neighbour frequency bins. Therefore we decided to consider only two neighbour frequency bins from each side and we set $\kappa_1 = 2$ and $\kappa_2 = 4$.

4. Comparison of the Proposed Techniques

We will now briefly compare these two imaging strategies in term of expected results and problems in realization and in calculation complexity.

The SM is a post-processing technique and the input in additional processing block is the standard radar image. However, LPFT changes input signal by multiplying it with the chirp functions and after that processing is performed on modified signal. In our algorithm for realization of LPFT, we calculate the standard radar image in order to extract well-concentrated components. If all components are well concentrated (focused) with the standard radar image we are skipping other steps.

In estimation of the calculation complexity we will consider only overhead introduced by additional processing with respect to the standard 2D FT-based imaging. In the case of the SM we are adding terms $2\,\mathrm{Re}\{\sum_{k=1}^{K(m',n')} Q(m'+k,n')Q^*(m'-k,n')\}$ to the basic radar image. Let the maximum number of these terms be $K_{\max}$. Then complexity of this operation is of the order $O(K_{\max}NM)$ where NM is size of the radar image. Commonly, $K_{\max}$ is small comparing to both N and M (typically $K_{\max}$ is about 10, while N and M are hundredths). Hence we can conclude that adding these terms is of the order of magnitude in complexity $O(NM \log_2 NM)$. Logical operations for threshold determination are also of the complexity $O(K_{\max} NM)$, while global threshold determination has complexity $O(I_{\max} NM)$ where $I_{\max}$ is maximum number of iterations. Again the number of iterations is commonly much smaller than both N and M. From these considerations it is easy to conclude that complexity of additional operations in the SM is of the same order of magnitude as the standard radar image evaluation.

In the case of LPFT we calculate the FT of signal modulated with linear FM signal for each value of the chirp-rate parameter from the set Λ. Therefore, complexity of the LPFT-based algorithm is $O(LNM \log_2 NM)$, where L is number of elements (chirp-rates) in the set Λ. The number of chirp-rates in the set Λ can be large (hundredths or thousands). This means that the LPFT-based algorithm has significant more calculations than the SM-based algorithm. Techniques for optimization of the LPFT-based algorithm are considered in Djurović et al. (2006); Stanković (2001). They are based on the iterative LMS algorithm. However, calculation complexity of this algorithm is about 10–15 times higher than the standard imaging technique and 5–10 times more than the SM-based technique.

Then, it remains to explain why we need sometimes the LPFT-based technique. We will explain it first on the case of the radar return that represents a sum of two parallel linear FM signals (with the same chirp-rate):

$$x(t) = \exp(jat^2/2) + \exp(jat^2/2 + jbt) \tag{17}$$

This signal can corresponds to two objects in the SAR images with the same parameters of motion (velocity and acceleration) separated for a relatively small distance proportional to the parameter b. In a similar manner this very simple model can be connected with objects in ISAR images. The absolute value of FT of this signal can be approximated as:

$$|X(\omega)| \approx \sqrt{\frac{2\pi}{a}} \left| w\left(\frac{\omega}{a}\right) \right| + \sqrt{\frac{2\pi}{a}} \left| w\left(\frac{\omega - b}{a}\right) \right|. \tag{18}$$

For example, if the width of the window is T, these components are overlapping when $|b| < aT$. As a result, the components are not separated in the standard radar image and in the process of sharpening images the SM would introduce cross-terms, i.e., the SM is unable to separate components (objects) that are not separated in the standard image. Even this situation is rather rare since it can happen for high values of chirp-rate parameter and/or for very close components (very small b). Then we should use the LPFT technique that is able to give ideally concentrated signal for properly adjusted chirp-rate parameter.

The LPFT will outperform the SM and in the case of the radar signal embedded in noise. The threshold determined by the algorithm used in the adaptive SM will be, for the same number of iterations and the same setup, higher in the presence of noise than in noiseless case. Hence, the value of K used in the adaptive SM for focusing parts of the radar image containing fast moving objects can be too small to produce good concentration. What is more important here, some of the moving objects can be almost invisible comparing to stationary objects. By increasing the number of iterations in the algorithm for threshold determination, threshold would decrease, but still not enough to produce high concentration of moving objects as in noiseless case. Here, by using the LPFT-based algorithm each object will be well focused. In addition, considerable amount of noise will be rejected.

5. Examples

In this section we provide several examples where advantages and disadvantages of the proposed techniques for radar imaging can be clearly observed.

Example 1. The simulation setup composed of seven point scatterers is considered in this example. Some of the objects (No. 1, No. 3 and No. 4) are stationary, while the rest are moving objects (No. 2, No. 5, No. 6 and No. 7). The position of the radar objects can be described as: $x_i(t) = x_{i0} + v_{xi}(0)t + a_{xi}t^2/2$ and $y_i(t) = y_{i0} + v_{yi}(0)t + a_{yi}t^2/2$, where the motion parameters are given in Table 2. Radar signal reflected from the 7 point scatterers can be obtained by using superposition principle as a sum of individual echoes.

TABLE 2. Motion parameters for the targets used in Example 1.

Scatterer no.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
$x_0[m]$	0	30	–9	9	30	–25.5	30
$y_0[m]$	90	90	0	0	–90	–90	–90
$v_x[m/s]$	0	–12	0	0	12	13	0
$v_y[m/s]$	0	–20	0	0	0	0	20
$a_x[m/s^2]$	0	2	0	0	0	0	0
$a_y[m/s^2]$	0	0	0	0	0	0	0.7

The CV 580 SAR system (C-band) parameters are used in this example. The radar operates at the frequency $f_0 = 5.3$ GHz. The bandwidth of linear FM signals is $B = 25$ MHz, the pulse repetition time is $T = 1/300$ s, with $M = 256$ pulses in one revisit. The number of samples within one pulse is $N = 256$. The aircraft with radar is moving along x-axis with velocity

$V = 130$ m/s . Radar altitude is $h = 6$ km , while radar ground distance to the origin of x/y coordinate system is 10 km at the beginning of the observation time.

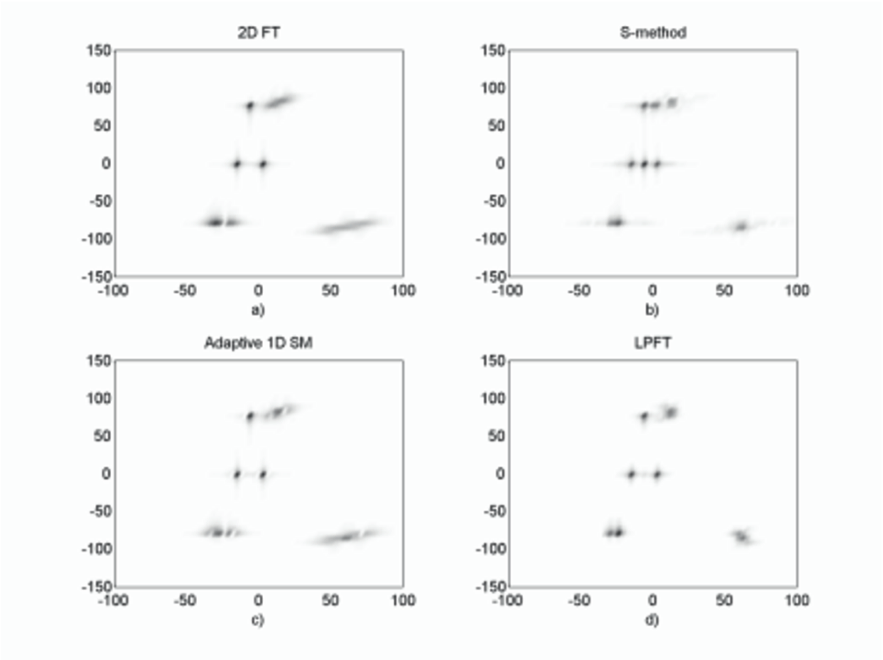

Figure 1. Simulated SAR image of 7 target points obtained by using: (a) 2D FT, (b) S-Method with K = 3, (c) Adaptive S-Method and (d) LPFT.

The radar image obtained by using the 2D FT is shown in Figure 1a. The 2D FT produces well focused stationary objects, while moving objects are defocused. Higher concentration of moving objects is achieved by using the signal independent 1D SM with a relatively small value of K, $K = 3$ is used for Figure 1b. Despite the small value of K used for the SM calculation, cross-terms appear between close moving objects (No. 1 and No. 2, and No. 5 and No. 6), as well as between close stationary objects (No. 3 and No. 4). By applying the adaptive SM, additional focusing of objects is obtained, as visible from Figure 1c. In addition, there are no cross-terms in the resulted radar image except between two very close moving objects (No. 5 and No. 6). In the case of very close stationary objects the cross-term appearing is prevented. Namely, in the adaptive SM a small value of K , or even a value of K equal to zero, is used in the case when no additional focusing is needed (stationary object case). In the case of moving objects, a value of K greater than zero is needed in order to focus them. Using adaptive values of K gives as a result a well focused radar image of each moving object, avoiding cross-terms appearing except in the case of very close objects (No. 5 and No. 6). Here, the LPFT should be used. All effects desired in radar imaging are achieved by using the LPFT. Namely, the radar image is highly concentrated as visible from Figure 1d, without defocusing of stationary object or introducing cross-terms even between very close objects. However, the price for these effects is additional computational burden of LPFT when compared to the adaptive SM. It can be concluded that in the case when objects are very close and moving, only LPFT will produce well focused image of each object, without introducing cross-terms.

Example 2. Here, the same setup as in Example 1 is used. The radar signal is embedded in Gaussian white additive noise with standard deviation $\sigma = 18$. LPFT, even in the presence of noise, produces well focused radar images without cross-terms, as visible from Figure 2d. The presence of noise limits performances of the adaptive SM, as shown in Figure 2c, resulting in the lower concentration of the objects as compared to the noiseless case shown in Figure 1c. As a consequence, a fast moving object (No. 7) is almost invisible compared to the other well focused objects. This can be explained by the fact that a threshold determined by the algorithm used in the adaptive SM will be higher in the presence of noise than in the noiseless case. Moreover, some of the objects can perform very fast motion, producing linear FM signal with a high chirp-rate, or higher than second order polynomial phase signals (Table 1). By increasing the order in polynomial phase of the signal the width of its 2D FT will also increase (smearing), while the magnitude of its 2D FT, used in the adaptive SM, will decrease. Then, the value of K used in the adaptive SM for focusing parts of the radar image containing this fast moving objects can be too small to produce good concentrations, i.e., to decrease the width of its 2D FT (focusing). Hence, some of the moving objects can be almost invisible if compared to focused objects. By increasing the number of iterations in the algorithm for threshold determination in the SM, the threshold would decrease, but still not enough to produce high concentrations of all moving objects as in the noiseless case. It should be noted here that the Otsu-based algorithm for threshold determination in the adaptive SM is just one of the various possible approaches for the threshold determination.

By comparing Figure 2d to the rest of Figure 2, it can be seen that the proposed LPFT-based algorithm reduces the level of noise comparing to the 2D FT, SM as well as the adaptive SM. The obtained result is expectable. Namely, in the proposed algorithm, only the well focused parts of the initial radar image, visible in Figure 2a, that correspond to the stationary objects, and the parts of the image determined as objects and additionally focused by applying the LPFT, will appear in the resulting radar image as shown in Figure 2d. Moreover, a relatively small portion of the radar image is related to the objects while the noise is spread along the entire radar image, therefore a significant portion of noise will be discarded by this algorithm.

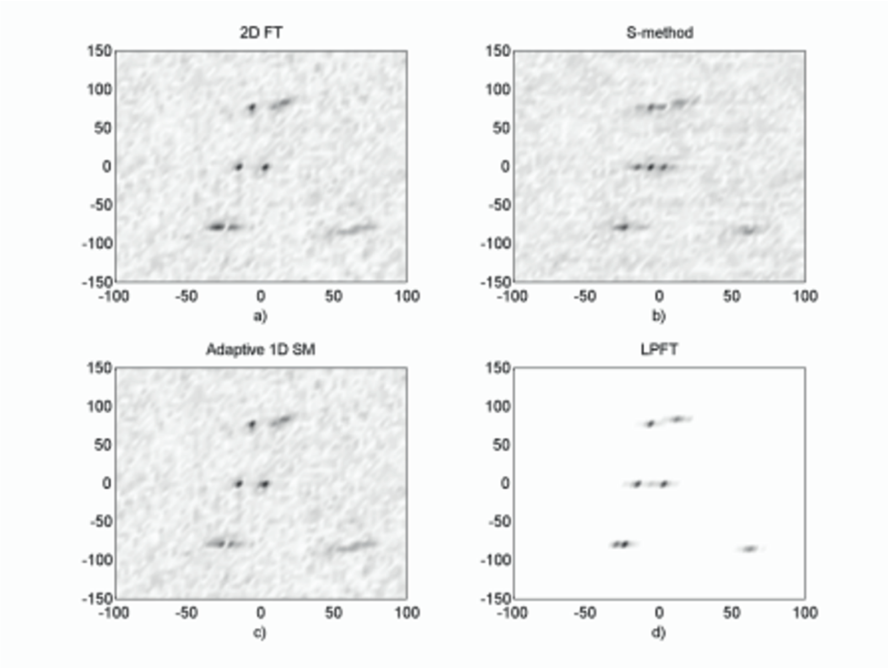

Figure 2. Simulated SAR image of 7 targets for radar signal embedded in white additive Gaussian noise obtained by using: (a) 2D FT, (b) S-Method with K = 3, (c) Adaptive SM, (d) LPFT.

6. Conclusions

In this chapter we demonstrated two novel techniques for radar imaging based on the TF analysis. The first technique is based on non-linear transform called the S-Method. Free parameter of this transform can be selected in semi-intuitive manner, but also we proposed simple adaptive technique for its selection that can be used for more complicated motion patterns. The second technique is based on linear representation called Local Polynomial Fourier Transform. The procedure for selection of the parameter in LPFT is relatively complicated and computational burden of this transform is higher than in the case of the SM. However, in some applications it can produce results of higher accuracy than the SM-based technique. We demonstrate also that LPFT has better robustness to additive noise. This property is of significant importance in practical applications in realistic noisy environments.

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PROCESSING OF MULTICHANNEL REMOTE SENSING DATA FOR ENVIRONMENT MONITORING

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Abstract. Several main practical tasks, important for effective pre-processing of multichannel remote sensing (RS) images, are considered in order to reliably retrieve useful information from them and to provide availability of data to potential users. First, possible strategies of data processing are discussed. It is shown that one problem is to use more adequate models to describe the noise present in real images. Another problem is automation of all or, at least, several stages of data processing, like determination of noise type and its statistical characteristics, image filtering and compression before applying classification at the final stage. Second, some approaches that are effective and are able to perform well enough within automatic or semi-automatic frameworks for multichannel images are described and analyzed. The applicability of the proposed methods is demonstrated for particular examples of real RS data processing.

Keywords: Multichannel RS Images, Pre-Processing, Compression, Automation.

1. Introduction

Customers of RS data (governmental boards, nature protection organizations, space agencies, marine traffic services, meteorologists, etc.) require more reliable information (Xiuping et al., 1999). Such information can be offered in different forms: as raw or pre-filtered images, compressed data, classific-ation maps (Chein-I, 2007). Depending upon qualification and resources of customer's personnel, application RS data are used for solving a specific task. For this reason a customer can prefer to get data in one or another

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form among those listed above. This means that an owner of RS data (or an organization that obtains them and/or is responsible for their dissemination) should be eager and able to perform different kinds of data processing and to offer processed data to customers in the most suitable (requested) form.

Information content of RS data and effectiveness of solving final tasks of environment monitoring depend upon many factors. Among them, the main factors are the following: (a) information content of original (raw) data determined by RS operation mode, range of wavelengths covered by an imaging system, number of its channels and resolution, (b) noise level and statistical characteristics of the formed images; adequateness of noise models and/or availability of a priori information about model parameters; (c) effectiveness of the methods used for RS data processing where by processing here we mean a wide set of operations that, depending upon application, might include evaluation of noise characteristics, filtering, compression, registration, geo-referencing, calibration, classification, interpretation, etc. (Kulemin et al., 2004).

To increase information content of RS data, nowadays multichannel complexes are designed and exploited. Saying "multichannel", we mean that a set of images of a terrain is formed either simultaneously or, in some cases, sequentially (e.g., to detect temporal changes). This tendency is observed for different RS imagers used in optical, infrared, and radio wave bands (Chein-I, 2007; Kulemin et al., 2004), and the number of channels (bands) continues to increase. This potentially expands facilities of such systems making them multi-purpose, i.e., providing an opportunity to solve a wider set of practical tasks for different applications by means of information retrieval from the most informative subsets of images. However, the volume of RS data radically grows and it becomes more and more difficult to manage them, to transfer them, to reduce redundancy, to process, to select the proper subset of channels (component, sub-band), images and appropriate methods for image enhancement.

Clearly, it is practically impossible to give one strict recommendation about the data pre-processing strategy, the best solution is to give a full description of possible approaches. Therefore, below we concentrate on possible strategies and stages of multichannel RS data processing assuming the following. First, processing can be carried out on-board, on-land, or, in general, both. Second, before transmission data are to be compressed and for this reason we focus on lossy compression since even the most powerful techniques of lossless coding are nowadays unable to provide a compression ratio (CR) larger than 3.5/4 (Mielikäinen, 2006). This is often not enough for practical applications due to downlink channel limitations.

Meanwhile, it has been recently understood (Aiazzi et al., 2005) that it is also possible and worth using near-lossy and lossy compression of multichannel RS data under conditions that the introduced losses relate to removal of noise present in images and these losses do not lead to distorting valuable information. However, it is an open question how to perform such lossy compression to simultaneously satisfy above-mentioned requirements, especially if this should be done in automatic manner. Note that at the same time it is desirable to provide high CR and appropriate accuracy of solving the final tasks of RS like multichannel image classification, anomaly or target detection, etc. This chapter partly answers this question.

2. Possible Strategies of on-Board/on-Land Processing and Compression

There are, at least, three possible strategies for on-board/on-land processing and lossy compression of multichannel RS data (Ponomarenko et al., 2007, 2008). Each of them can exploit component-wise processing (sub-band, each channel separately) and 3D (grouped, vector-like) processing (pre- or post-filtering) as well as compression.

According to a first strategy (Ponomarenko et al., 2007), a multichannel image is a subject to lossy compression without pre- and post-filtering. In Section 3 we focus on some details of just this strategy. This strategy (**strategy 1**) assumes that the first (on-board) stage is blind evaluation of noise variance. It is applied component-wise to obtain a set of estimates of noise standard deviations (SDs) $\hat{\sigma}(n), n = 1,...,N$ where N denotes a number of components of multichannel image. Then the component (sub-band) images can be either grouped or compressed separately. If grouping is applied, it is carried out with taking into account two rules. First, each group should contain either 4, or 8, or 16 sub-band images (for hyperspectral data like AVIRIS). The second less strict rule is that images with indices $n = n_{\min},...,n_{\max}$ are grouped if standard deviation estimates for these component images do not differ significantly, for example, if:

$$\max\{\hat{\sigma}(n), n = n_{\min},...,n_{\max}\} / \min\{\hat{\sigma}(n), n = n_{\min},...,n_{\max}\} \leq 1.4 \qquad (1)$$

The detailed description of the algorithms for blind estimation of SDs and image grouping is presented in (Ponomarenko et al., 2007). If grouping is not used, each component image is compressed by setting a 2D coder quantization step equal to $QS(n) = C_1\hat{\sigma}(n), n = 1,...,N$ where C_1 is a parameter. If grouping is used, then a 3D coder is used where the quantization step for it is determined as $QS_q = C_1 \min\{\hat{\sigma}(n), n = n_{\min},...,n_{\max}\}$ for each qth group. Here it is worth mentioning that as a 2D coder we propose to apply the coder AGU (Ponomarenko et al., 2005). This coder is based on discrete cosine transform (DCT) in 32 × 32 pixel blocks, more advanced probability models, and image deblocking after decompression.

This coder outperforms most wavelet-based coders and it has been modified to 3D case (Ponomarenko et al., 2007). One more advantage of this coder is its relative simplicity, as the parameter controlling CR is the quantization step. Just to provide fast implementation, the aforementioned condition of sub-band grouping by 4, 8, or 16 channels, has been introduced. However the 3D version of this coder can be applied to any number of channels. Recommendations concerning selection of the parameter C_1 will be given in the next section.

An advantage of the strategy described above is its simplicity. The only operation to be done before lossy compression is automatic estimation of $\hat{\sigma}(n), n = 1,...,N$, and this operation is rather fast. Another advantage is that this strategy provides CR from 4.5 to 9 for component-wise compression and from 8 to 25 for compression with adaptive sub-band grouping for 224-channel AVIRIS data. As seen, the latter approach is better, larger CR results from incorporating inter-channel correlation inherent for hyperspectral data. There are also two main drawbacks of this strategy. The first disadvantage consists in that although such lossy compression performs some denoising, such denoising is not perfect in the sense that advanced filtering techniques are able to carry out noise removal considerably better (Lukin et al., 2006a, b). Besides, it can be difficult to further improve decompressed data quality on-land by post-filtering. Note also that the strategy described above is based on the assumption of an additive noise model although recent investigations (Barducci et al., 2005) show that noise model can be more complex.

Because of the aforementioned drawbacks we have started to consider in parallel two alternative strategies of automatic compression of multichannel images (Lukin et al., 2006; Ponomarenko et al., 2008). According to the strategy that we will further refer as **strategy 2**, multichannel data are compressed in near-lossless manner by taking into account noise characteristics of component images. Again the first stage of RS data processing is blind evaluation of $\hat{\sigma}(n), n = 1,...,N$. Then the data can be either compressed component-wise or grouped as described above and compressed using 3D version of the AGU coder. The only difference is that $QS(n) = C_2\hat{\sigma}(n), n = 1,...,N$ for component-wise compression and $QS_q = C_2 \min\{\hat{\sigma}(n), n = n_{\min},...,n_{\max}\}$ for each qth group for adaptive grouping based compression where the parameter C_2 is considerably smaller than C_1 for the **strategy 1**. More in detail, we recommend to use $C_2 \approx 1.3$.

The consequence of such decision is twofold. On the one hand, **strategy 2** produces sufficiently smaller CRs than **strategy 1**, namely, from 3.3 to 7.2 for component-wise compression and from 5.4 to 14.2 for compression with grouping. The intervals of CR values are given for the same AVIRIS data (conventional test images Moffett Field, Cuprite Mine, Lunar Lake, Jasper Ridge). On the other hand, **strategy 2** provides practically full potential for consequent effective filtering of decompressed images on-land (if needed). Note that more efforts and time can be spent on data filtering on-land where resources are not so limited as on-board and filtering can be carried out not in a blind but in interactive manner.

Thus, upon user's request, both almost original and filtered RS data can be offered and this is the main advantage of **strategy 2**. Concerning better compression, it is reasonable to apply the 3D coder version.

Finally, there is also a third strategy (**strategy 3**). It presumes that filtering is carried out on-board. Then pre-processed data is compressed in a lossy manner, and transferred by a downlink communication channel. On-land these data can be either disseminated or stored in compressed form, or decompressed and further processed. More in detail, the first stage of processing is again blind evaluation of $\hat{\sigma}(n), n = 1,...,N$. This operation serves two purposes. The first is the use of the obtained estimates for component-wise filtering of images. Recall that many advanced methods for image filtering like wavelet (Sendur and Selesnick, 2002) and DCT based (Oktem et al., 2007) denoising, require a priori knowledge or pre-estimation of noise variance (standard deviation) for threshold setting. The second purpose is to set a coder quantization step. For component-wise compression we use $QS(n) = C_3\hat{\sigma}(n), n = 1,...,N$ and for the adaptive grouping based compression $QS_q = C_3 \min\{\hat{\sigma}(n), n = n_{\min},...,n_{\max}\}$ for each qth group where C_3 is a parameter recommended to be approximately equal to 1.5. The values of CR provided by **strategy 3** for AVIRIS images are from 3.4 to 10.0 for component-wise compression and from 5.6 to 20.0 for compression with adaptive grouping. As in the previously considered cases, 3D compression provides sufficiently larger compression ratios.

An advantage of **strategy 3** is that it produces higher quality of images than **strategy 1**, examples are shown by Lukin et al. (2006) for radar images. The simultaneous advantage and the drawback of **strategy 3** is that it provides already filtered multichannel images. An insight on this property depends upon user's priority of requirements. One user can prefer not to deal with on-land post-processing of RS data, i.e., he/she would like to obtain already filtered data after transmission and dissemination and de-compression. Another user might argue that it is possible (or he/she would like) to apply his/her own methods of image filtering or more advanced techniques than those ones realized on-board in automatic manner. In fact it is possible to reach in an interactive manner higher effectiveness of filtering than in automatic manner. Note that currently new effective methods of automatic filtering of images corrupted by different kinds of noise are under design and are developing rapidly (Foi, 2007; Lukin et al., 2007). This allows expecting in future more effective filtering of multichannel RS data to be carried on-board. One more drawback of **strategy 3** is that it requires more resources and time for on-board data processing than the two other strategies, since filtering of multichannel images is to be done.

For all three strategies, an achieved CR depends upon a multichannel image at hand. If an image has a simpler content or a smaller signal-to-noise ratio, a larger CR is automatically provided. If a number of channels (sub-bands) and/or their inter-channel correlation are larger, a reached CR also increases for the method of 3D-based compression in adaptively formed groups. All three strategies are organized in such a manner that they satisfy “higher quality” requirement in the first place and “higher CR” requirement in the second place. At the same time, if higher CR is desirable, setting larger values of the parameters C than recommended can increase it.

3. Peculiarities of Data Processing for Strategy 1

As shown by Al-Chaykh and Mersereau (1998), lossy compression of noisy images has to be characterized by peak signal-to-noise ratio (PSNR) calculated with respect to noise-free image ($PSNR_{nf}$) rather than conventional PSNR. Note that $PSNR_{nf}$ can be calculated only for test images when the corresponding noise-free image $I_{ij}^{nf}, i = 1.,...,I_{im}, j = 1,...,J_{im}$ is available

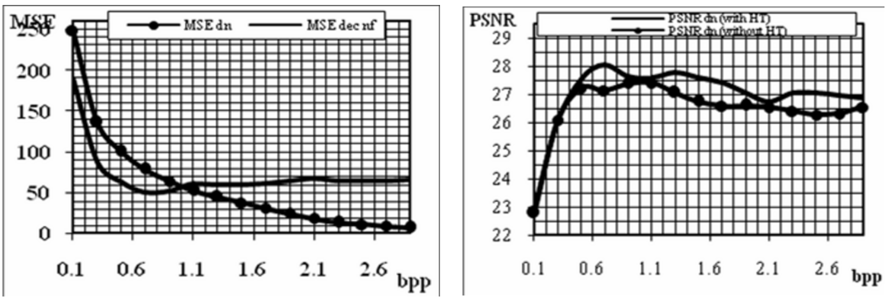
$$PSNR_{nf} = 10\log_{10}((I^{\max} - I^{\min})^2 / MSE_{dec\,nf}), \tag{2}$$

$$MSE_{dec\,nf} = \sum_{i=1}^{I_{im}}\sum_{j=1}^{J_{im}}(I_{ij}^{dec} - I_{ij}^{nf})^2 /(I_{im}J_{im} - 1), \tag{3}$$

where $I^{\max}, I^{\min}$ denote the maximal and minimal values of the images, respectively, I_{ij}^{dec} is the *ij*th pixel of decompressed image, $I_{im}J_{im}$ define the image size. Al-Chaykh and Mersereau, 1998, also demonstrated that for different types of noise there exists a so-called optimal operation point (OOP), i.e., such CR (or bit rate expressed in bits per pixel (bpp)) for which $PSNR_{nf}$ attains maximum or, equivalently, $MSE_{dec\,nf}$ reaches minimum. However, it has not been shown how to reach this OOP in practical cases when noise-free image is absent (not available). Fortunately, recently such procedures have been proposed by Lukin et al. (2006) and Ponomarenko et al. (2006). In particular, it has been shown that for pure additive noise case by setting $C_1 \approx 4.5$ it is possible to get into the neighbourhood of OOP (Ponomarenko et al., 2006). The situation is slightly more complicated for pure multiplicative noise. However, by means of logarithmic type direct homomorphic transform (HT) it can be reduced to additive noise case. Then the optimal QS that corresponds to OOP can be easily determined as $QS \approx 4.5\sigma_{at}$ where σ_{at} denotes additive noise standard deviation after direct HT. Following the same approach, it becomes possible to cope with Poisson-like noise typical of modern optical sensors (Foi, 2007).

Let us suppose that one applies the Anscombe transform ($I_{ij}^{A} = (I_{ij}^{n})^{1/2}$, where I_{ij}^{n} denotes the *ij*th pixel of noisy image) to an original image corrupted by Poisson or Poisson-like noise. Then, in case of Poisson noise, $\sigma_{at} \approx 0.5$ for the obtained image. In fact, it is possible to use also Anscombe-like transforms where $I_{ij}^{A-l} = B_0 (I_{ij}^{n})^{1/2}$ where B_0 is a parameter that for 8-bit image representation can be set equal to $\sqrt{255}$. Then, $\sigma_{at} \approx 0.5 B_0$. Inverse HT can be easily determined and it should be applied after image decompression where a subject of compression is the image $\{I_{ij}^{A-l}, i = 1,...,I_{im}, j = 1,...,J_{im}\}$ and the recommended $QS \approx 4.5\sigma_{A-l} = 4.5B_0/2$.

Figure 1a gives an example of the curves $MSE_{dec\,nf}$ vs. bpp and $MSE_{d\,n}$ vs. bpp for the Airdrome test image, which was corrupted by Poisson noise where $MSE_{d\,n} = \sum_{i=1}^{I_{im}} \sum_{j=1}^{J_{im}} (I_{ij}^{dec} - I_{ij}^{n})^2 / (I_{im} J_{im} - 1)$. As seen, if bpp reduces (QS and CR increase), $MSE_{d\,n}$ constantly grows as expected. Meanwhile, $MSE_{dec\,nf}$ has minimum (OOP) for bpp of about 0.7. This shows that filtering effect is observed due to lossy compression. Note that bpp = 0.7 for the considered case corresponds to $QS = 35 \approx 4.5B_0/2$. Figure 1b presents two other dependencies. The first is $PSNR_{nf}$ vs. bpp, that has OOP (maximum for bpp = 0.7). This dependence has been obtained for the proposed compression method that includes direct HT, lossy compression with different QS (bpp), decompression and inverse HT. Another dependence $PSNR_{nf}$ vs. bpp relates to direct application of AGU coder to original test image corrupted by Poisson noise. This dependence has similar behaviour and also has OOP (bpp = 0.7). However, for the former method (that employs the pair of Anscombe-like HTs) the value of $PSNR_{nf}$ for OOP is about 1 dB larger. Thus, it is more reasonable to use the compression method based on HTs.



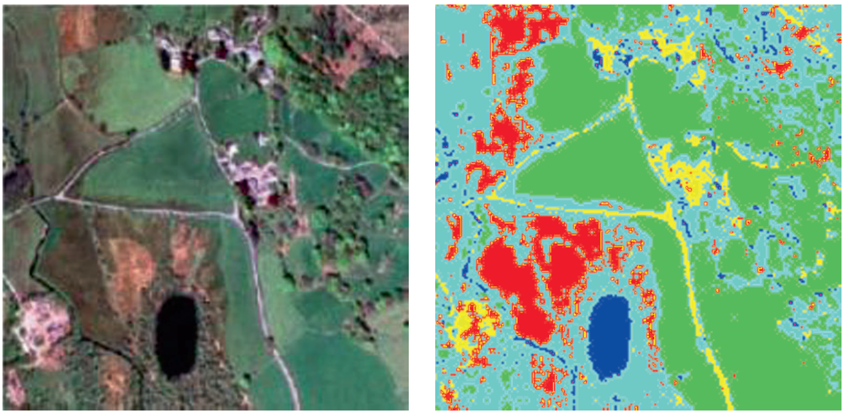
(a) (b)

Figure 1. Dependencies for the test image Airdrome corrupted by Poisson noise: the curves $MSE_{dec\,nf}$ vs. bpp and $MSE_{d\,n}$ vs. bpp (a), the curves $PSNR_{nf}$ vs. bpp for compression methods with and without using HTs.

Similar dependencies have been obtained for other test images, i.e., the observed phenomena are stable in the sense that they take place for different images. However, the values of bpp (CR) that correspond to OOP depend upon an image at hand. For images with more complex content, the achieved CR is commonly smaller. In future we plan to extend the described methodology of processing the images corrupted by Poisson or Poisson-like noise to hyperspectral (AVIRIS and other) images for which this noise model seems to be more adequate than pure additive noise model (Barducci et al., 2005).

4. Classification of Compressed Multichannel Images

One can argue that providing minimal $MSE_{dec\,nf}$ (or maximal $PSNR_{nf}$) does not guarantee the best solution for specific RS data processing tasks like classification, object and anomaly detection, etc. A very good study and discussion concerning correspondence between image quality (similarity) metrics and classification accuracy is presented in Christophe et al. (2005). However, it is clear that, in general, larger $PSNR_{nf}$ should lead to better classification. It has been shown by Lukin et al. (2006b) that lossy compression of noisy images can lead to better classification of decompressed RS data if compared with the same classification methods applied to original noisy images (or images compressed/decompressed in a lossy manner). The studies in (Lukin et al., 2006b) have been carried out for a three channel Landsat image artificially corrupted by pure additive noise (Figure 2). There were five classes, namely, bare soil, grass, water surface, roads and urban areas, and bushes. Neural network (NN) and support vector machine (SVM) classifiers have been applied and provided similar results.



(a) (b)

Figure 2. The test three-channel image in RGB representation (a) and the corresponding classification map for noise-free multichannel data (b).

However, classification accuracy has not been examined for different compression ratios that, for the AGU coder applied component-wise, are determined by QS. As a sample case, let us present some recently obtained data for additive noise variance of 100. The simulation results are given in Table 1. P_c denotes probability of correct classification for all considered classes. As seen, maxima of P_c and $PSNR_{nf}$ practically coincide. This means that providing the maximal $PSNR_{nf}$ by selecting the proper QS leads to reaching the neighbourhood of P_c maximum. This also holds true for all particular classes although maxima of correct classification probability for them do not exactly coincide. For example, for the class "Roads and urban areas" maximum of P_c is observed for slightly smaller QS than for other classes.

TABLE 1. Compression and classification characteristics for different QS.

QS	P_c (NN)	P_c (SVM)	*bpp*	$PSNR_{nf}$, dB
Noisy image	0.766	0.729	–	28.10
25	0.777	0.742	1.63	28.22
35	0.855	0.819	1.06	29.03
45 (OOP)	0.871	0.835	0.75	29.11
55	0.873	0.836	0.58	28.87

5. Conclusions

Three different strategies for automatic processing and compression of multichannel RS images have been described. Recommendations concerning parameter selection for them have been given. The advantages and draw-backs of these strategies have been considered. The simplest strategy (without any filtering) is analyzed more in details. It is shown that with the proposed modifications (the use of the corresponding HT) this can be applied if component images are corrupted not only by additive but also by multiplicative or signal-dependent (Poisson-like) noise. The relationship between compressed data quality in terms of PSNR and classification accuracy is considered. It is demonstrated that attaining of high $PSNR_{nf}$ results in providing probability of correct classification close to maximal.

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EARTH OBSERVATION AND REMOTE SENSING

EXPLOITING EARTH OBSERVATION MISSIONS: OPPORTUNITIES AND ISSUES IN GROUND SEGMENT INTERFACES HARMONIZATION

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Abstract. This chapter addresses issues and opportunities raised by global EO programmes, with particular reference to the ground segment harmonization for Global Monitoring for Environment and Security in Europe and the System of Systems by the Group for Earth Observations. Building on the experience made within the Heterogeneous Missions Accessibility project the chapter describes the lessons learned as well the challenges and the road ahead to widen the harmonization effort.

Keywords: Ground Segment Interfaces Harmonisation, Standardisation, Earth Observation, Systems of Systems.

1. The Challenges Raised by the Global Programmes

Europe is addressing global issues (see Reeves and Lenoir, 2003) related to the monitoring and management of environmental global change phenomena (see Achache, 2004) and the need for security related observations such as the GMES (Global Monitoring for Environment and Security) programme for the implementation of information services to support decisions concerning environment and security (see Liebig et al., 2007). GMES is based on observation data received from Earth Observation satellites and ground based information.

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of GMES complementing the activities and initiatives of the European space agencies and other actors involved in understanding the environmental change on our planet.

GMES is also the European contribution to the worldwide monitoring and management of the environment within the Group on Earth Observations (GEO). GEO was established, with the goal of addressing the information requirement for the environment on a global scale. This will be achieved via a 10 year implementation plan of an integrated Global Earth Observation System of Systems (GEOSS). The running of parallel initiatives like the ongoing definition of the implementing rules for the INSPIRE Directive (see INSPIRE, 2007), demands a high level of consistency and convergence, which at European level is addressed in the GIGAS Support Action financed by the Directorate General Information Society of the European Commission. GIGAS[1] (GEOSS, INSPIRE and GMES, an Action in Support) promotes the coherent and interoperable development of the GMES, INSPIRE and GEOSS initiatives through their concerted adoption of standards, protocols, and open architectures.

2. Preparing for Coordinated Data Access

In the above described context, the required GMES Ground Segment Coordinated Data Access System GSCDA is under design and implementation. This objective has motivated the definition of the interoperability standards between the Coordinated Data Access System and the GMES Space Component GSC contributing missions GSC CM.

It is interesting to note that similar cooperation and harmonization issues are being addressed in the context of dual use and space-based reconnaissance within the Multinational Space-based Imaging System – MUSIS (de Selding, 2007).

The Coordinated Data Access process (see Figure 1) entails the interaction with the GMES Service Projects which define their EO data requirements, the management of the Data Access Portfolio DAP which provides the match between the EO data requirements on one side and the EO data products available from the Contributing Missions on the other side.

[1] http://www.thegigasforum.eu/

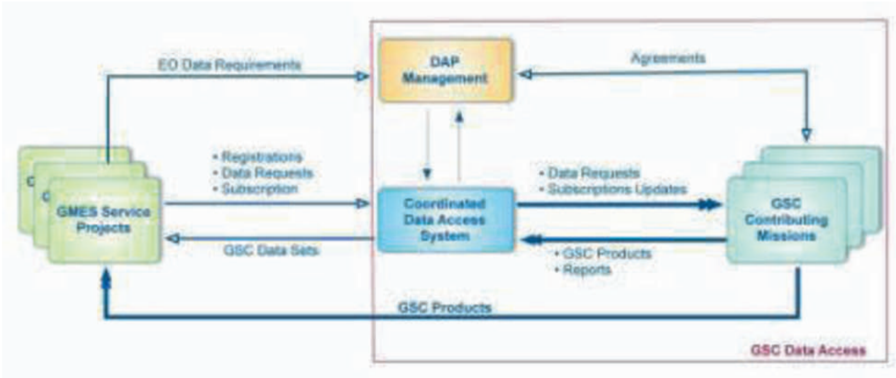

Figure 1. Coordinated data access process and external interfaces.

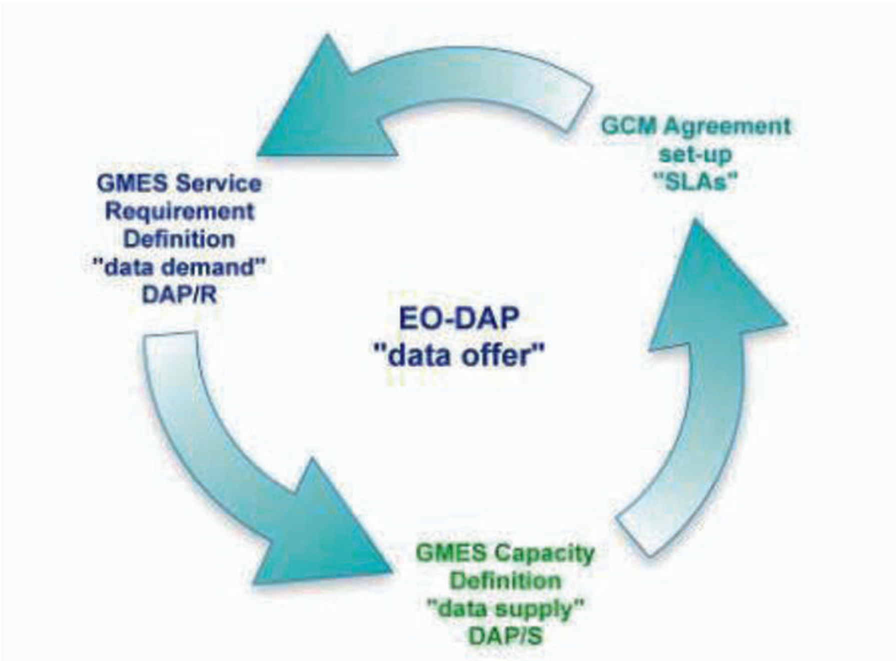

Figure 2. DAP elaboration process.

The Data Access Portfolio itself will be updated regularly following a circular review process executed at regular intervals, typically every 15–18 months. The DAP elaboration process is made of the following three main steps (see Figure 2):

1. GMES Services Requirements Definition: it identifies the EO data and performance requirements and establishes the "data demand". The output of this step is the DAP Requirement Document DAP/R which lists the data requirements, the frequency of revisit and the required (or desired) data delivery mechanism.
2. GMES Contributing Missions Capacity Definition: it establishes the EO missions capabilities, namely the "data supply", the datasets, including costing and mission capacity analyses. The output of this step is the DAP Specification Document DAP/S which provides an indication of the EO data capacity on the basis of available missions (from national agencies and other actors).
3. GMES Contributing Missions Agreement set-up and generation of DAP. It establishes the "data offer" towards the eligible GMES services, namely what the GMES services can access during the applicable period of the DAP version. The outputs of this step are contractual agreements with the GMES Contribution Missions.

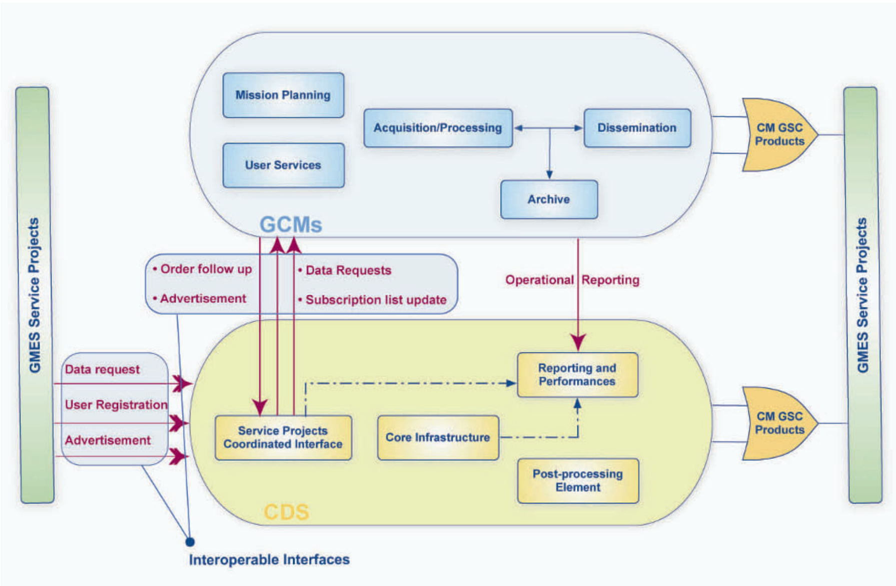

Figure 3. Interoperable interfaces for the GMES contributing missions.

The Data Access Portfolio process and the Coordinated Data Access system should not only serve the GMES purposes, but in general they should overcome the issues identified in the Oxygen project (see Achache, 2003) which quantified the access to EO data for the extraction of the relevant information as representing up to 60% of the effort in the data exploitation and service delivery. In the framework of the GMES Preparatory activities, and as follow one of the findings of the Oxygen project, the Agency had launched an harmonization effort: the Heterogeneous Mission Accessibility (HMA) projects to define the interoperability concepts across the ground segments of the GMES Contributing missions (see Forcada et al., 2007) and a set of possible interoperable interfaces which are indicated in Figure 3.

3. State of Play in Ground Segment Interfaces Harmonisation

The state of play of the standardization of the ground segment interfaces for EO missions can be assessed (see Marchetti and Biancalana, 2008) making reference to the diagram in Figure 4, where the interactions between ground and satellite are schematically described. The interoperable interfaces indicated in italics are the ones defined within the HMA project.

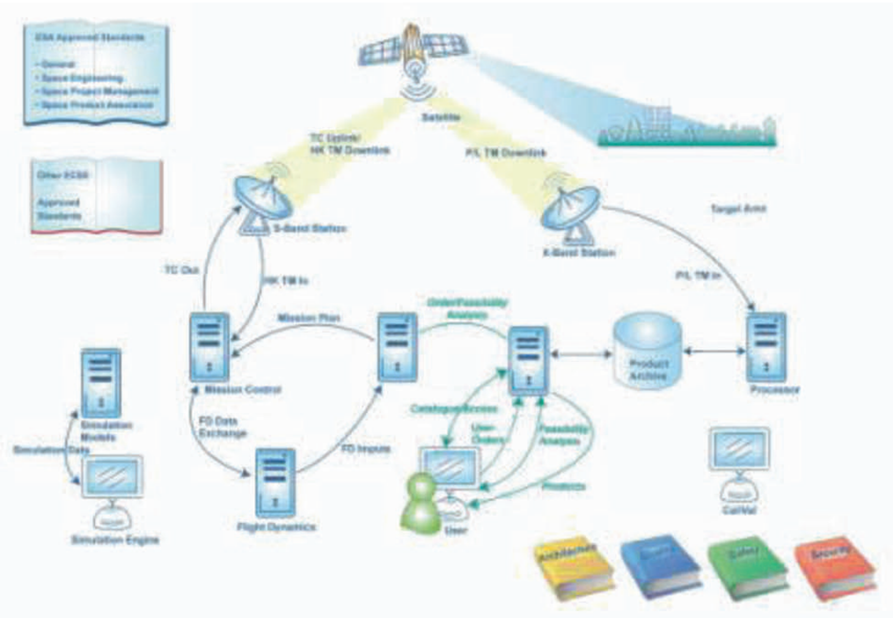

Figure 4. Simplified ground segment diagram and relevant standards.

In order to keep Figure 4 simple, a single mission is described, whilst the remaining of the chapter addresses a multi-mission (and as well multi constellation) context. It has to be noted that the feasibility analysis and tasking are particularly relevant in optical high resolution missions addressing security and dual use requirements, whilst global missions tend to be realized with acquisitions in "carpet" mode. The starting point for any interaction is the User, a generic customer of a space observation system.

The User may be also a large scale service receiving data from the system. The User browses a catalogue and issues orders to get products. Products include a wide range of items (at different levels of processing) from single images/products to huge data sets (e.g., wide coverages, continuous or periodic monitoring, etc.). Product orders may refer to:

- Products already available in the Product Archive which are quickly delivered after retrieval and (possibly) processing.
- Products requiring the acquisition of new data triggering the process schematically described hereafter.

Orders for the acquisition of new data are passed from User Services to a Planner entity. The Planner builds a plan allocating the acquisition of new data by the satellite in the next period. The mission plan takes into account information coming from Flight Dynamics/Mission Control including satellite orbit, unavailability, etc. The Planner sends the mission plan to the Mission Control entity which converts the plan into a set of tele-commands (TC) to be up-linked to the satellite during the visibility periods. During the visibility periods the Satellite (for simplicity a single satellite is shown but the description can be extended to a constellation) receives the TC from the S-band Antenna executes them (immediately or at scheduled times) and downloads back the housekeeping telemetry.

The telemetry acquired by the X-Band station are transferred to the Processor entities which generate the final products to be stored into the Product Archive and/or disseminated/delivered to the User, closing the loop started with the product order. This download/generation schema includes near real time patterns where

- Data are acquired by the satellite and down-linked in pipeline at the same time during a visibility over the X-band station.
- Data are received at the X-band station processed and immediately delivered (electronically) to the user.

Moreover the Earth Observation scenario is completed with simulation systems, Calibration/Validation (Cal/Val) systems and activities.

The Figure 4 highlights the existing space standards, mainly from the European Cooperation for Space Standardisation (ECSS)[2], covering the overall Earth Observation process, and the interfaces where the harmonization work within the HMA project is focused. Other relevant standards deal with Architecture, Quality, Safety and Security issues.

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[2] See http://www.ecss.nl/

4. A Methodology Context for Interoperable Harmonized Interfaces

The trend in large scale interoperability projects (see, e.g., HMA, INSPIRE and GEOSS) is to define interoperable interfaces making use of the Reference Model of Open Distributed Processing – RM-ODP (see RM-ODP, 1998). The RM-ODP model has been modified (see Uslander, 2007) to take into account the objective of addressing a set of distributed Ground Segments rather than a distributed processing system for which the RM-ODP was originally defined.

The RM-ODP model analyses open distributed systems through five different views of the system and its environment:

- The enterprise viewpoint: focuses on the purpose, scope and policies for the system.
- The information viewpoint: focuses on the semantics of the information and information processing performed.
- The computational viewpoint: enables distribution through functional decomposition of the system into objects which interact at interfaces.
- The engineering viewpoint: focuses on the mechanisms and functions required to support distributed interaction between objects in the system.
- The technology viewpoint: focuses on the choice of technology in that system.

In the analysis of the interoperability issues, the RM-ODP was tailored by replacing the computational viewpoint with a service viewpoint. The following points represent the outcome of the HMA project (see Coene et al., 2007).

4.1. ENTERPRISE VIEWPOINT

The enterprise viewpoint: focuses on the purpose, scope and policies for the system. These activities can be represented by two sets of scenarios related to respectively the interactions from the GMES services and the ones with the GMES Contributing Missions.

The enterprise viewpoint thus addresses following high level objective: to provide interoperability for the Coordinated Data Access system enabling the interactions with services and Contributing Missions (see Figure 3).

4.2. INFORMATION VIEWPOINT

The information viewpoint specifies the modelling of all categories of information that the proposed system deals with, including their spatio-temporal characteristics as well as their metadata.

4.2.1. EO collection metadata model

EO collections are datasets sharing the same product specification. In the Earth Observation context, a collection typically corresponds to the series of products derived from data acquired by a sensor onboard a satellite and having the same mode of operation. The EO collection metadata can be described by employing the ISO 19115 standard for geographic metadata (see Geographic information, 2003).

4.2.2. EO product metadata model

The most important information model is the EO product metadata which has been based on the Open GeoSpatial Consortium – OGC® Geography Mark-Up Language – GML. GML is a modelling language and encoding for the transport and storage of geographic information, including both the geometry and properties of geographic features. These base properties are not sufficient to model the EO product metadata. Hence a set of specific application schemas are extending the generic EO product metadata for the different types of missions or sensors: OPT for optical, SAR for synthetic aperture radar and ATM for atmospheric products (see Figure 5).

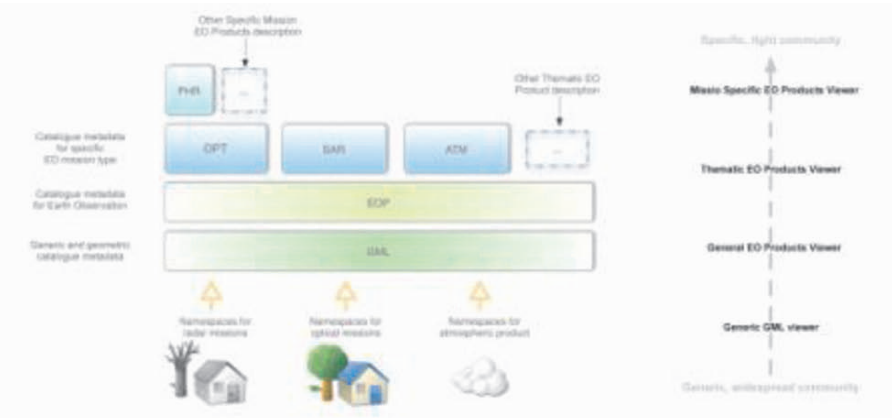

Figure 5. EO product metadata model.

4.3. SERVICE VIEWPOINT

The computational viewpoint in the RM-ODP is replaced within the proposed architecture by the service viewpoint: it specifies the services that support the syntactical and semantic interoperability between the services.

We can group services into categories related to the specific functions performed by the service. The following set of EO data access services has been defined to specifically support the interoperability of the Coordinated Data Access CDA system within the GMES Space Component:

Collection and service discovery: collection discovery can be used to locate dataset collections meeting the needs of the application domain, e.g., urban planning, precision farming, etc. The service discovery then provides access to the services that operate on these dataset collections, e.g., catalogue, ordering, data access or programming services.

Catalogue service: the catalogue service allows a user to find datasets or products within a discovered dataset collection that meet specific search criteria such as time, geographic extent, cloud cover, snow cover, polarisation, etc. and it gives access to all dataset metadata available in a catalogue.

Product programming and order: a user accesses the ordering service to order datasets referenced from within the (distributed) catalogue service. He can also order future products, not yet in the catalogue by using the programming service.

Online data access: to provide access to ordered datasets via the Internet. Such services typically use the File Transfer Protocol (FTP) for allowing access to EO data, but also more advanced methods such as OGC® Web Services for data delivery and visualisation may be supported: Web Coverage Services (WCS) for access to EO datasets, Web Feature Services (WFS) for access to information features derived from EO imagery (e.g., land cover classification), Web Map Services (WMS) for visualisation and evaluation purposes.

Identity (user) management: the objective in the long term is to allow for a single sign-on to the Coordinated Data Access system by users registered in the various EO ground segments by providing a federated identity across participating ground segments.

Processing services: within the operational ESA Grid infrastructure a preliminary definition of a Grid-based Processing Service has been performed. The Grid allows to host the processing algorithms on the computing element close to the storage element that stores the coverages to be processed eliminating the burden caused by the transfer of large amount of EO data.

The implementation of any interoperable interface within the Coordinated Data Access system and the Contributing Missions will be supported by a testbed HMA-T[3] allowing testing, conformance testing and evolution of agreed standards on a persistent platform.

5. High Level Objectives for an EO Ground Segment Interface Harmonization Activity

The number of national and third party missions necessary to ensure the data capacity indicated in the Data Access Portfolio (ranging between 20 and 40) suggests that a ground segment interface standardization programme is beneficial in the context of the Coordinated Data Access to GMES Contributing Missions. The overall context of the standardization in the space domain is being addressed in the Working Group 202 of Comité Européen de Normalisation CEN. The results of Phase 1 of the CENBT/WG 202 study indicate that the high level objectives for such a programme should be:

- To manage and reduce technical risks in EO systems and operations
- To manage and reduce cost of EO systems and operations
- To establish the baseline for the development of the European Space infrastructure in the context of the GMES Programme capable of harmonizing and exploiting relevant national initiatives and assets
- To allow interoperability within and across organizations
- To increase competitiveness of European Space (and downstream) industry
- To maintain the leadership in EO systems and operations and avoid insurgence of undesired standards
- To ensure that technology drivers for the European guaranteed access to Space are lead by European requirements

5.1. LESSONS LEARNED FROM THE HMA STANDARDIZATION ACTIVITY

The following points are the lessons learned within the HMA project and related contracts.

First point that emerged is that the standardization process is part of a larger process (see Figure 6) which includes prototyping, take-up,

[3] http://wiki.services.eoportal.org

conformance testing and final adoption. Therefore specific actions are needed to support product and software evolution in order to ensure industry and small and medium enterprises uptake of the new standards.

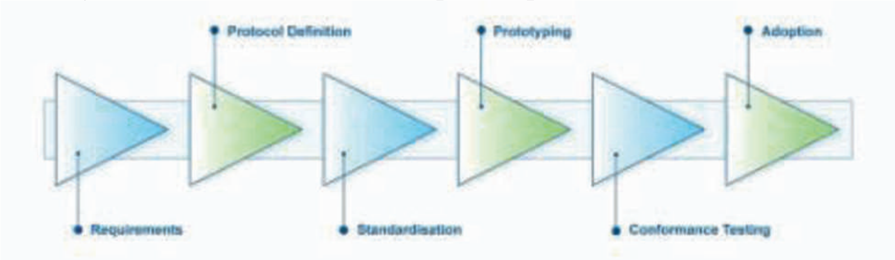

Figure 6. The standardisation process and its main elements.

Furthermore the project found that harmonising the civil ground segment interfaces of dual use missions is a cumbersome exercise as only limited information is available to the civil branch on the overall mission functionality and capability. A methodology could be developed to allow the sharing of "abstract" scenarios and use cases between the various elements of a dual use mission, thus possibly leading to the definition of common requirements which are the pre-requisite to define a set of harmonized interfaces. These abstract scenarios properly placed within the relevant RM-ODP views could be the winning elements for such a generic methodology to be applied in the border line between civil and defence dual use ground segments.

A governance mechanism needs to be established in order to manage the evolution and changes to the defined standards. To this scope an HMA Architecture Working Group has been established.

The protocol definition and standardization is a time and resource consuming process and in particular that the Open Geospatial Consortium (OGC®) processes are very open however convergence may be very slow, and conformance testing very demanding. On the other side the OGC® Web Services (OWS) interoperability initiative showed to be an essential instrument to foster cooperation on geospatial interoperability with universities and institutions worldwide (see Coene, 2006; Guillo, 2007).

For what concerns the recognition at European level, the Workshop Agreement (WA) from the Comité Européenne de Normalisation CEN is an easy way to ratify an agreement at project specific level. However the CEN WA still lacks the acknowledgement as "official" standard.

For what concerns the identity management for the GMES Contributing Missions – GCM the requirements are very challenging in a federated scenario, commercial off the shelf and Open Source tools are available but their integration in legacy ground segments is far from straightforward. A trade off between requirements and implementation options is needed.

The requirements for information security management can be addressed exploiting and tailoring the ISO 27001 (see Information technology, 2005) which is very useful in a multi partner context. Whilst the tailoring on high level objectives is easy, the implications related to the implementation of an Information Security Management System for the GCMs are still to be addressed.

The management of the standardization activity via a project structure (as opposite to a voluntary based approach) is proven successful and timely.

A Persistent test bed which is designed to provide a valid support in any standardization and harmonization process is needed. The persistent test bed will have to support as well the verification and support to the implementation of the standards in use, the identification of gaps vis-à-vis requirements, the definition of the requirements for new or updated standards for an increased interoperability and multiple mission inter-accessibility. It will have to provide capabilities to validate new requirements and or scenarios including conformance test tools, being an open, permanent infrastructure in which organisations or external projects (e.g., EC projects, OGC's OWS and GEOSS Interoperability Programs, etc.) can integrate their (compliant) services.

6. Conclusions and Future Work

This chapter provides a high level overview of the efforts performed in harmonizing the ground segment interfaces for Earth Observation missions and of the lessons learned in the exercise. Harmonisation aspects which will be addressed in the near future concern the extension of EO product metadata to radar altimeter, limb looking and occultation missions, the completion of the work on feasibility analysis and programming by use of the Sensor Planning Service and the online data access.

It has to be noted that the challenges in the harmonization and standardization work are related to the number of steps and the necessity of establishing support measures and the appropriate tools and environments able to ensure continuity and facilitate the different steps (i.e., prototyping, conformance testing, take-up by industry).

With reference to the MUSIS activity mentioned in Section 2 above, the convergence of the interfaces of civilian and defence ground segments it is not yet on the agenda of the institutions potentially involved. However such convergence should be beneficial for all the actors (public sector, industry) as consequence of the establishment of a wider market (see Marchetti and Biancalana, 2008). Furthermore a convergence of interfaces is beneficial for organizations working with multiple environments of which the European Union Satellite Centre is a well known example.

Future work should therefore concern the set-up of a methodology for the neutral capture of interoperability requirements from systems of systems including dual use missions which should bring another interoperability dimension in the future consolidation of security related services on one side and ensure further synergy with the GEOSS initiative on the other.

Acknowledgements

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DATA FILTERING AND DATA FUSION IN REMOTE SENSING SYSTEMS

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Abstract. Target detection in a radar image is a complicated task, particularly when assessing a battlefield situation over large areas to locate individual targets in the presence of clutter. A brief theory of filtering is presented. The most popular approach in target tracking theory is the Kalman filtering that is effective for simple scenery such as a clutterless environment or a single sensor tracking a single target. The concept of the proposed backpropagation neural network and Kalman filter to reduce the estimation error due to an imperfection of a radar system and tracked target is presented. One of the distinguishing features of the research in sensor networks is its inter-disciplinary, as it encompasses methodologies ranging from remote sensing to distributed detection or estimation and data fusion.

Keywords: Remote Sensing, Filtering, Target Tracking, Data Fusion, Neural Network.

1. Introduction

Remote sensing may be taken to mean the observation of, or gathering of information about, a target by device separated from it by some distance. (Cracknell and Hayes, 2007).

There are active and passive microwave remote sensing instruments (sensors). Active sensors, such as radar systems, generate their own illumination by transmitting pulses of microwave radiation and then using a specialized receiver system to measure the reflected (scattered) signal from the area of interest or target. They primarily use wavelengths about 3 cm (10 GHz) where the atmosphere becomes virtually transparent. Passive

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sensors measure the microwave energy that is radiated or reflected from the target or other radiating objects (Woodhouse, 2006).

One type of active remote sensing systems, are the systems for observation and imaging of Earth and another planetary bodies surface. Typical active microwave remote sensing system is the Synthetic Aperture Radar (SAR). SAR is a coherent imaging sensor based on concept of the synthetic antenna (aperture). A very long antenna is synthesized by moving a small antenna along a convenient path and then properly processing the received signals (Franceschetti and Lanari, 1999). Concerning the Earth observation, a new generation of SAR is under study with advanced capabilities and performance. SAR applications include: the detection and recognition of targets in SAR imagery, and the detection of targets under trees (as well as in open spaces) using change detection (coherent change detection, full-polarization change detection, etc.).

Sensor-management in tracking consists of: (1) sensor mode control, (2) scheduling, (3) target selection, and (4) situation assessment. In a dynamic environment, airborne radar necessitates active mode control for the acquisition of a SAR image of stationary targets (Blasch, 1999).

Another active microwave remote sensing systems may be ground, space borne or naval radars which are designed for tracking of ground or air targets. Target tracking is an important issue in military and civil surveillance systems, especially when such systems employ multiple sensors to interpret the environment. The radars report measurements from various sources including target kinematics, attributes, clutter and background noise (Chin, 1994).

The passive military microwave remote sensing mainly includes the ELINT/ESM microwave systems, which consist of two or more terrestrial stations receiving simultaneously the signal from a signal source (target). The signal source position is evaluated using the corresponding Times of Arrival (TOA) or Times Difference of Arrival (TDOA) measurement (Bezousek and Kubecek, 2000).

When multiple sensors are used, the integration of information from multiple sources that produce a unified picture about an entity is called data fusion (Waltz and Llinas, 1990; Hall and Llinas, 1997). With the expansion of computer processing capabilities, application of data fusion theories have been introduced in the past two decades in response to the ever-increasing interest of this field. Among these approaches there are the classical and Bayesian inference theories, evidential reasoning, cluster analysis, fuzzy logics, and most recently, neural networks. In general these approaches can be partitioned into two schools of thoughts, namely, algorithmic and non-algorithmic. The foundation for the algorithmic approach is Kalman filtering (Bar-Shalom, 1990; Bar-Shalom and Li, 1993; Yeddanapudi et al., 1997; Sotak and Kralik, 2007) and the foundation for the non-algorithmic is neural networks. The combination of the algorithmic and non-algorithmic approaches in data fusion is shown in Ochodnicky and Spirko (2001).

A particle filtering approach to data fusion and situation assessment for military operations in urban environments is presented by Das et al. (2005). The algorithm samples discrete modes and approximates the continuous variables by a multi-normal distribution, updated at each time step by an unscented Kalman filter. The approach is demonstrated using a Marine Corps operational scenario involving a potential ambush on city streets.

Interesting experience is accuracy adjustment by fusion method with GIS data and remote sensing data (Jeong and Masataka, 2002).

Generally, filtering is a powerful tool for target detection, target tracking and data fusion in remote sensing systems or sensor networks.

2. Filtering for Target Detection and Target Tracking

2.1. FILTERING FOR TARGET DETECTION

The radar is a typical microwave sensor. During radar technology operational-tactical calculations frequently there is the need for information on parameters such as the target detection probability within radar interception area circumstances for different than "standard" case. Meanwhile it appears that, some given characteristics of different provenance radars are incomparable, one may have the need for objective technical parameters comparison and judgment (Spirko and Matousek, 2008).

A filter is any kind of processing that has one characteristic. It takes a signal as the input and it produces a relevant output signal after processing it in some way. A filter can always be mathematically described – think of it as a function, for instance as:

$$y = f(x) \tag{1}$$

A filter can take any number of arguments that further define its behaviour. In fact, when designing a filter, we usually need to give it a few guidelines according to which it will be built.

It must be noted that we defined the dimensions of a filter as one parameter – this suggests that most filters have uniform side length. For a 1D filter this will define the length while for 2D and 3D filters the dimension will define the length of the sides. If we look at an image (e.g., GIS image), we refer to the spatial domain; in the case of a radar signal we refer to the time domain and when we look at a frequency spectrum, we refer to the frequency domain.

The matched filter is important in its own right, but it is of considerable interest also in pointing the way towards the solution of a fundamental problem in radar systems: the conflict between detectability and resolution. The main goal of the matched filter impulse response is the choice which maximizes the receiver output signal to noise ratio (SNR). Generally, the matched filter is described as convolution integral according to Eq. (2)

$$u_2(t) = \int_0^t u_1(x) g(t-x) dx \tag{2}$$

where the $u_1(x)$ is the input signal and noise, $u_2(x)$ is the output signal and noise and the $g(t)$ is the filter transfer function (Ochodnicky et al., 2008).

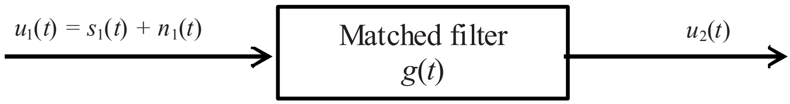

Figure 1. Principle of the signal processing in matched filter.

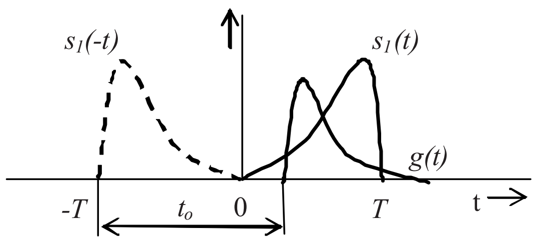

Figure 2. Pulse response of the matched filter.

The principle of the signal processing in matched filter is shown in Figure 1, (where the $n_1(t)$ is the noise) and its pulse response is in Figure 2. Basic condition for matched filter is $t_o \geq T$.

If the noise bandwidth of the receiver is B, then the obtained average output SNR is (Curlander and McDonough, 1991):

$$SNR_{out} = B\tau SNR_{inp} \tag{3}$$

where the τ is the signal duration. Thus the matched filter achieves a SNR increase equal to the bandwidth times the product of the transmitted pulse. After developing the matched filter, the procedure of pulse compression generalizes to the algorithm of image formation from (SAR or GIS) signals.

2.2. FILTERING FOR TARGET TRACKING

Target tracking is the maintenance of a target's kinematic information of position, velocity, and acceleration in time and space. In the case of multiple targets, the tracker could use identity information to determine targets from cluttered measurements. While many sensors may be used to collect the kinematic measurements such as cameras, infrared sensors, SAR and other sensors, the standard radar will be discussed since it is wide used.

Consider a dynamical system of target tracking as follows:

$$X(k+1) = FX(k) + Gw(k) \tag{4}$$

where X is the state vector, F is the transfer matrix, G is the gain matrix and w is the noise of the system (Gaussian with zero-mean).

Suppose that the system is completely state controllable and observable. If a state control (measurement of radar) law:

$$Z(k) = HX(k) + v(k) \tag{5}$$

is applied to the system (Eq. 4) then the Kalman filter for target tracking has the form:

$$\hat{X}(k) = F\hat{X}(k-1) + K(k)\left[Z(k) - HF\hat{X}(k-1)\right] \tag{6}$$

where $\hat{X}$ is the estimated (filtered) state, Z is the measured vector, v is the noise of radar measurement, H is measured matrix, and K is the matrix of Kalman gain. The symbol k stands for processing cycle in time. The recursive solution of the Kalman filter is well-known (Bar-Shalom and Fortmann, 1987).

The standard Kalman filter (KF) is deficient in adaptive capability, at the same time, the estimation accuracy of the neural network (NN) filter is not very good and its performance depends on the training phase of the NN.

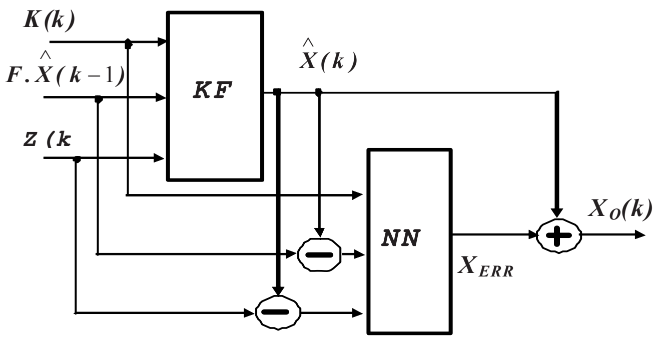

Figure 3. Structure of neural Kalman filter.

The basic of concept of the KF and NN combination is shown in Figure 3, where a backpropagation NN is used to help the KF reduce the estimation error due, among other imperfections, to model varying effect.

Since the exact range is known (as far as simulation is concerned), the supervised learning algorithm can use the error (difference between known range and estimated range) to train the network, i.e.:

$$X_{ERR} = X_0(k) - \hat{X}(k) \tag{7}$$

The standard Delta rule is used to update the weights. During the operation, the output of the neural network (X_{ERR}) is used to correct the state estimate.

The backpropagation neural network has a two parts: one for coordinate X and one for coordinate Y.

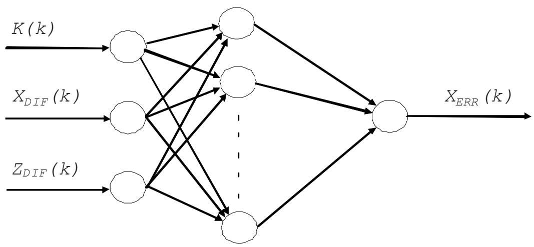

Figure 4. The structure of the proposed one hidden layer backpropagation neural network.

To demonstrate the improvement, a one hidden-layer neural network is used as shown in Figure 4 (one part) using 3 input signals for each part of the neural network: the Kalman gain – $K(k)$, the difference $Z(k) - \hat{X}(k) = Z_{DIF}$, and the difference $F.X(k-1) - \hat{X}(k) = X_{DIF}$

2.3. SIMULATION RESULTS

In this section, a manoeuvring target scenario moving at constant velocity is simulated using the standard KF. The purpose is to demonstrate the different results in two cases: with and without the aid of the neural network.

Let the state vector be $X = [x \quad V_x \quad y \quad V_y]^T$. The system dynamics can be written according to Eq. (4). V_x and V_y are respectively the velocity components of coordinate X and coordinate Y. The initial conditions are: X_0 = [0 0 0 0] and the sampling period T = 5 s. The measured and KF track are shown in Figure 5. The target travels in a line with two curves (right and left) with a speed of 260 ms^{-1}. The measurement noise variance R = 0.2 km^2 and system noise variance Q = 0.00036 km^2 s^{-4}. An absolute error of KF is shown in Figure 6. The Kalman filter diverges in moment of the manoeuvre and the result of this divergence is the high absolute error.

The error signal, which is used to train the neural network is the difference between the actual range and the estimated range value.

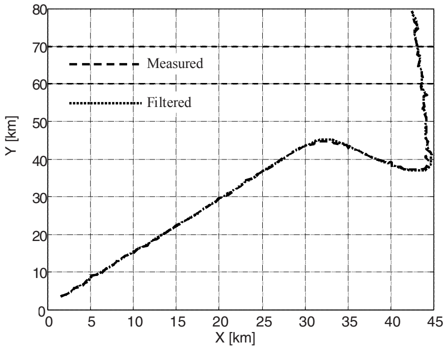

Figure 5. Measured and estimated track.

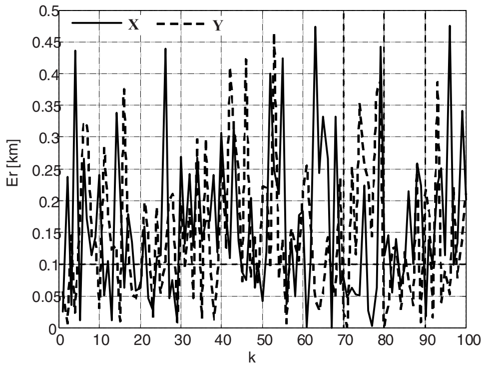

Figure 6. Absolute errors of the measurement.

Simulation results show that the improvement of the mean square error with the neural network is about 20%.

In this chapter, we proposed to incorporate a neural network learning mechanism into the classic 2D KF. The simulation results confirmed that combination of KF and NN creates the conditions for enhancement filtering quality of targets tracking.

3. Data Fusion for Target Tracking with Neural Network

The research on sensor networks has received a tremendous attention in the last years because of the potential applications in a variety of fields. One of the distinguishing features of the research in sensor networks is its interdisciplinary, as it encompasses methodologies ranging from remote sensing to distributed detection or estimation, data fusion, communication, networking, belief propagation, fault tolerance, energy-efficient design, scalability, and so on. Some of the major issues in the design of sensor networks are energy efficiency and tolerance to node failure, on one side, and high reliability of the decision taken by the network as a whole, on the other side. One of the major challenges in sensor networks is how to build a very reliable remote sensing machine composed of a set of many, potentially unreliable, units.

Fusion is necessary to integrate the data from different sensors and to extract the relevant information on the targets. The traditional architecture for the fusion is centralized. Recent advances in computing and communication have made other architecture options feasible. In a fully distributed architecture, there is no fixed superior/subordinate relationship. In this case, each sensor may have its own processor to fuse the local data and cooperate with other sensor nodes. There are two main types of fusion problems: fusion for making a decision on a hypothesis such as detecting the presence of targets or classifying signal, and fusion for target tracking.

There are three broad alternatives to fusing location information to determine the position and velocity of an object: (1) fusion of the raw observational data (data level fusion), (2) fusion of state vectors (distributed fusion), and (3) a hybrid approach which allows fusion of either raw data or state vector data. We prefer distributed fusion, where each sensor performs

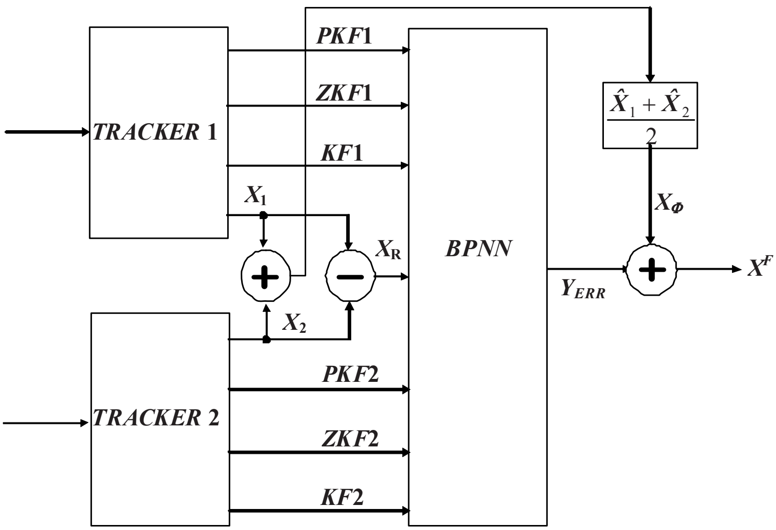

Figure 8. Neural network in distributed data fusion system.

single-source positional estimation, producing a state vector from each sensor. A distributed fusion architecture that requires a complicated fusion algorithm may not be a good choice.

A standard tracking algorithm, represented by the KF, is applied with the aid of a neural network, and it is shown in Figure 8. Basic problem of the proposed method is the definition of the BPNN input signal (descriptors).

Descriptors can be defined according to the following equations:

$$PKF_1(k) = F_1\hat{X}_1(k-1) - \hat{X}_1(k) \tag{8}$$

$$ZKF_1(k) = Z_1(k) - \hat{X}_1(k) \tag{9}$$

$$KF_1(k) = K_1(k) \tag{10}$$

$$PKF_2(k) = F_2\hat{X}_2(k-1) - \hat{X}_2(k) \tag{11}$$

$$ZKF_2(k) = Z_2(k) - \hat{X}_2(k) \tag{12}$$

$$KF_2(k) = K_2(k) \tag{13}$$

where:

F_i is the state transition matrix of the tracker ***i***

$\hat{X}_i(k-1)$ is the estimation state of the tracker ***i*** in the moment (***k*** – 1)

$\hat{X}_i(k)$ is the estimation state of the tracker ***i*** in the moment ***k***

$Z_i(k)$ is the measurement state of the tracker ***i*** in the moment ***k***

$K_i(k)$ is the Kalman gain of the tracker ***i*** in the moment ***k***

and

$$\hat{X}_R = \hat{X}_1(k) - \hat{X}_2(k) \tag{14}$$

Since the exact range is known (as far as simulation is concerned), the supervised learning algorithm can use the error to train the network, i.e.,

$$Y_{ERR} = X^F - X_\Phi \tag{15}$$

where

$$X_\Phi = \frac{\hat{X}_1 + \hat{X}_2}{2} \tag{16}$$

The standard Delta rule is used to update the weights. For the supervised learning of the BPNN, the definition of the training set is necessary. The training set contains a lot of simulated tracks that characterized the possible scale of the manoeuvring targets. The training set size depends on the required quality of the fusion (generalization ability).

Comparison of absolute error for standard correlation and neural network data fusion is shown in Figure 9.

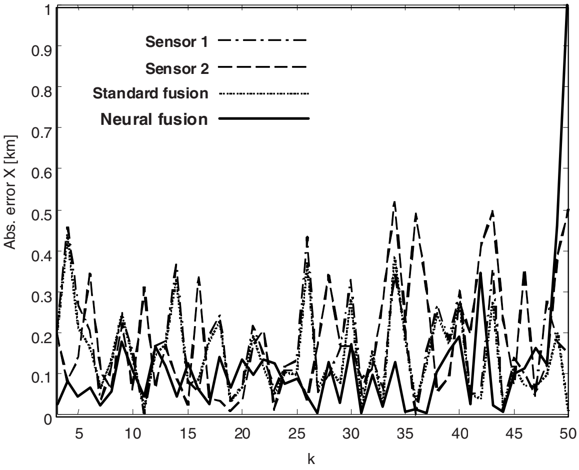

Figure 9. Error comparison of the standard correlation and fusion with neural network.

4. Conclusion

Data filtering and data fusion in remote sensing systems is a complicated task, especially in presence of clutter. The purpose of data fusion is to produce an improved model or estimate of a system from a set of independent data sources. There are various multi-sensor data fusion approaches, of which Kalman filtering is one of the most significant. Methods for Kalman-filter-based data fusion include measurement fusion and state fusion. This chapter gives a simple review of data filtering and data fusion, and secondly it proposes some approaches with a neural network application in those processes. Results of simulations show, that the application of artificial intelligence methods may be efficient and powerful tool for remote sensing data processing.

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SOIL MAPPER® MULTI-SENSOR AND MULTI-TEMPORAL APPLICATIONS FOR SEMANTIC-BASED IMAGE INFORMATION MINING

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Abstract. Based on a spectral-domain prior knowledge-based classification system, recently presented in remote sensing literature, an original spectral rule-based per-pixel classifier, called SOIL MAPPER®, has been developed and commercialized by MEEO S.r.l. The SOIL MAPPER® classifier consists of a modular hierarchical data processing structure. As input, it requires a multi-spectral remote sensing image, whose spectral channels range from visible to thermal infrared wavelengths, radiometrically calibrated into top-of-atmosphere reflectance and at-satellite temperature. As output, it provides a preliminary classification map consisting of a set of kernel (i.e., reliable) semantic labels equivalent to colour-based semi-concepts. The symbolic meaning of semi-concepts is either equal or inferior (not superior) to that of concepts (object models) constituting the so-called world model (e.g., concepts equivalent to land cover classes in the USGS classification scheme). In operational terms, the degree of novelty of SOIL MAPPER® is relevant. It is fully automated, computationally efficient and easy to modify, augment, or scale to different sensors' spectral properties. Second-level application-specific processing systems (e.g., fire detection, flood detection, land cover change detection, etc.), which incorporate the "stratified" or "layered" approach, can be developed in cascade to the general-purpose SOIL MAPPER® first-stage.

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1. Introduction

In recent years, the availability of satellite Remote Sensing (RS) data featuring enhanced spectral, spatial, and temporal resolution, increased dramatically. In this technological scenario, upcoming scientific and operational challenges become on the one hand, automated near real-time RS image understanding, and on the other hand user-friendly and computationally efficient extraction of meaningful information from a large image database.

The implementation of fast and reliable spectrally based image information mining systems permits real time elaborations and information compression, but the extraction of kernel image information layers from multispectral (MS) remote sensing images is a well-known problem in RS literature (Nagao and Matsuyama, 1980; Mehldau and Schowengerdt, 1990; Ton et al., 1991; Baraldi and Parmiggiani, 1994; Binaghi et al., 1997; Bardossy and Samariego 2002; Sugumaran et al., 2003; Avci and Akyurek, 2004). In Ton et al. (1991), kernel image information layers are defined as those reliably extracted from RS imagery by means of: (i) domain-specific (e.g., spectral, geometric, textural, semantic, contextual) prior knowledge, and (ii) unsupervised (automatic, data-driven) image processing techniques. This definition implies that kernel image information layers employ no inductive learning-by-example mechanism, i.e., they require no target class sample (Baraldi et al., 2006).

SOIL MAPPER® is a spectral rule-based per-pixel classifier that takes inspiration from the method proposed by Baraldi et al. (2006), and allows processing, for instance, a Landsat scene in less than 1 min, generating a preliminary classification map consisting of a 1-byte-depth discrete set of spectral categories that represent land cover information compressing the information contained on the multispectral image. Due to its characteristics, SOIL MAPPER® represents an adequate solution to the above-mentioned problem for existing and future missions.

In the following sections a description of the SOIL MAPPER® system and some application examples are presented.

2. SOIL MAPPER® Description

2.1. FUNCTIONING PRINCIPLES

SOIL MAPPER® is an innovative state-of-the-art application-independent RS image rule-based classifier based exclusively on spectral prior knowledge.

As input, it requires RS images calibrated into planetary reflectance values and at-sensor temperature, and it generates a preliminary (baseline, BL) classification map consisting of a discrete set of spectral categories. To run, SOIL MAPPER® requires neither user supervision nor ground truth data sample, i.e., it is fully automatic (unsupervised).

Originally conceived to map Landsat 5 TM and Landsat 7 ETM+ images, the MEEO SOIL MAPPER® has been scaled to several other satellite sensors as described on Section 2.2.

SOIL MAPPER® consists of a two-stage architecture: the first stage matches each pixel-based input data vector with a dictionary of reference spectral signatures modelled as a logical (and, or) combination of inter-band relative relationships (e.g., band 1 greater than band 2) provided with tolerance intervals, while the second stage matches each pixel-based input data vector with a dictionary of reference spectral signatures modelled as a logical (and, or) combination of fuzzy sets (e.g., band 1 is high). These fuzzy sets provide a so-called irregular but complete grid-partition of the input feature space.

As output, it detects a discrete set of spectral categories (layers, or strata) featuring a semantic meaning consistent with land cover classes found in Levels I and II of the USGS classification scheme (Anderson et al., 1976). In particular:

- Several spectral categories belong to the land cover class Vegetation.
- Several spectral categories belong to the land cover class Rangeland.
- Several spectral categories belong to the land cover class Bare soil and Built-up areas.
- Several spectral categories belong to the land cover class Water.
- Several spectral categories belong to the land cover class Clouds.
- Several spectral categories belong to the land cover class Smoke.
- Several spectral categories belong to the land cover classes Snow and Ice.
- One spectral category belongs to the land cover class Pit bogs.
- One spectral category belongs to the land cover class Greenhouses.
- Spectral category Unknowns.

Classification maps are crisp (mutually exclusive) and totally exhaustive (i.e., each pixel is provided with a label), where outliers are managed explicitly.

In its current version, SOIL MAPPER® automatically generates three output classification maps featuring different levels of informational granularity: “Large”, “Intermediate”, and “Small” set of (output) spectral categories. Besides classification maps, SOIL MAPPER® generates a series of Value Added Products (VAPs) providing continuous spectral indexes potentially useful for further application-dependent image analysis, like the Greenness index, the Canopy chlorophyll content index, the Canopy water content index, and the Water index. Moreover a series of masks for Vegetation, Clouds, urban seed pixels, bare soil and build up areas, water, shadow, red roof mask (only for very high resolution data) can also be generated. Classification maps, VAPs and masks can be stored/delivered in different data formats: binary file, ENVI format, GeoTIFF, JPEG, etc.

2.2. SENSORS APPLICABILITY

SOIL MAPPER® can be applied to a series of sensors with different spatial and spectral characteristics. Table 1 lists the sensors that can be processed with SOIL MAPPER®, together with the levels of classification provided.

TABLE 1. List of sensors that can be processed with SOIL MAPPER®.

Sensor name	**Resolution (m)**	**Revisit time (days)**	**# Spectral categories (large/intermediate/small)**
ETM+	15	16	85/41/16
TM	30	16	85/41/16
ASTER	15	16	85/41/16
MODIS	1,000	2	85/41/16
SPOT-4 HRVIR	2.5	2/3	59/35/14
SPOT-5 HRG	2.5	2/3	59/35/14
SPOT-4/-5 VMI	1,000	1	59/35/14
AVHRR	1,100	1	73/37/15
AATSR	1,000	3	85/41/16
IRS 1C and 1D	5.8/188	5/24	59/35/14
IRS-P6 LISS 3-4	5.8/56	5/24	59/35/14
QUICKBIRD	2.44/0.62	1/3.5	46/25/11
IKONOS	4/1	3	46/25/11
ALOS AVNIR-2	10	46	46/25/11
MSG-2 SEVIRI	3,000	0.01	73/37/15

3. SOIL MAPPER® Application Examples

SOIL MAPPER® has a wide range of potential application fields related to RS image understanding.

In general, SOIL MAPPER® can be run:

- As a standalone application-independent classifier, to provide a quick-look preliminary BL output map consisting of fuzzy spectral primitives (layers, strata, categories). These spectral categories are provided with a semantic (symbolic) meaning inferior or equivalent to land cover classes belonging to Level 1 of the USGS and CORINE classification schemes (which justifies the exploitation of term "preliminary mapping" driven from computer vision literature). For example, BL maps may ease the selection of labelled region of interest in very high resolution (VHR) RS raw imagery by expert photo interpreters.
- In fully unsupervised multi-temporal (MT) RS image analysis. In particular, SOIL MAPPER® can provide a time series of single-date BL maps suitable for (i) efficient rule-based extraction of land cover classes (e.g., agricultural fields), (ii) change detection.
- As a batch (off-line) classification system, to provide BL maps suitable for semantic queries of an image database (e.g., to minimize purchased risks resulting from undesired cloud cover or surface conditions).
- As a first step of an automated two-stage hierarchical stratified classification approach, based on a first-stage fully automated preliminary spectral classification provided by SOIL MAPPER®.
- As an auxiliary source of semantic raster-based information. In this framework SOIL MAPPER® can be adopted to upgrade/update existing vector-based Geographic Information Systems (GIS).

The following sections provide some application examples of the use of SOIL MAPPER®.

3.1. SINGLE IMAGE PROCESSING

SOIL MAPPER® can presently process a wide range of optical satellite sensors, from mid resolution to very high resolution. Here some elaboration examples are presented.

Figure 1 shows a mid resolution satellite image (a MODIS scene over Europe suitable for large scale – continental studies) processed with SOIL MAPPER® with "Large" number of classes (85). Pseudo colours based on the semantic meaning of each class label are used to provide "real" aspect to the classified image: vegetation classes are represented in green tones, bare soil in brown shades, water in blue, clouds in white and ice in cyan.

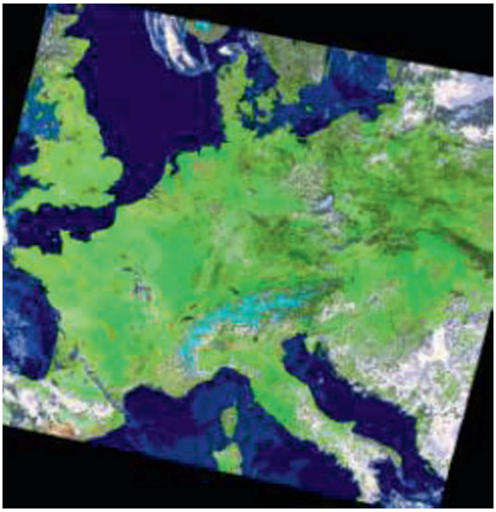

Figure 1. SOIL MAPPER® classification map (large number of classes, depicted in pseudo colours) extracted from a MODIS image acquired on February 14th 2008, 10:00 UTC. Besides vegetation and water patterns, ice and snow on the Alps and clouds can be easily detected.

Figure 2 shows a Quickbird image representing the city of Goro (Italy) right on the Po river delta in true colours and classified with SOIL MAPPER® (Large number of classes – 46). In this case buildings, agriculture fields, natural and anthropic structures can be clearly identified and are correctly classified by SOIL MAPPER®.

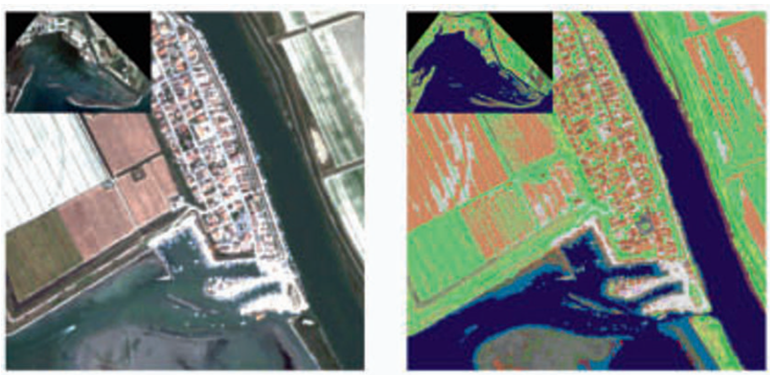

Figure 2. True colour Quickbird image (full scene and zoomed area, right side) and SOIL MAPPER® classification map (large number of classes, depicted in pseudo colours, left side) of the city of Goro, Italy, acquired on May 3rd 2003. The classification map correctly classifies urban structures, agricultural fields, bare sandy areas and two classes for water areas, depending on the water turbidity.

3.2. BI-MULTI TEMPORAL APPLICATIONS

Bi-temporal semantic-based spectral classification studies have been already realized (Cantone et al., 2007) and have shown the capability of SOIL MAPPER® output maps to be used for bi-temporal change detection purposes.

In the framework of different projects sponsored by ESA, the European Spatial Agency, (see for instance, the "Classification Application-services and Reference Datasets" – CARD Project), a series of bi and multi-temporal applications based on SOIL MAPPER® have been implemented for vegetation changes assessment, and burned areas identification.

The availability of time series of SOIL MAPPER® classified images allows monitoring the temporal evolution of the classification at the maximum level of detail (thus at pixel level). Each land cover change event is characterized by a characteristic temporal evolution and a characteristic land cover type evolution. Each event can be identified by a specific trajectory in the time-features space.

A series of evolution models can then be defined on a pixel basis, modelling the time evolution of the pixel in the feature (classes/strata) domain.

The advantages brought by a multi-temporal semantic system based on BL maps are:

- It is fully automatic, fully unsupervised.
- It is pixel based (no segmentation or texture analysis is required).
- It is sensor independent, thus time series formed by data coming from different sensors can be used (classification maps can be calculated for a wide range of sensors that can be used to create multi-sensor time series).

The main problems in the application of this method are related to:

- The temporal consistency of the ingested time series. In fact the application of the evolution models can suffer from lack of images that often occur for HR and VHR time series.
- Cloud coverage as optical images suffer of high cloud coverage occurrence in specific seasons and over specific areas (e.g., tropical regions during the rainy season, mid latitudes during fall and winter).
- The need of a high performance geographic and geometric preprocessing tool for remapping and co-registration of the image time series.

3.3. SECOND LEVEL PROCESSING SYSTEMS

The use of preliminary classification maps allows developing second level algorithms working on stratified basis that improves the performance of each single image processing tool. Moreover, the presence of a semantic label associated to each strata permits to implement second level semantic-based processing tools.

Based on a first-stage fully automated preliminary spectral classification provided by SOIL MAPPER®, an automated two-stage hierarchical stratified classification approach, inspired to that presented by Shackelford, and Davis (2003a, b), can be created. This implies the development of stratified class-specific feature extraction modules exploiting semantic spectral-based strata provided by SOIL MAPPER®: chromatic (colour) properties, achromatic (brightness) properties, texture properties (where texture is defined as the visual effect generated by spatial variations in gray values), morphological properties (investigated by means of morphological filters, where the target object's shape and size are known a priori and the target object is a bright object in a dark background, or vice versa), geometric properties of an image object, spatial non-topological relations among image objects (segments), and spatial non-topological relationships among image segments.

Second level stratified land cover-specific classification modules have been already implemented, e.g., suitable for ship detection, cloud classification, separating Grass from Forest areas, separating Urban areas from Bare soil areas, fire detection. Moreover, a stratified image topographic correction system has been implemented and tested.

Some application examples of second level processing tools are presented hereafter.

SOMAFID (Soil Mapper Fire Detection system) is a fully automatic MODIS image processing system implemented by MEEO. The MODIS fire detection (MOFID algorithm, Justice et al., 2006) system created by NASA makes use of bands 21–22 and 31 (3.9 and 11 μm respectively) to identify active fires. This method requires high computational resources and its performance is highly affected by false alarms caused by clouds, water bodies, etc. The use of SOIL MAPPER® to effectively mask these patterns permits to create the new fire detection analysis system called SOMAFID. This system allows improving the original method performances in terms of reduction of computational time, false-alarm detection and quality of results (it discriminates nine different file classes depending on background type – vegetated or non vegetated – and fire type – flaming or smouldering). Figure 3 shows an example of application of SOMAFID to a very intense fire event occurred in Greece during summer 2007.

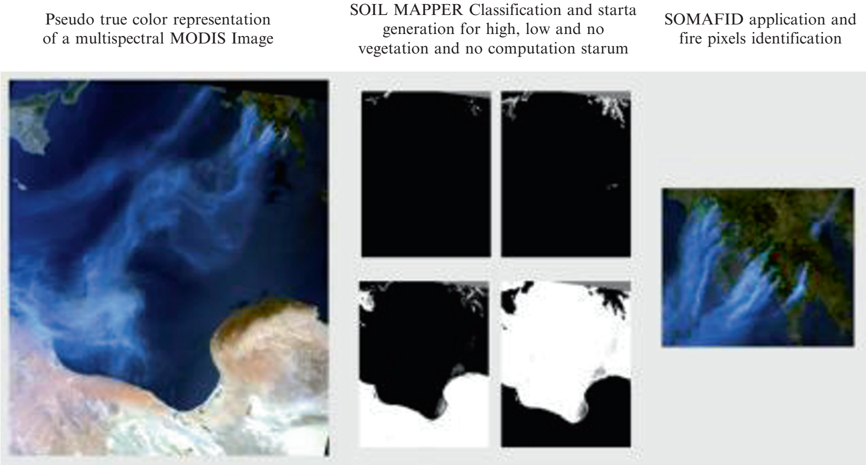

Figure 3. MODIS image collected on August 23rd 2007, 9:35 UTC representing a intense fire event occurred in Greece. The original pseudo true colour image on the left us processed with SOIL MAPPER® in order to generate e series of masks (central panel) for high vegetation (top left), low vegetation (top right), no vegetation (bottom left) and no computation pixels. These masks are used to generate the fire pixels map showed on the left side superimposed with the pseudo-true colour image. Red pixels represent flaming fire pixels, green pixels represents smouldering fire pixels while orange pixels represent mixed fire pixels.

4. Conclusions

In this chapter a novel rule-based classifier based on spectral prior knowledge exclusively is presented. Its characteristics are outlined and already implemented applications demonstrated.

Future developments of the SOIL MAPPER® system comprises:

- Enlargement of the application domain to future missions (e.g., RapidEye, Pleiades, etc.).
- Implementation of further second level processing tools for land cover change/land use based on image time series.
- Implementation of an automatic SAR-Optical data fusion systems to take advantage of the characteristics of the two sensor types (based on schemas already proposed and tested, see Cantone et al., 2007).

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COOPERATIVE DECENTRALIZATION: A NEW WAY TO BUILD AN ADDED VALUE CHAIN WITH SHARED MULTI-RESOLUTION SATELLITE AND AERIAL IMAGERY AND GEOINFORMATION

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Abstract. In this chapter we try to show that present Geospatial Information production, dissemination and use scenario is very far from optimal, causing a lot of problems and shortcomings. The reason is that usual present organization of the GI life cycle in most countries was conceived in the 19th century, in a completely different social and technological environment. New technologies recently developed in the GI domain can help us face successfully the enormous challenges of 21st century. To take full advantage of this technical advances and improve the knowledge of our world, completely new ways of organizing the GI processes are needed.

Keywords: Decentralization, Cooperation, Shared Geospatial Information.

1. 21st Century World Challenges: Geospatial Information Needs They Imply

If we had to describe in one word the present state of Geospatial Information (GI from now on) in the world we would choose: “Chaos”.

In our days, there are plenty of world challenges that demand better geospatial information: overpopulation, resources shortage (mineral, energy, food, etc.), loss of biodiversity, desertification, soil sealing, urban sprawl, pollution.

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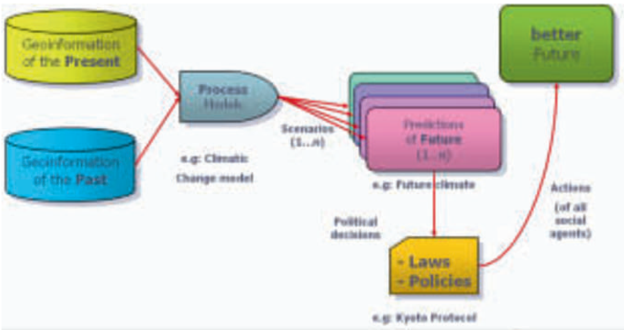

Figure 1. How process models help us improve the future.

To let us face this challenges, GI should be: existing (and its existence known by potential users), accessible, understandable, usable, reliable, of enough and known quality, complete, coherent, certified, structured, up to date (ideally "real time"), mixable, able to be "mosaicked", able to be introduced in process models, reusable, shared, cost efficient, captured only once, captured by the one that knows best each feature or phenomenon, able to be automatically generalized, captured in a decentralized and cooperative process, using licenses not breaking the "Added Value Chain", encouraging (not discouraging or prosecuting) reuse and adding value, etc.

2. The "Traditional" Way to Collect and Disseminate Geospatial Information

The scenario in which GI has been collected, maintained, disseminated and used from 19th century up to present days can be described as follows: each country has a certain number of Public Organizations ("legally mandated organizations" – LMO – in European INSPIRE terminology) with the mission to collect, keep and (sometimes) disseminate Geospatial Information. Each LMO assigns itself a certain "kind" (a "part") of all possible Geospatial Information: a certain geographic extension (nation, region, town,…), a certain GI "theme", a certain "scale" or level of detail.

Each LMO sets up a certain number of "Geospatial Information Programs" (GIPs) to collect, keep, update and disseminate the information it has been assigned. GIPs design include: technical specifications, contents, level of detail or scale, data sets and products, quality assurance, data models, update period, procedures, workflow, costs, data policy, etc. Each GIP is financed, managed and carried out by only one LMO. The design of each GIP is cost–benefit optimized for the part of the GI included in the "mandate" of the

LMO. The information managed by each GIP, include: data sets, services, products, metadata, reports, etc. These are (sometimes) "available" for use by other parties. However it is obvious that the benefits of the GIP investment come with use of these results.

Data Models are designed primarily with the aim of obtaining "Maps".

3. Problems and Shortcomings of the Traditional Way (the Bad News…)

3.1. ECONOMIC ASPECTS

GIPs are normally very expensive to launch and maintain. Most times overlaps do exist, and produce "effort duplication" (or multiplication) and, consequently, a great economic waste. In an effort to face the great costs of GIPs with a limited budget, many LMOs begin to charge (sometimes heavily) for the data, products and services. Sometimes even other public organizations of the same country and level (national, regional, etc.) are charged heavily! If other public organizations do not have enough budget to pay the data, products or services they needs for their activity, it is given no access to them. This diminishes greatly the social benefit of this GIP.

3.2. PRODUCTS, DATA SETS AND SERVICES

The design of each GIP is made taking into account only the needs, opinions and point of view of the LMO in charge. Nobody looks at the needs of other organizations, private companies, citizens, etc. The great number of LMOs that collect the different themes of GI produce thousands of GI databases in each country, and millions of GI databases worldwide. This enormous amount of different databases have a huge diversity in: data models, scales, resolutions, precisions, dates, formats, etc. This produces interoperability problems, dataset incompatibilities, impossibility to join (or "mosaic") data from different GIPs, impossibility to compare information between different areas or dates. Lack of coordination between different GIPs produce a lot of "gaps" in available information: spatial (areas without data), temporal (time intervals without data), resolution (certain level of details without data) and semantic (thematic features without data). At the same time, GIPs overlaps and "task duplication" (or multiplication) produces contradictory information.

3.3. PRODUCTION PROCESS

Information is collected almost exclusively by the LMO. Private companies only participate in the production phase (taking part in public tenders). As different GIPs workflows and production chronograms are not coordinated, the amount of production work available in each moment for public tenders is very unpredictable and variable, and so, private companies cannot adapt their resources (human, technical, etc.) in advance to prepare for each situation. Different GIPs have completely different technical specifications (even for similar information production in different geographic areas). This produces a lot of problems to companies in terms of offers presentation, methodology, development, quality, deadline compliance, project management. As the workflows of different GIPs are not coordinated, every production process starts always "from the beginning" (again and again). This produces waste in effort, time and money.

3.4. DATA MODELS

An important technical shortcoming of the traditional GI scenario is that data models and data collection campaigns are "limited" to collect only the information required by the LMO in charge of the GIP. Most of these "limited" data models are obsolete: they are "map-oriented" data models, as they derive from a "map-centric" vision of GI: legends, nomenclatures, classifications, etc. This point requires some explanation as, historically, this information has been stored in maps. But the information one can store in a map is a very small fraction of information one could retrieve or need about reality (maps are a good way to show information, but a very bad way to store it). The problem is that the first information introduced in digital databases was the information already present in maps, so the first digital databases were designed to store only the information that was already in the maps. So data models have been designed in a "map-oriented" manner, that is: nomenclatures, legends and classifications. This instead of modern, powerful parametric feature data models ("application schemas" in ISO 19109 and ISO 19110). As we will see later the databases that would be able to store all the information needed are completely different (and more complex) if compared with old GI databases.

3.5. DISSEMINATION AND USE OF INFORMATION. DATA POLICY

As each GIP is designed, managed, financed and carried out by only one LMO. This LMO "is" (or "feels" it is) the "owner" of the information (not only the custodian). Private citizens are not allowed to participate in the decisions about what information should be collected an how, and what should be its data policy. Society, nations, regions, cities, or the citizens are not considered "owners" of information, nor are considered as having rights to access the information that Public Organizations are gathering about their country, region, town or home! As there is no interest in a wide use of information, few efforts are made to increase the knowledge of the existence of the information, and its characteristics (production and dissemination of metadata).

3.6. REMOTE SENSING SCENARIO SHORTCOMINGS

The scenario in high and medium resolution Remote Sensing information is even worse: most public Remote Sensing Satellite Systems ("RSSS") are designed independently of others countries systems, or to compete with them, instead of complementing them. Many public RSSS are designed, operated and commercialized with the only aim of maximizing the economic revenues, not to serve the information needs of the countries, citizens and social agents. Most Remote Sensing satellite data "Use Licenses" prohibit explicitly to give the data or added value products to others. This "breaks" every time the "added value chain", dramatically decreasing the usefulness of Remote Sensing data, and making the cost/benefit ratio of this data extremely poor. This Use Licenses go against the principle "Information captured only once", and should be changed.

In some countries, even Aerial Data are "handicapped" with this same limitations in "Use Licenses", because the legal owner of the images is the company that makes the aerial survey, not the Public Organization that pays for it. Sometimes, it is the LMO the one who impose a limiting Use License.

4. A New Scenario in GI Production and Use: "From Autarchy to Cooperation"

Trying to really implement the INSPIRE Principle mentioned above (which we could synthesize as "do it once-do it right") triggers a sequence of important and inevitable changes in the way we understand GI production, dissemination and use. The adequate scenario to accomplish these objectives can be structured as illustrated in the following sections.

4.1. ORGANISATIONAL AND FINANCING SCHEMA

- **Avoid duplications**. Each time it is found that one task is being carried by two or more public bodies, they must sit down and study which of them is the most adequate to do it. Of course, the information produced by this task must go to all the bodies that where formerly doing it (as well as in others, as we will see later on).

- **Co-financing**. GIPs costs must be shared between all interested organizations. From our experience, this is the key that opens the door to collaboration between different LMOs.
- **Bottom-up approach (decentralization)**. Information should be captured at the highest level of detail (greater scale), by the local/ regional authority in charge of that GI theme. This information should be integrated ("mosaicked") at lower resolution by national authority: this is the so-called "Bottom-up approach". A live debate in European Union is whether GI should be captured in a "bottom-up" or in a "top-bottom" way (centralized capture by European organizations). From our point of view, it is completely clear that only the bottom-up approach accommodates the SDI principle "Data collected once". The problem is that many regional and national public organizations would not give their data to European bodies, nor adapt them to European needs. So European bodies are obliged to capture lots of data by themselves. Once again, the consequences are: duplication of efforts, economic waste, information inconsistency, poor data quality. The only way to break this perverse "status-quo" is to set up a scenario of decentralised collaboration and co-financing, as the one we are trying to describe here.
- **Ask the owners**. Many times, the one who knows best each feature or phenomenon (building, parcel, road, forest) is the owner (or the custodian) of that element, not the authority in charge of Geospatial Information. As consequence, a great part of GI should be supplied by the owners or custodians, through well designed Internet Forms. In this case, GI authorities should only check, organize and integrate this information in the datasets and services.
- **Consensus**. All decisions should be met by consensus. It is necessary to organize meetings, workshops, Working Groups, documentation, to generate this consensus.
- **Promote collaboration**. Do not promote competition, between public and private agents.

4.2. GEOSPATIAL INFORMATION PROGRAMS

- **Foster consolidation** as much as possible **of the requirements** of all participating organizations, other agencies, private companies, citizens.

A very simple example of needs consolidation is: organization N1 needs a 50 cm pixel image and a 2 year update period, while organization N2 needs a 25 cm pixel size image with a 4 year update period. If they join their programs, and do alternate 50 cm/25 cm pixel orthophotos with 2 year update period, the cost is reduced by 25.7% (Villa 2007).

- **Define consolidated workflows**: identify common processes of different workflows, and join them in a single, "virtual", de-centralized workflow.
- **Create a single "virtual" workflow and data flow**: promoted, fed, co-financed and fuelled by all public organizations that can and want contribute.
- **Create a single "virtual" distributed database**: held by many different organizations, made up of millions of features, each one with a unique identifier.
- **Foster consolidation of resources**: technical, budgetary (co-financing), political (many organizations together are more powerful than one).
- **Promote common technical specifications**: for similar processes and datasets in different areas: workflow, product list, data models, precisions, quality, metadata, formats, etc.
- **Foster the use of standards** (ISO, OGC, Inspire,…). It is important to mention that standards should be good to be beneficial. A bad standard getting approved is worse than not having a standard (see comment about LCCS later on).
- Deliver coherent, shared, multi-temporal and multi-resolution **aerial image coverages**, designed in a consensus process and served through Internet, for free visualization, as well as free downloading.
- Deliver coherent, shared, multi-temporal and multi-resolution **satellite image coverages**, designed in a consensus process and acquired with multi-user license, that allows any national public organization to use them, as well as any derived product generated from them.
- **Create real time production chains** for time-sensible data (e.g., satellite images).
- **Common identities** of Real World Objects–see GSDI (2004).
- **Foster the use of new technologies** including Web 2.0, Web 3.0, social networks, Chained Internet services.

4.3. DATA MODELS

Data models used in this new scenario should be:

- Parametric object-oriented feature data models (ISO 19109 Application Schemas)
- Multi-resolution in the following terms:
    - Spatial (and allowing automatic spatial generalization)
    - Semantic (and allowing automatic semantic generalization)
    - Temporal
- Capable to allow information to be fed in "Process Models"
- Indefinitely extensible
- Capable to allow integration with Remote Sensing derived parameters
- Capable to allow different updating periods for different attributes (or parts of the data model)

Classical "mapping" data models do not meet these requirements, so it is imperative to use Parametric Object-oriented Feature data models (ISO 19109 compliant). Traditional "map-centric" data models (classifications, legends, and nomenclatures) are not suitable for the needs of 21st century GI data flows. For instance, if we consider a Land Cover data set, when we aggregate polygons into bigger ones, there is no way to automatically derive the class of the resultant polygon.

Ontologies sometimes, are used in a not adequate way, to describe classifications or legends. Instead, they should be used to make more rigorous "taxonomies" in Parametric feature data models. So Parametric feature data models and Ontologies are complementary, not alternatives.

4.4. LAND COVER CLASSIFICATIONS IMPORTANT SHORTCOMINGS: THE SOLUTION

Traditional Land Cover data models are Classification Nomenclatures and Legends (such as European CORINE Land Cover, USGS's Anderson or FAO's LCCS). All these have shown severe limitations up to now and should be urgently substituted by modern Parametric Feature Data Models. This is a very important problem, because Land Cover is a GI theme that includes all the other themes, and so is "key" for the possibility of developing a "consolidated" data model for all GI themes, that is an important objective in INSPIRE and any other SDI. Land Cover information is a very important input to Climate Change Process Models, and many other environmental processes (desertification, soil sealing, urban sprawl, etc.).

An advanced Parametric Object-Oriented ISO compliant Land Cover Feature Data Model has been developed using UML for Spanish SIOSE project. This data model overcomes the severe limitations and shortcomings of Land Cover Classifications (Villa et al. 2008).

4.5. DATA SHARING, DATA DISSEMINATION AND DATA POLICY

- All data (images, vector data, alphanumeric data,…) should be shared between all organizations involved in each GIP, and also other organizations or social agents.
- Information property and copyright, should be shared between all organizations that are co-financing the GIPs.
- Data policy should be as open as possible. Information and services should be free for all users and all uses (with the only possible exception of re-selling data). All this should be addressed in accordance with the EU Directive on the re-use and commercial exploitation of Public Sector Information".
- Data sets should be easily downloadable by Internet (anonymous FTP).
- Permission to reuse, modify, transmit to others, the datasets by anybody (with only exception: satellite images until data policies of public RSSS change). Private companies should be encouraged to use public data and services, either for internal use (completely free) or to generate added value products. Only in the case that this added value products contain public data and are resold, the private company could pay a reasonable quantity, proportional to the percentage of included data in the price of the VAP. Even this case is in discussion in Spain, as there are people (the author of this chapter is one of them) that think that even reselling public data should be completely free: in any case, the state would recover an important part of the benefits that the private company makes through the "corporate tax". The only limitation we would impose, would be the obligation to declare explicitly and in detail which free public data are included in the product, and the URL where they can be downloaded for free by anybody.
- Intermediate products: today's workflows are totally digital and very complex, so a very high number of intermediate products are generated and stored, but normally not documented nor offered to others. Nevertheless, they can be very useful to generate new added-value products and services. So they should be organized and shared.

5. Conclusions

New technologies recently developed in the GI domain can help us face successfully the enormous challenges of the 21st century. To take full advantage of this technical advances, and to improve the knowledge of our world, completely new ways of organizing the GI processes are needed. The world desperately needs the best information we can provide!

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COSMO/SKYMED TO SUPPORT MGCP MAPPING

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Abstract. In recent years, the increased demand for updated cartographic information resulted into international efforts devoted to cartographic mapping using remote sensing data worldwide. Among others, the most impressive effort to obtain this information is related to the Multinational Geospatial Co-Production Program (MGCP) undertaken by NATO nations to obtain updated cartographic information worldwide. In this chapter preliminary results on the use of Cosmo/SkyMed data to support MGCP activities are presented. In particular, an analysis of the speckle regime of Cosmo/SkyMed data has been carried out by analyzing the signal-to-noise-ratio over areas with reflecting elements of different type. In spite of the fact that acquisitions were accomplished with the same spatial resolution, the different level of noise, characteristic of the different areas, reflect the different mapping capabilities of the sensor in the different areas.

Keywords: SAR, COSMO/SkyMed, Speckle Noise, Mapping, MGCP.

1. Introduction

In recent years, peace keeping and humanitarian aid missions in remote regions, arose the need for updated cartographic information at the global scale. Awareness of NATO nations for the necessity of fresh cartographic information resulted into an impressive international co-production program related to the definition of cartographic information worldwide. This program, named MGCP (Multinational Geospatial Co-Production Program), implied the definition of common mapping standards (legend and scale) and the subsequent use of optical remote sensing satellites data as source of

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information for photo-interpretation activities (Nordic MGCP, 2006). The program foresees the definition of cartographic information worldwide at the MGCP scale (1:20,000 or 1:50,000, depending on the population density of the area under mapping) within a period shorter than 5 years, implying in this way, that cartographic information is considered out-of-date when older than 5 years.

This period of time, however, has to be considered the result of a compromise between effective need of cartographic information and operative capabilities to obtain such information. In this logic the lifetime cycle of 5 years for cartographic information cannot be considered as absolute value, but just as an order of magnitude that provides an indication on the level of reliability of the data. For this reason, in operative conditions presupposing exposition of field operators, it necessary, before the mission is undertaken, to verify the reliability of the cartographic information. In these conditions, optical remote sensing data may be unreliable, owing to the possible contamination of the operation area by severe cloud cover, which obscures the observation area for unforeseeable long periods. This latter circumstance is likely to occur in tropical regions, where, during the rainfall season, large areas of the territory are completely covered by clouds making optical remote sensing a useless monitoring tool. In order to overcome this difficulty, SAR remote sensing has proven to be a valuable tool (Reichert et al., 1991).

The Cosmo/SkyMed SAR constellation is currently operating with two spacecrafts and allows daily acquisition of the same area with a spatial resolution from 1 m to 20 m. The possibility to operate a SAR sensor allows obtaining information on the ground in all weather conditions in spite of severe cloud covers. In this logic, Cosmo/SkyMed could be an important tool to verify the reliability of cartographic information provided that the nature of the remotely sensed signal in the microwave range at such a high resolution is investigated and understood in terms echoes reflected by surface targets (Goodenough et al., 1987).

In practice, SAR signal are strongly affected by the presence of speckle noise which is difficult to be filtered out owing to the correlation with the signal. In this logic, signals reflected from the surface are embedded in to chaotic patterns, which reduce the capability to interpret the data (Evans, 1999). In practice, this reflects in to the necessity to define the actual size of the patterns that can be effectively recognized and interpreted in the data given the selected spatial resolution (Gamba and Houshmand, 2001; Dell'Acqua et al., 2006).

Furthermore, given the particular nature of SAR signals, interpretation of remotely sensed radar signals may not relay upon the experience made on interpreting remotely sensed data in the visible region (Goodenough et al., 1987). Therefore, in order to use Cosmo/SkyMed data for cartographic purposes, some research is necessary in order to define photo-interpretation techniques of SAR remotely sensed data.

This manuscript aims at presenting preliminary research results carried out in order to define such a classification algorithms.

The chapter is organized as follows: in Section 2 some information on the constellation Cosmo/SkyMed is provided and data used in this work are briefly described; in Section 3 preliminary, but relevant results are presented and, Section 4, contains a brief discussion and concluding remarks.

2. The Cosmo/SkyMed Constellation and Description of Data

COSMO-SkyMed (Constellation of Small Satellites for Mediterranean basin Observation, see Figure 1) is a constellation composed by four satellites orbiting in low orbits and deployed by the Italian Space Agency (ASI). Each spacecraft is equipped with an X band SAR (9.6 GHz). Orbit design along with instrument characteristics are conceived to allow revisit time of the order of 18 h over the equatorial region and, thus, is adequate for on-line monitoring applications.

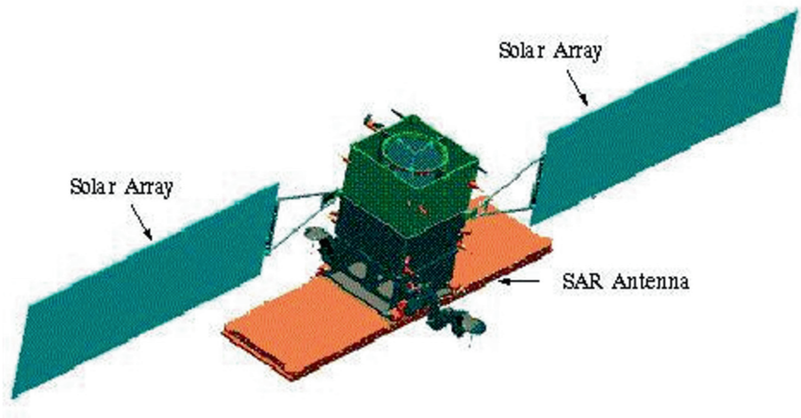


Figure 1. Cosmo-SkyMed spacecraft.

TABLE 1. Orbital characteristics of Cosmo/SkyMed.

Orbit inclination (respect to the equator)	97.86°
Period	97.1′
Orbit type	Sun-synchronous
Cycle	16 days of orbit cycle in 237 orbit per orbit cycle
Altitude	619.6 Km
Eccentricity	0.00118

Cosmo/SkyMed satellites are deployed over eliosynchronous orbits at 97.86° respect to the equator and at an altitude of approximately 620 km (see Table 1 for a summary of orbital characteristics).

The sensor on board Cosmo/SkyMed, named SAR 2000, is a polarimetric SAR operating in the X band. Figure 2 summarizes the engineering factors of the sensor respect to other currently operating sensors. SAR 2000 can operate in several imaging modes: STRIPMAP, SCANSAR, SPOTLIGHT. The operating principles of SAR 2000 are summarized in Figure 3.

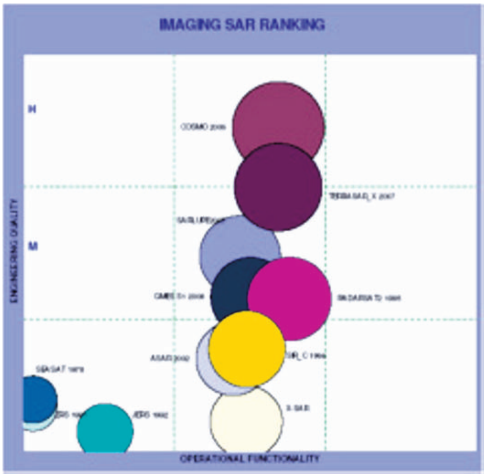
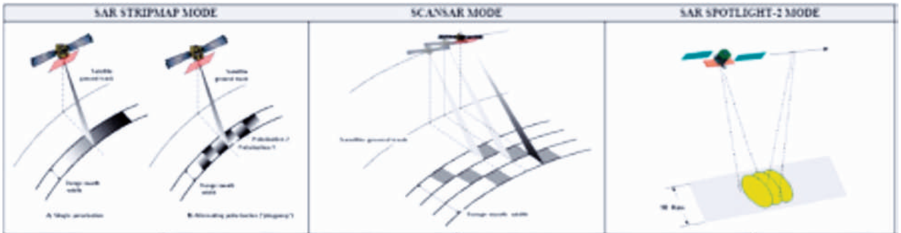


Figure 2. Cosmo/SkyMed SAR respect to other operating SAR.



SAR STRIPMAP MODE		SCANSAR MODE		SAR SPOTLIGHT-2 MODE	
Swath width	**40 km** *(single polarization)* / **30 km** *(alternate polarization)*	*Swath width*	**100 km** *wide region* / **200 km** *huge region*	*Scene extension*	**10 km** *(azimut)* **x 10 km** *(range)*
		No. of sub-swaths	**4**		
Azimut resolution	**3 m** *single polarization* / **15 m** *alternate polarization*	*Azimut resolution*	**30 m – 100 m**	*Azimut resolution*	**1 m**
Acquisition length	**max. ca. 3800 km**	*Acquisition length*	**max. ca. 3800 km**		
Incidence angle range	**25°- 50° full performance** */ 20°-57° access*	*Incidence angle range*	**25°- 50° full performance** */ 20°-57° access*	*Incidence angle range*	**25°-50°** *full performance / 20°-57° access*
Ground range resolution	**3 m / 15 m** *alt pol*	*Ground range resolution*	**30 – 100 m**	*Ground range resolution*	**1 m**
Noise Equivalent σ	≤ **-22 dB**	*Noise Equivalent σ*	≤ **-22 dB**	*Noise Equivalent*	≤ **-22 dB**

Figure 3. Operation modes of Cosmo/SkyMed.

Characteristic of data acquired in the different operating modes are summarized in Table 2.

TABLE 2. Operation modes of Cosmo/SkyMed.

Spotlight (also referred to as "Frame")	• Spatial resolution: ≤1 m • Spot observation area: 10 km × 10 km
Himage (Stripmap)	• Spatial resolution: 3–15 m • Swath width: 40 km
Wide Region (ScanSAR)	• Spatial resolution: 30 m
Huge Region (ScanSAR)	• Spatial resolution: 100 m • Swath width: 200 km
Ping Pong (Stripmap)	• Spatial resolution: 15 m • Swath width: 30 km

Data used in this work consists in one image (Figure 4) acquired in the "Wide Region" mode over the coastal area of the "Red Sea".

Original images, consisting of approximately 20,000 × 20,000 pixels, were segmented in to 16 sub-frames composed by 5000 × 5000 pixels. Individual sub-frames were visually analyzed in order to detect cluster associated with specific ground classes.

Histograms of backscattered radar cross sections in regions surrounding visually identified class borders were extracted and analyzed in order to verify how classes can be recognized within noisy radar patterns.

3. Results

In Figure 4 the regions selected for the analysis are represented.

With reference to Figure 4, region A contains no classes while region B contains two distinct classes of aggregated values.

In Figure 5 the histograms of regions A and B are shown. First note that, in both cases, the histograms closely resemble a Poisson distribution (similitude coefficient 0.82, with 1 indicating "identical"). In both cases, from the analysis of single histograms no evidences of classes can be recognized (i.e., histograms are mono-modal).

Figure 6 shows the histograms of four equal sub-regions in which the region A has been divided. As it was clear from the visual inspection no classes leave their signatures on the histograms of sub-regions and, in every sub-frame, the average value along with the most probable value are equal and approximately equal to the value of the same parameters computed on the overall region.

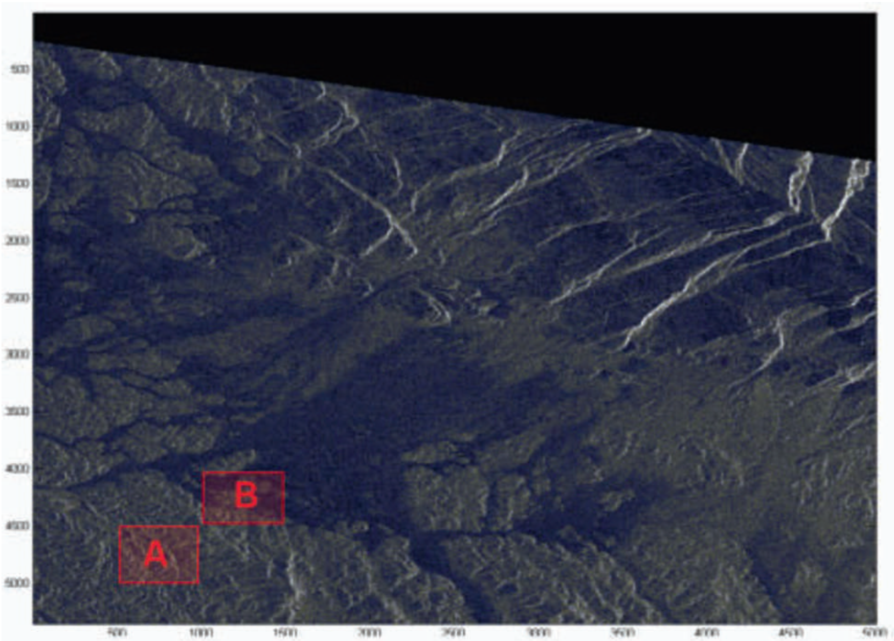


Figure 4. Cosmo/SkyMed data. A and B indicate subregions selected for the statistical analysis.

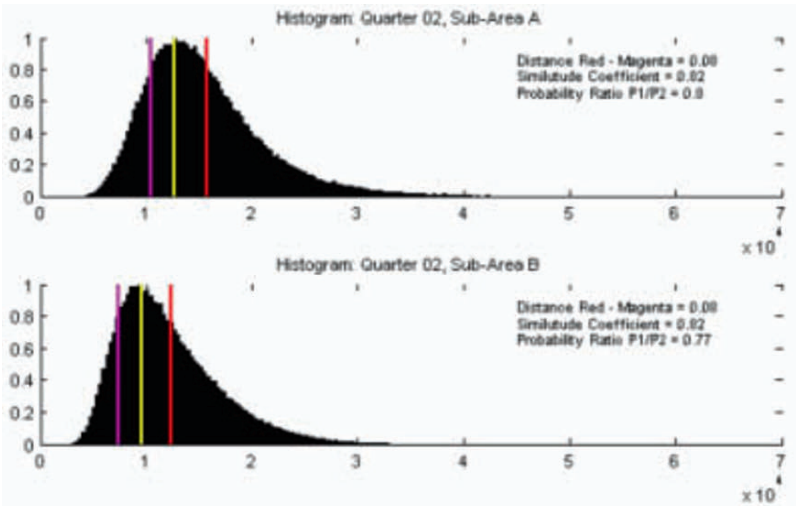


Figure 5. Red line indicates the average value, magenta the pseudo average (i.e., the value with probability to occur equal to the probability to occur of the average value) and yellow the most probable value. analysis.

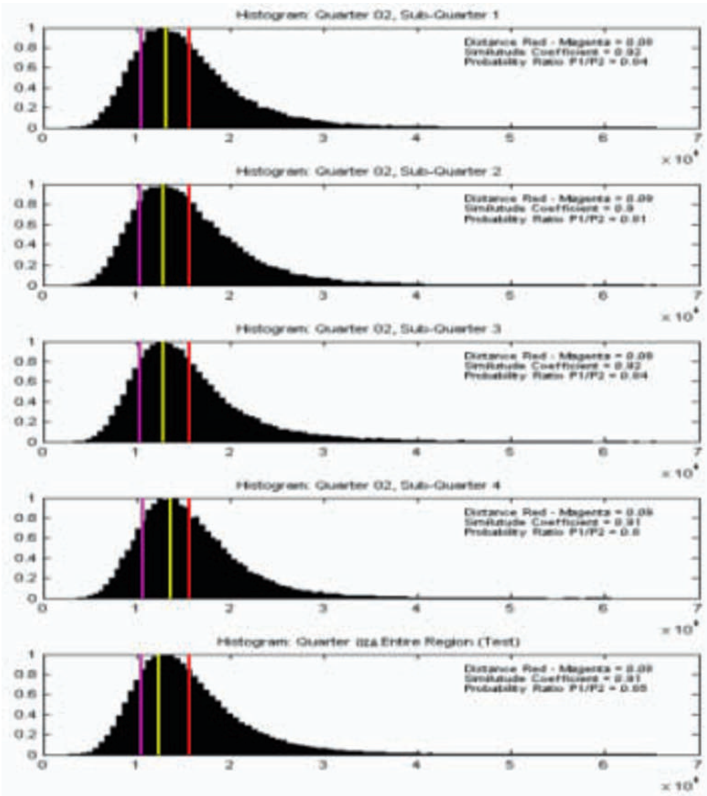


Figure 6. Histogram of region A (bottom) and of the four regions in which region A has been divided.

Figure 7 shows the histograms of four sub-regions in which region B has been subdivided. As it can be seen, in presence of specific classes, the segmentation process enables to detect variations in the histograms characteristics and it produces remarkable shifts in most probable values along with on average values.

4. Concluding Remarks

The analysis of Cosmo/SkyMed data confirmed that classical photo-interpretation techniques used in optical data cannot be used to identify classes in remotely sensed Cosmo/SkyMed data due to the fact that the multi-modal separation of pixel intensity distribution function associated with area covering multi-classes regions, does not occur in SAR data. This circumstance is associated with the typology of noise that, in remotely sensed SAR data, is strongly dependent on the signal and makes the distribution function of Poisson type rather than of Gaussian.

However, it has been observed that segmentation and analysis of histograms of pixel intensities of segmented regions, from the analysis of the variation of average and most probable values, may provide information on the existence of different classes and, thus, provide a tool for interpretation of remotely sensed SAR images. Specifically, it is felt that, systematic use of segmentation and variations of statistical properties of individual windows may provide the key to photo-interpret SAR remotely sensed images. In this logic, an adaptive filter based on the analysis of statistical properties of moving windows is being developed. The systematic use of this filter, through comparisons between filtered and unfiltered data, provides a tool for automatic detection of patters in the remotely sensed SAR image. In the filtering approach, however, the choice of the window size is critical. In fact the window needs to be wide enough to contain a statistically relevant number of data, but small enough not to filter out structures observe in the remotely sensed image.

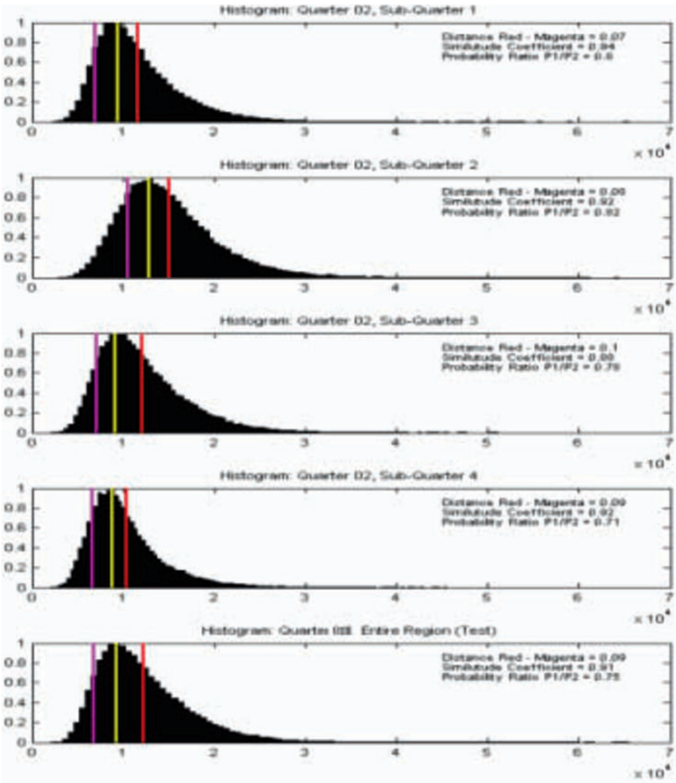


Figure 7. Histogram of region B (bottom) and of the four regions in which region B has been divided.

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SCIENTIFIC VISUALIZATION

VISUAL PROCESSING OF GEOGRAPHIC AND ENVIRONMENTAL INFORMATION IN THE BASQUE COUNTRY: TWO BASQUE CASE STUDIES

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Abstract. The Basque Meteorology Agency is conducting an initiative to improve the collection, management and analysis of weather information from a large array of sensing devices. This chapter presents works carried out in this context proposing the application of 3D geographical visualization and image processing for the monitoring of meteorological phenomena. The tools described allow users to analyze visually the state of the atmosphere and its interaction with the topography, and process live outdoor images to automatically infer weather conditions. This kind of systems can be applied in the surveillance of other environmental events and enable better decision making for several purposes, including important issues related with environmental security.

Keywords: Visual Analytics, GIS, Geographic Information, Computer Graphics, Weather, Meteorology, Environmental Security.

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R. De Amicis et al. (eds.), *GeoSpatial Visual Analytics: Geographical Information Processing and Visual Analytics for Environmental Security*,

1. Introduction

Geographic information processing together with computer graphics visualization and analysis has a considerable potential in environmental monitoring and decision making. The Basque Meteorology and Climatology Agency along with VICOMTech Research is conducting a strategic project that aims at establishing tools to centralize and enable analysis of the large amounts of data collected from weather sensors spread around the Basque Country. These sensors are heterogeneous devices such as those in 96 automated weather stations (temperature, pressure, humidity, wind, solar radiation, etc.), a Doppler radar, a wind profiler and several oceanic probes.

This chapter presents work carried out in the context of this initiative that brings computer graphics-based tools to assist in analyzing the global situation. Properly using the data from sensors requires calibration procedures and filtering of noise to ensure reliability.

The first part of the work involves the creation of an integrated 3D geographic information system for visually analyzing weather data, mainly weather radar scans, together with other georeferenced information. The work starts with an analysis of output data from the weather radar located on Mount Kapildui and the task of improving the quality of the readings.

The second part proposes video cameras as additional weather sensors. Computer vision techniques can process images coming from cameras in the automated stations and provide information on the state of the local atmosphere. A coordinated operation of all stations with such a system installed could give a global depiction of the state of the sky along the territory and its evolution, potentially allowing the forecast of special environmental situations.

1.1. GEOGRAPHIC VISUALIZATION AND IMAGE ANALYSIS

The Autonomous Community of The Basque Country is a territory in northern Spain bordering with southern France. It spans an area of 7,234 km^2 and is crossed by a few mountain ranges. Established 1990, the Basque Meteorology Agency, *Euskalmet*, has deployed a large network of automated weather stations, including a long-range radar, and provides past, present and forecast meteorological information.

The physical data collected by sensors in the network needs to be stored and properly managed and retrieved to provide useful information (e.g., for decision making). This process involves the use of traditional tools as well as innovative computer visualization and image processing as key technologies. Visual analysis tools help users understand the state and evolution of the environment by providing integrated graphical representations and visual metaphors.

In the case of weather and other environmental information we consider geographic (i.e., topographic) data especially relevant. These phenomena occur in specific locations and are influenced by the topography. We thus want to present incoming sensor data coupled with a detailed 3D representation of the territory in order to give it a context and allow a visual analysis of the interaction between ground and atmosphere.

The above mentioned system transforms numerical sensor readings into visual representations to enable humans to interpret them. This initiative also proposes a system working in a very different way: taking live images of the environment, as a human observer would, and automatically process and interpret them to infer the state of the environment.

Both approaches (producing visual metaphors for humans to interpret and letting computers interpret visual information) are different aspects of the application of computer graphics processing in environment related information analysis. Current focus is in meteorology, but a similar approach can be applied to other environmental monitoring such as forest fires, pollution or floods, all with implications in environmental security.

2. Weather Radar Data Processing and Visualization

The Basque Weather service operates a dual Doppler Weather Radar, located on top of Mount Kapildui, 1,000 m high and 100 km away from the coast. It is a Meteor 1,500C model from Selex-Gematronik. The radar computes the reflectivity, radial velocity and spectral width fields every 10 min through two volumetric and two elevation scans.

Radar scans are typically represented as 2D images in the form of either PPI (plan position indicator) or CAPPI (constant altitude PPI) products. Here we want to display the complete radar volumes, not only individual slices from it, correctly aligned and scaled over digital terrain model of the territory. The result is a form of a geographic information system (Peuquet and Marble, 2004).

2.1. VOLUMETRIC DATA ANALYSIS

The volumetric data sets acquired by the radar are composed of 14 scans at increasing elevations (from –1° to 35°). Given the topography of the Basque Country, the lower scans are affected by the surrounding mountains and other topographical elements, adding almost constant noise to the data, which should be ignored. This constant noise is known as ground clutter.

Ground clutter is noticeable in the lowest elevations, since the radar beam frequently hits the topographical elements. On the other hand, the lowest levels give more useful information to meteorologists, so a compromise has to be found. Normally, the lowest elevation free of clutter is used as the main information source. In Mount Kapildui clean scans can be obtained at elevations greater than 1°. It would be better to have lower scans (at –0.5°, 0° and 0.5°), but this part contains noticeable ground clutter.

Since ground clutter is in theory constant in time its effects in the lowest scans can be reduced by subtracting a fixed mask to the retrieved data. Basically, this clutter mask consists of the reflectivity acquired in a clear day. Under those conditions, all perceived reflectivity should be caused by surrounding topography.

We have observed that ground reflectivity is not exactly constant but has slight random variations from one scan to another. This is probably due to slightly changing atmospheric conditions and small movements of the radar support structure.

2.2. CLUTTER MASK CREATION AND SUBTRACTION

Given the variability of radar echoes caused by topography a single scan of a clear sky is not enough to create a reliable clutter filter. In order to avoid this problem, a clutter mask was created through a combination of a small set of radar scans taken at different times with a clear sky.

The resulting mask effectively removes clutter from the scans used to produce it, by definition, but may not filter correctly all ground echoes in other scans due to those random variations. In order to increase its effectiveness, the mask is processed by a *dilate* filter. While this increases the risk of producing a filter which is too aggressive our preliminary tests seem to give acceptable results.

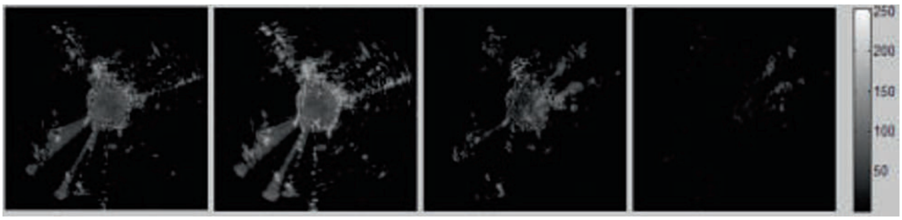

Figure 1. A low level scan subtraction. From left to right: (a) original clutter mask, (b) dilated clutter mask, (c) a random volumetric scan and (d) the subtraction of the scan and the clutter mask, removing the ground clutter.

Figure 1 shows a combination of several slices, its dilated form and an example of application (subtraction) from a new incoming reflectivity slice.

2.3. 3D VISUALIZATION ON GEOGRAPHIC MODEL

Our model of the Basque Country is based on a detailed digital elevation model (Jenson and Domingue, 1988) and a set of properly adjusted high resolution orthophotographs, provided by the Basque Government. In order to allow rendering at interactive rates the original elevation data in GeoTIFF format and the textures were processed to produce a set of hierarchically arranged tiles of varying resolution. The resulting data set, almost 1 gigabyte in size, enables progressive level of detail by retrieving the required terrain tiles on demand.

Volume scan files include metadata specifying the geographical location of the radar (longitude, latitude and elevation) and the sample separation. This information is used to position and scale the reflectivity field on the map. The map uses UTM coordinates and since the Basque Country is located nearly in the middle of zone 30T, very small scale distortion is expected.

The union of radar and topographic data clearly highlights the presence of ground clutter around the highest mountain ranges (see Figure 2). The application currently also allows applying a pre-calculated clutter mask to remove such noise and produce cleaner precipitation representations.

Two visualization styles have been tried. In the simplest one, reflectivity is mapped to the opacity and greyscale intensity of all slices. In the second one, a standard reflectivity colour map is used, and values lower than 10 dBZ are completely transparent, which seems to be more intuitive to meteorologists.

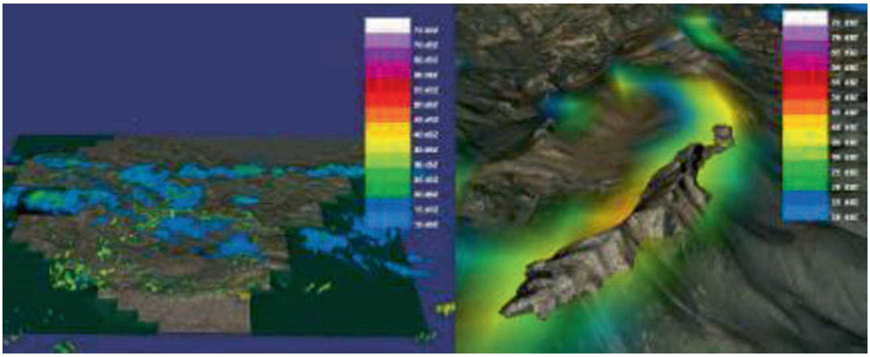

Figure 2. Unfiltered Kapildui radar volumetric information visualization using a reflectivity colour map. In the left image, the rain areas can be seen in blue as well as ground clutter. In the right image, a close up of the ground clutter is shown, matching the mountain causing it.

3. Automatic Analysis of Sky Images

The main goal of the Skeye project consists of the automated visual analysis of the images acquired by cameras located on ground stations. The Skeye architecture allows the integration of any analysis module and in this context we will focus on cloudiness estimation and fog detection that can provide information about the visibility condition in this area. Figure shows the different modules developed to compose the Skeye system.

Figure 3. Skeye system architecture.

3.1. IMAGE CAPTURE

This module works at the terrestrial weather station. It takes pictures of the sky covering all elevation angles from –10° to 90° and 360° in azimuth.

Pictures can be taken in the visual electromagnetic spectrum or in infrared band. Infrared cameras have some advantages since they can work at night and the images provided contain thermal information, but on the other hand, texture-based analysis algorithms get less accurate data as input.

The amount of necessary images to cover the whole sky is inversely proportional to the field of view of the camera (Kelby, 2006). The quality and properties of the images depend on the camera parameter's settings which will be adjusted according to the environmental light conditions. The proper calibration of all these parameters will have a strong influence in the system's final precision and recall.

Data transmission is not a trivial aspect in our case. Terrestrial automated weather stations are usually placed at remote locations and the scalability of the system requires wireless solutions to keep the costs in a reasonable level. Therefore, this project has been coordinated with a WIMAX network deployment that will ensure the delivery of the information from all these remote stations. Mobile telephony networks such as GSM, GPRS, UMTS or HSDPA are also being considered depending on signal coverage.

3.2. IMAGE PROCESSING

This module centralizes all the information coming from the different terrestrial weather stations. It creates a 2D panoramic view of the whole sky dome keeping areas' relations using geometric transformations and Gall-Peters projection mode (Peters, 1983). This function allows representing the local weather conditions in a unique image and centralizing the visual information from the geographically separated places for the meteorologist.

Furthermore, it analyzes the images and extracts features using digital image processing techniques in order to segment the image and carry out the cloudiness calculation and fog detection which are processed by independent software modules.

For cloudiness, the image is segmented and labelled in four classes: *Earth*, *sun*, *sky* and *cloud*. Colour and texture (entropy) features are used in this process (see Figure 4).

The fog detector is based on the topographic outline analysis. The local terrain shape is analyzed and assumed to be fixed. Shape variations provide hints to detect fog which disturbs the terrain visual observation.

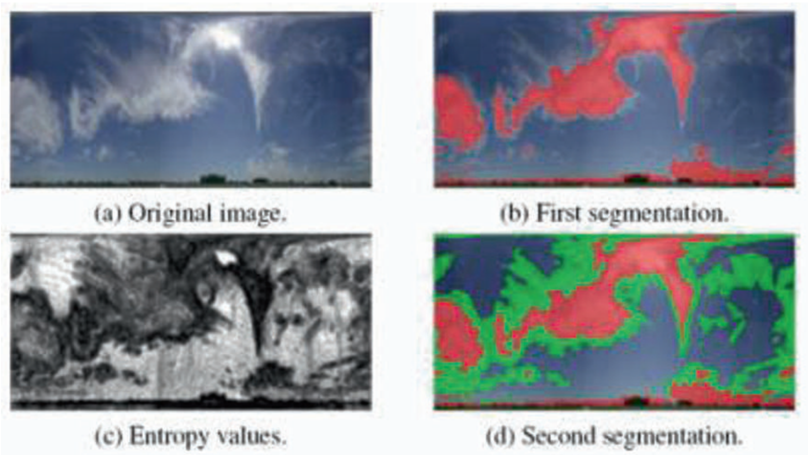

Figure 4. Cloud segmentation process.

3.3. DATA STORAGE AND DELIVERY

The processed information is stored in common servers where different meteorological stations upload their data. This information can be accessed from anywhere and used to combine many data sources. It provides the way to find correlations among geographically separated weather phenomena and their effects or to track features in very wide areas.

4. Environmental Monitoring

The potential of these two presented use cases operated by Euskalmet go much further than simple local weather analysis applications. The idea behind is a global approach to data analysis where different kinds of data (visual information, radar readings, digital terrain models, etc.) coming from different places can be combined in order to get a better understanding the state and evolution of environmental phenomena. These include weather alerts involving potential floods or fast temperature changes, chemical leaks to the atmosphere, forest fire and smoke, etc.

Current existing network infrastructures where communications costs are dramatically reduced by wireless technology deployments and the availability of a wide range of sensors and cameras provide a huge amount of data that after adequate pre-processing phases can be analyzed for different purposes. Data mining techniques can also help discover unknown correlations among geographically separated features and effects improving the knowledge of researchers and professionals.

Moreover, the network of stations can be considered as single entity able to carry out surveying activities of the areas covered by the network nodes. Some interpolation techniques could even find out effects produced in non monitored areas located among nodes.

5. Conclusions

A novel weather analysis system has been presented in this chapter. In combination with classical weather instrumentation (thermometers, barometers, anemometers, etc.) the two use cases offer methods to improve forecast, general knowledge and environmental surveillance.

The Doppler weather radar visualization system with the explained clutter filtering techniques and more integrated sensors will provide the basis for a new data source to help prevent natural disasters like floods and big storms, and allows defining behavioural patterns.

The Skeye project defines a centralized image analysis framework where different cameras can be connected. All the visual information is processed by pre-calibrated analysis modules and cloudiness degree and fog presence can be automatically estimated.

Acknowledgements

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DYNAMIC TERRAINS: CITIES AND REAL-TIME VIDEO ON GIGANTIC TERRAIN MODELS

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Abstract. Real-time inspection and visualization of huge terrain models is a promising topic with many potential applications. Interactive rendering of planet-size, photo-textured digital elevation models hosted on remote servers is a challenging problem, requiring a careful management of the data. Typical user requirements include the access to as many accessible datasets as possible, scalable algorithms and a client–server architecture. Besides efficient handling of out-of-core gigantic models, our work has been specially focused to urban rendering and to video mapping. Our technique for the visualization of large scale urban models is based on the image-based rendering of a hierarchical collection of relief-mapped polygons. Moreover, real-time video mapping of captured video from flying cameras onto the digital terrain model can be a powerful tool for environmental security and protection.

Keywords: Terrain Models, Gigantic Geometric Models, Urban Rendering, Real-Time Video Display.

1. Introduction

Interactive rendering of planet-size, photo-textured digital elevation models hosted on remote servers is a challenging problem with many potential applications. Typical user requirements include the access to as many accessible datasets as possible, scalable algorithms and a client–server architecture. Present solutions must include efficient algorithms to handle the corresponding distributed, out-of-core gigantic models together with

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many other acceleration techniques like the use of cache memories and hierarchical data structures. A detailed survey can be found in Dietrich et al. (2007) or in Kasik et al. (2006).

One of the most relevant algorithms for massive terrain rendering is BDAM. By extending this idea, Gobbetti et al. (2006) have proposed a compressed multiresolution representation for supporting interactive rendering of very large planar and spherical terrain surfaces. The technique, called Compressed Batched Dynamic Adaptive Meshes (C-BDAM), is an extension of the BDAM and P-BDAM level-of-detail hierarchies. In this C-BDAM approach all patches share the same regular triangulation connectivity. The structure provides a number of benefits, from the simplicity of data structures to the support for variable resolution input data, management of multiple vertex attributes or efficient compression and fast construction times.

The next two sections of the chapter describe the two main techniques that we have been using in the context of terrain rendering: image-based rendering of large scale urban models, and real-time video mapping of captured video from flying cameras onto the digital terrain model.

2. Image-Based Techniques for Urban Rendering

Image-based rendering techniques offer a good solution for the real-time visualization of large multiresolution urban models. They outperform the standard rendering of textured-mapped simplified meshes when replacing distant geometry, achieving better results than classical simplification techniques on dense collections of small components and buildings.

Among image-based algorithms, relief mapping schemes have been shown to be useful for highly-detailed 3D models. Relief mapping use textures with colour and depth values, providing parallax and self-occlusion effects. Policarpo and Oliveira (2006) propose GPU-based algorithms for relief mapping rendering. However, most relief mapping approaches show under sampling problems in regions misaligned with the plane supporting the relief map. In the context of urban rendering, this means that relief maps defined on a horizontal plane are unable to capture the appearance attributes of vertical building facades.

Omni-directional relief impostors (ORIs), proposed by Andujar et al. (2007), overcome this limitation by representing detailed objects through a small set of properly oriented relief mapped polygons. Unlike other approaches, each relief map provides a global view of the whole model from a particular direction (see Figure 1). At runtime, the current view direction is used to select a small subset (typically three) of the pre-computed maps which are then rendered using a GPU-based ray-height field intersection algorithm. The combination of the selected relief maps provides a high-quality representation of the underlying 3D object.

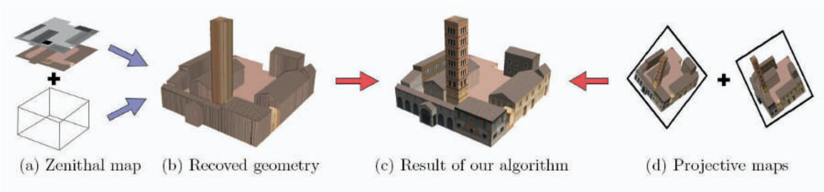

Figure 1. Overview of the impostor-based urban rendering algorithm. We replace the geometry of urban model subparts with a small collection of textures with depth (a,d). The zenithal map encodes all the geometry (b). Details on mostly vertical surfaces like facades are extracted from carefully-aligned textures (d) through a variant of projective texture mapping. The resulting image provides a high-quality representation of the objects (c).

For the particular case of urban rendering, we use a collection of up to eight properly aligned relief maps plus a zenithal map. This zenithal map encodes colour and depth. It is computed by rendering the selected part of the input model from a vertical axonometric camera. Then, we optimize the amount of visual information in the non-vertical maps to find the number and orientation of these relief maps. See Andujar et al. (2008) for more details. The scene is then rendered with orthogonal cameras aligned with the chosen directions to acquire the corresponding depth and colour maps. We use the zenithal map plus two slanted relief maps to minimize sampling artefacts in the final image.

Omni-directional relief impostors can be used in a hierarchical way to allow for the interactive inspection of complex scenes. We have adopted a simple quadtree-based representation, although any kind of subdivision (bintree, kD-tree) could have been used.

We have tested our system on a 2GB textured model of Rome (Figure 2). We first created a 4-level quadtree covering around 10.2 km^2 and then we refined 16 h m^2 to a maximum depth of 8. We used this quadtree hierarchy to build 256×256 relief maps using a bottom-up construction. For each quadtree cell, an average of 6.5 relief maps were generated.

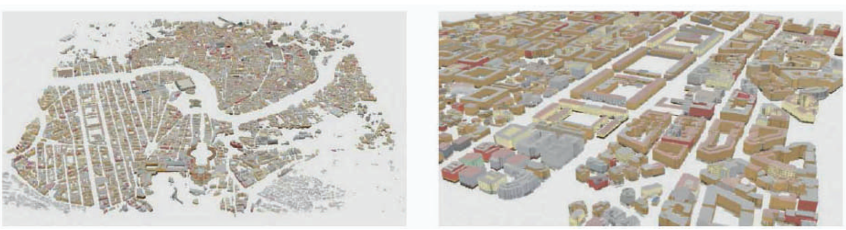

Figure 2. Two snapshots from the virtual Rome navigation.

3. Video-Mapping in Terrain Models

To include real-time video and display in onto the digital terrain, a number of technical issues have to be addressed. The final goal is to receive video information in real time from fixed or moving cameras (in this last case, cameras are usually driven by flying devices) and to project it onto the terrain model in a way that it is perceived by the users as a dynamic part of the terrain itself. Users can inspect both the terrain and the projected video from different perspectives and interact with the model for better understanding of the situation. The virtual location of the camera can also be displayed to facilitate the overall comprehension (Figure 3). Video projection requires the continuous acquisition and transmission of video and camera (geo-referenced) location information. The final rendering on the terrain will be correct, unless occluded terrain zones from the camera location are being inspected by the final user:

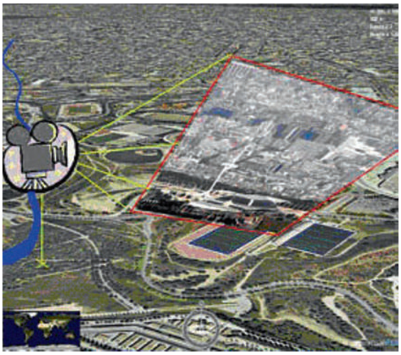

Figure 3. Projecting video onto the terrain model.

4. Conclusions

Real-time inspection and visualization of huge terrain models is a promising topic with many potential applications. Interactive rendering of planet-size, photo-textured digital elevation models hosted on remote servers is a challenging problem that requires a careful management of the data and its multiple levels of detail. Typical user requirements include the access to as many accessible datasets as possible, scalable algorithms and a client–server architecture. Besides efficient handling of out-of-core gigantic models, our work has been specially focused to urban rendering and to video mapping. Our technique for the visualization of large scale urban models is based on the image-based rendering of a hierarchical collection of relief-mapped polygons. Real-time video mapping of captured video from moving flying cameras onto the digital terrain model can be a powerful tool for environmental security and protection. Having the dynamic evolution of the incidence (fire, etc.) mapped in real-time onto digital elevation model will certainly give a better perspective to managers for adequate and precise planning.

Acknowledgements

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DIGITAL TERRAIN MODELS: A TOOL FOR ESTABLISHING RELIABLE AND QUALITATIVE ENVIRONMENTAL CONTROL PROCESSES

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Abstract. Geospatial datasets representing our natural environment is widely used and applicable for various engineering, environmental, and social processes. Digital Terrain Models (DTMs) describing the terrain relief are among the most relevant sources for quantitative and qualitative environmental evaluation. Using simultaneously several geospatial datasets requires addressing the issue of data integration/comparison. This chapter introduces three novel algorithms for these tasks, which deal with the problem of achieving terrain continuity and completeness despite discrepancies that might exist among the different data sources. The main novelty of these algorithms is in using localized topographic structure of the terrain described by the DTMs, rather than trying to match whole datasets based solely on their coordinates. Several applications based on the suggested algorithms demonstrate their usefulness and applicability for establishing a reliable tool for environmental control processes.

Keywords: DTM, Conflation, Rubber Sheeting, Integration, Modelling, Spatial Analysis, GIS.

1. Introduction

Terrain relief is a continuous spatial surface entity describing our natural environment – the topography. Since terrain reality is continuous, the digital description of the relief is expressed by discrete data (discrete points and/or

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typical break-lines) known as Digital Terrain Model (DTM) or Digital Elevation Model (DEM). In general, DTMs contain spatial elevation data of the terrain while disregarding vegetation, roads, buildings and other man-made features. DTM databases are usually structured as square grids in a Cartesian coordinate system {x, y, and z}; similarly to raster images. Digital description of the topography is among the main elements of mapping in general and photogrammetry in particular. Using DTMs in various mapping and Geographic Information Systems (GIS) applications requires continuous and contiguous terrain relief models describing their coverage region with no gaps or irregularities. This means that there exists a height value in the DTM for each point within the region covered and that there are no discontinuities between adjacent parts of the DTM or neighbouring DTMs. The need for digital models describing terrain relief of large regions, such as countries and continents, is increasing. Current digital mapping systems and GIS provide tools for visualizing, analyzing and using DTMs. However, these systems do not provide solutions to problems which are related to the completeness of the terrain description. Examples are integrating datasets of various sources, densities and classes (data types), completing missing data (holes), etc.

Traditional production of DTMs is usually done by using stereoscopic sampling of photogrammetric models, while using aerial/satellite imagery, by automatic, semi-automatic or manual techniques, or by manual or algorithmic digitization of existing topographic maps contour lines (Robinson, 1994; Li, 1994; Eklundh and Martensson, 1995). As mentioned, these models are generally presented by an equally-spaced data structure, square grid, with spacing of few meters up to several dozens between the discrete data described in the model. The vertical accuracy of these models can reach 1 m while designated processes will result with models of sub-meter accuracy. This data structure is the most common one, and the majority of commercial and non commercial software packages can use the data described in these models for various topographic analyses.

Modern technologies for producing updated models scan the terrain relief by sending high frequency laser pulses via airborne campaigns, i.e., Airborne Laser Scanner (ALS). This technique produces dense 3D point clouds, which describe the terrain as well as the surface, i.e., natural and artificial objects (buildings, trees, vegetation, etc.). This model, which is considered as Digital Surface Model (DSM) and is usually presented as Triangulated Irregular Network (TIN), presents a dispersal and irregular data structure with density of up to 16 points per square-meter, and positional accuracy in the order of sub meter and vertical accuracy better than 0.25 m (Kraus and Pfeifer, 2001). Though this technology provides reliable, up-to-date and accurate spatial data in relatively very short time, the fact that it combines terrain as well as surface data – as opposed to DTMs – requires additional data processing, mainly filtering and segmentation procedures (Mass, 1999; Kraus and Pfeifer, 2001). These processes affect directly the data quality and correctness in achieving a reliable representation of the natural environment.

2. Motivation

Digital terrain models that cover very large regions are usually stored as grid databases, in which for each grid-point a height value is given. The main advantages of this method are data handling simplicity and fast data access (needed for various analyses procedures – mostly real-time ones). Usually, databases that were sampled with high accuracy (and hence are usually dense) will cover smaller regions than the ones sampled with lower accuracy. The cause for this is the fact that the sources used for producing the models – as well as the techniques – vary. A model produced via an aerial imagery with a scale of 1:40,000 is more accurate and dense than a model produced via topographic maps contour lines digitization. As a result, the commercial software packages that use these diverse data are required to use continuous representation of the entire area they cover. The limitations of existing methods for manipulating the data stored in these models – mainly for extraction and visualization, or even comparing and integrating separate models – can produce model errors, discontinuity and incompleteness. For applications, such as line of sight, visibility maps, orthophoto production, using models that are incomplete and discontinuous will eventually lead to wrong outcome.

Direct comparison of different models that represent the same area is usually used for morphologic tasks, such as change detection. The assumption here is that by super-imposing the two models the height difference value of the two models will give a qualitative analysis of topographic changes occurred between the two models' epochs. Erroneously, though both models are geographically registered to a certain coordinate reference system, zonal topographic inconsistencies as well as different data structures affect topographic ambiguity (Wilson et al., 2000). This reflects semantically on the correct representation and location of the described entities – resulting in geometric discrepancies. A correct positioning that is not based just on planar coordinates of the two models is essential in order to achieve a correct comparison process to avoid the modelling errors and to preserve their characteristics.

Integrating several models is required when these models represent different zones within a larger region and a continuous terrain relief representation is needed. Existing methods for digital models integration usually provide partial solution (Laurini, 1998). This is mainly because they address only the height dimension of the terrain relief without addressing its spatial characteristics and relative accuracy. Two of the more common techniques (depicted in Figure 1) are: 1. *Cut & Paste*, in which the more accurate model is placed on top the less accurate one; and, 2. *Height Smoothing*, were a mathematical algorithm is implemented on the height values along the seam line region of the two models. This algorithm uses a weighted average that is usually derived from the mutual accuracy of both sets. This translates to a smoothing outcome on the height from the seam line into both models within a certain threshold distance. An implementation of the height smoothing technique is given in Figure 2, which depicts two sources (i.e., models), which present different density and accuracy. The seam line is not visible within the merged area as well as no discontinuity in the terrain relief along it. Nevertheless, it is evident that the spatial morphology and topography are not preserved: a certain entity appears twice.

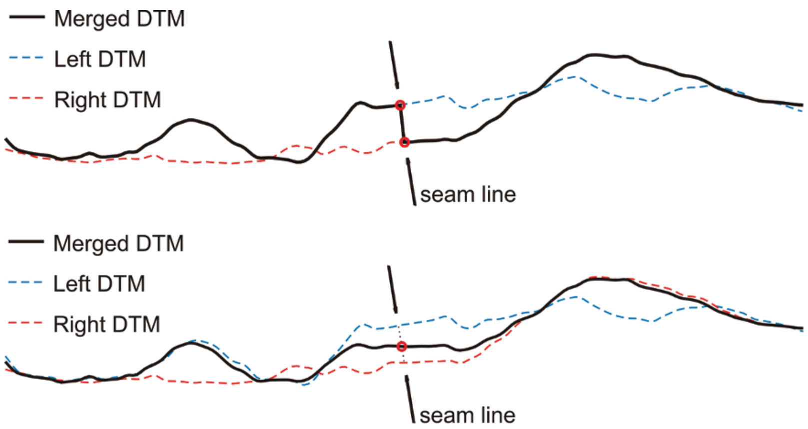


Figure 1. Cut & Paste (top) technique shows an evident seam line feature in the integrated model, while *Height Smoothing* (bottom) technique shows height alterations in the topography in the surroundings of the seam line.

In both techniques the integrated model will have no inner continuity or completeness of the terrain relief representation. Moreover, varied-scale discrepancies might exist among the different models. These discrepancies occur due to natural causes or human activities that took place during the data acquisition epochs; inherent errors occurring in the measurements or production stages (object modelling); different data structure each dataset presents, such as resolution, datum, detailing level, or accuracy (Hutchinson and Gallant, 2000). These factors present global-systematic and local-random errors, which reflect on different geometric discrepancy scales. The implementation of the two discussed techniques coerces a global estimation to best represent a uniform relation between the datasets. This will eventually lead to a wrong representation, and to ignoring local geometric trends. One of the common effects of ignoring the existing inter-relations might be the integration of different morphological entities, such as hills and valleys. This will produce wrong terrain relief representation, and as a result will alter the correct one. Consequently, a product that uses the integrated model will show inferior result in respect to using only one of the source data models. Thus, alternative techniques and algorithms that will preserve terrain continuity and completeness despite discrepancies that might exist among the different data sources are needed. The requirement of these algorithms is that they will ensure that the integrated model will be continuous in respect to the height values it represents, while preserving the topological completeness of the terrain relief objects.

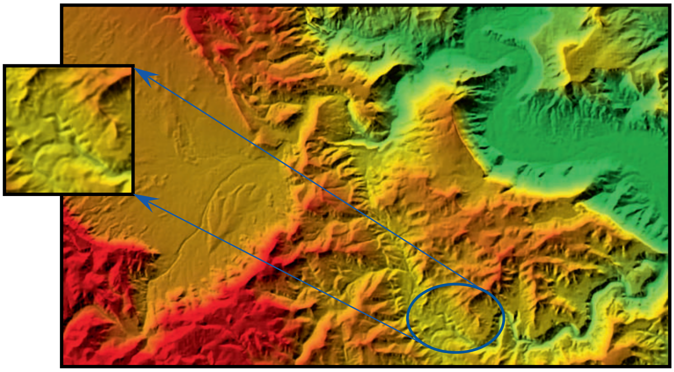


Figure 2. Height Smoothing integration outcome of two terrain relief models with different density and accuracy. Though the seam line is hard to detect it is evident that the spatial morphology and topography are not preserved as a certain entity appears twice.

3. Proposed Algorithms

In order to avoid the discussed complications when integrating terrain relief models, several alternative approaches and new algorithms are suggested in this chapter. These algorithms serve as the basis of establishing reliable and qualitative environmental control processes. As will be discussed in further detail, these algorithms deal with the reciprocal and overlapping region of the two integrated models. As opposed to the techniques discussed earlier, which did not or only globally analyzed the corresponding topography of both models, in these algorithms a local thorough investigation of the relative spatial correlations that exist between the models is required. This investigation will prevent distortions as well as an ambiguous and ill-defined modelling analysis. The chosen analysis mechanisms in each one of the suggested algorithms address the height representation of the terrain, as well as its spatial characteristics: topology and morphological structures. The first algorithm addresses mainly models with adjacent zones. This algorithm is aimed at achieving a continuous topological representation and correct structures of the terrain as represented in the merged DTM while taking into account the differences in both height field and planar location of terrain entities. The other two algorithms suggest a comprehensive solution for integrating models that have complete (or close to complete) overlapping areas that covers and represents the same area.

3.1. SPATIAL RUBBER SHEETING

This algorithm proposes a new conflation method, in which the integration of the overlapping region (referred to as the "rubber band") of two adjacent DTMs is performed (Katzil and Doytsher, 2005). The algorithm is aimed at achieving a continuous topological and "correct" morphological structures representation of the terrain. Based on homologous 3D polylines within the two adjacent DTMs, a seam line of the rubber bands is defined and thus a spatial 3D transformation for merging the rubber bands can be applied. The proposed algorithm facilitates an accurate 3D conflation and merging process of different DTMs into a unified DTM, while taking into account both the completeness and the continuity requirements. Following is a description of the five steps this algorithm consists of.

3.1.1. Global geometric correction

A global geometric correction is implemented on one of the adjacent DTMs by a three-dimensional affine transformation calculated using a given set of homologous point pairs. Using a given set of pairs of homologous points – left and right – $\{L_i, R_i\}$ respectively, a three-dimensional affine transformation is calculated and applied to the less accurate of the two adjacent DTMs, as well as to its corresponding points in the set of homologous point pairs. The source grid coordinate system of transformation is the inferior DTM and its target grid is the superior DTM in relation to their accuracy.

3.1.2. Seam line construction

This step is based on the given set of homologous point pairs. The seam line S of the two adjacent DTM datasets is constructed using a given set of homologous point pairs $\{L_i, R_i\}$ registering the two adjacent DTM datasets. The seam line is a polyline whose vertices S_i are a weighted (or un-weighted) arithmetic average of each homologous point pair $\{L_i, R_i\}$, as shown in Eq. (1) for the un-weighted arithmetic average. In addition to the seam line, two other polylines are defined. The first, S_L, is the polyline whose vertices are the points L_i of the homologous point pairs of the first DTM, with the other polyline S_R, defined by the vertices R_i on the second DTM.

$$S_i = \begin{pmatrix} {}_xS_i \\ {}_yS_i \\ {}_zS_i \end{pmatrix} = \frac{1}{2}\left(L_i + R_i\right) = \frac{1}{2}\left[\begin{pmatrix} {}_xL_i \\ {}_yL_i \\ {}_zL_i \end{pmatrix} + \begin{pmatrix} {}_xR_i \\ {}_yR_i \\ {}_zR_i \end{pmatrix}\right] \tag{1}$$

3.1.3. Rubber band construction

A rubber band is defined by a parallel polyline to the right or left of the seam line at a given distance D and the seam line itself. The distance D is the selected width for the spatial morphing, which is calculated as a function of DTM density. In the case of fusing two adjacent DTMs, two rubber bands R^L and R^R are defined. Rubber band R^L is defined by the polyline B^L parallel to the left of seam line S^L at the given distance D, and R^R is defined by the polyline B^R parallel to the right of seam line S^R at distance D, as shown in Figure 3. The rubber band width, when constructed as above, is not constant and varies around vertices where the polyline direction changes by more than 180°.

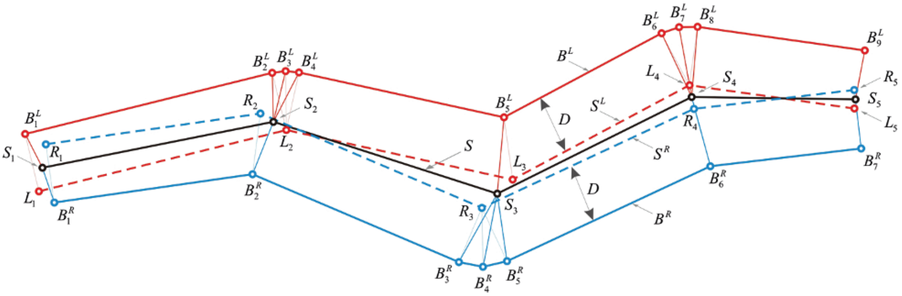


Figure 3. A rubber band defined by a parallel polyline to the right or left of the seam line at a given distance D, where the two rubber band quadrilateral grids are defined: one on the source DTM, and the other on the target DTM.

3.1.4. Local geometric correction

This correction is achieved by morphing the rubber band of each of the adjacent DTMs to the seam line on the merged DTM. The local geometric corrections are performed by spatial morphing of source rubber bands R^L and R^R, constructed as described in 3.1.3 and shown in Figure 3, into target rubber bands R'_L and R'_R which share the same seam line – S. The spatial morphing of each rubber band is performed by splitting the rubber band into a set of quadrilateral and triangle components whose vertices are those of the rubber band, and by bilinear interpolation for calculating the correction of each DTM cell within the quadrilateral.

3.1.5. Piecewise rubber sheeting

Imagine stretching a DTM band as if it was made of rubber. This is done by stretching (spatial morphing) each of the quadrilateral and triangle components participating in the assembly of the rubber band into their target position. The target position of each component is defined by replacing the edge lying on the seam line (S^L or S^R) with the corresponding segment of the target seam line S. In this case, the correction ΔP_i of the quadrilateral nodes used to transform the quadrilateral from its source to the target position is calculated as described in Eq. (2).

$$\begin{aligned} S_i &= L_i + \Delta L_i \;\Rightarrow\; \Delta L_i = S_i - L_i \\ S_i &= R_i + \Delta R_i \;\Rightarrow\; \Delta R_i = S_i - R_i \end{aligned} \qquad (2)$$

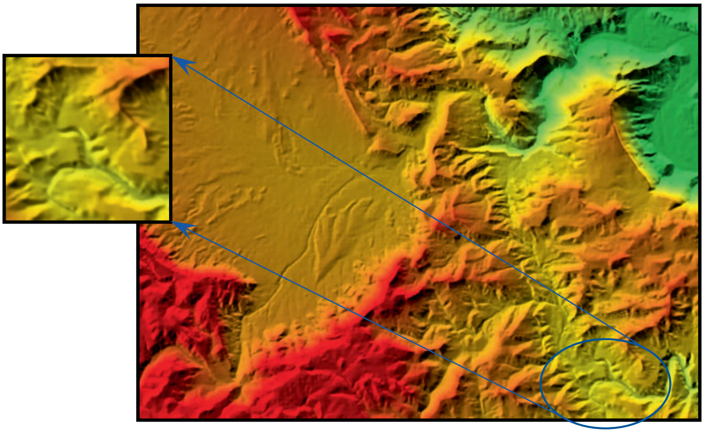


Figure 4. Result of applying the suggested spatial rubber-sheeting algorithm: no seam line is visible; terrain's topology and morphological structures are preserved, therefore no entity appears twice.

The correction ΔP_i to each of the quadrilateral nodes lying on the seam line is defined by the correction to the node that would transform it to the corresponding vertex of the target seam line. The correction ΔP_i is a three dimensional entity, expressing both the topology and continuity requirements. Figure 4 shows the result of applying this algorithm. Compared to Figure 2, which presents the results of *Height Smoothing*, it is shown that this algorithm provides a solution to the morphologic and topologic problems discussed earlier as well as to the height field. In the region enlargement, it is clear that the terrain feature, which is duplicated by applying *Height*

Smoothing, is complete with no discontinuities in the result of applying the suggested spatial rubber-sheeting algorithm.

3.2. PIECEWISE SPATIAL CONFLATION

This algorithm deals with the overlapping region of two models assuming the existence of a set of homologous point pairs between the two DTMs (Katzil and Doytsher, 2006). In this approach, the set of homologous point pairs is automatically extracted using the Scale Invariant Feature Transform (SIFT) algorithm described in Lowe (2004). SIFT is a methodology for finding corresponding points in a set of images. The method designed to be invariant to scale, rotation, and illumination. This methodology is applied to a set of shaded relief images of the source overlapped DTMs. The shaded relief images are calculated using the algorithm described in Katzil and Doytsher (2003). The suggested algorithm consists of the following three steps.

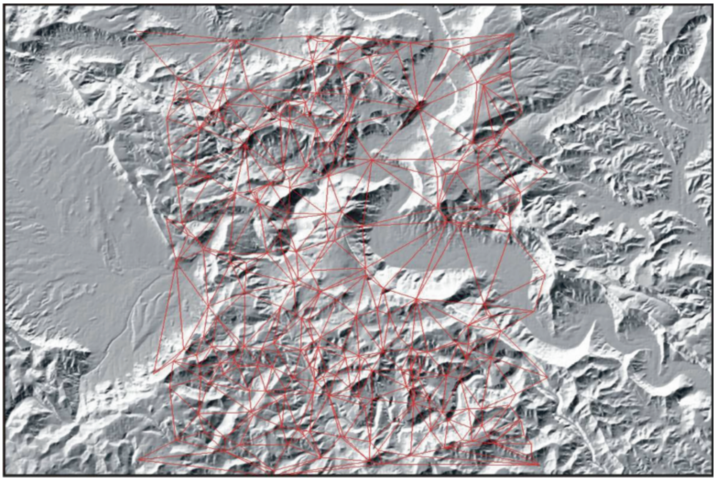


Figure 5. Homologous point pairs triangulation.

3.2.1. Global geometric correction

This is a similar process to the global geometric correction described in Section 3.1.1, in which one of the adjacent DTMs (the one with inferior accuracy) is transformed while using a three dimensional affine transformation that is calculated using a given set of homologous point pairs.

3.2.2. Homologous point pairs triangulation

A triangulation (triangular network) is constructed in the overlapping region of both DTMs based on the given set of homologous point pairs. The triangulation is built by applying Constrained-Delaunay-Triangulation (CDT) on one part of the set of the homologous point pairs (depicted in Figure 5).

Based on the homologous point-pairs triangulation in the two source DTMs, a triangulation is constructed in the overlapping region to be used as the target coordinate system. Each target triangle is a linear combination of the two homologous triangles pair. The linear combination takes into account both the accuracy of each source DTM and the distance from the sides of the overlapping region, resulting in a target triangulation constructed by applying a linear combination to each of the homologous point pairs.

3.2.3. Local geometric morphing

The source location of each of the DTM grid points within each of the triangles of the target coordinate system is calculated for both source homologous triangles using iso-parametric triangle coordinate system. Then, the height of these source points is measured from the source DTMs, while the target height is calculated using the linear combination with weights calculated for the source points.

The geometry of a triangle is specified by the location of its three corner nodes on the {x, y} plane. The nodes are labelled 1, 2, and 3, while traversing the sides in counter clockwise fashion. The location of a triangle corner nodes are defined by their Cartesian coordinates: $\{x_i, y_i\}$ for i = 1, 2, and 3. The area A of the triangle, given by Eq. (3), is a signed quantity, positive if the corners are numbered in cyclic counter clockwise order.

$$2A = \begin{vmatrix} 1 & 1 & 1 \\ x_1 & x_2 & x_3 \\ y_1 & y_2 & y_3 \end{vmatrix} = (x_2 y_3 - x_3 y_2) + (x_3 y_1 - x_1 y_3) + (x_1 y_2 - x_2 y_1) \quad (3)$$

The target height is calculated for each of the target grid points using the homologous triangles containing that grid point. Using the plane coordinates {x, y} of each grid point, the triangular coordinates $\{t_1, t_2, t_3\}$ are calculated for that point from the destination triangle as shown in Eq. (4). Then, these triangular coordinates – $\{t_1, t_2, t_3\}$ – are used to calculate the height of the source points in each of the source triangles – $h_L(x_L, y_L)$ and $h_R(x_R, y_R)$ applying the triangular interpolation of each of the source triangles. Given these source heights $h_L(x_L, y_L)$ and $h_R(x_R, y_R)$ the target height is calculated using a weighted average. The chain of calculations needed in order to provide the target height is presented in Eq. (5). Figure 6 presents the result of applying this algorithm aiming at fusing two DTM datasets.

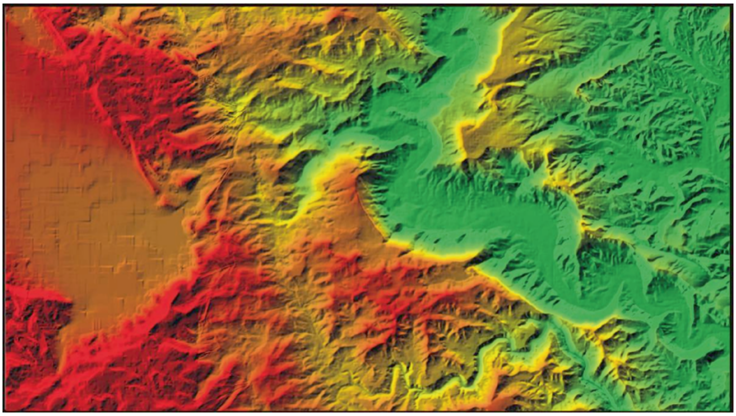


Figure 6. Fusion of two DTM datasets by applying the proposed piecewise spatial conflation showing smooth transition from one source DTM to the other, while preserving the terrain's topology and morphological entities.

$$\begin{bmatrix} t_1 \\ t_2 \\ t_3 \end{bmatrix} = \frac{1}{2A} \begin{bmatrix} (x_2 y_3 - x_3 y_2) & (y_2 - y_3) & (x_3 - x_2) \\ (x_3 y_1 - x_1 y_3) & (y_3 - y_1) & (x_1 - x_3) \\ (x_1 y_1 - x_2 y_1) & (y_1 - y_2) & (x_2 - x_1) \end{bmatrix} \cdot \begin{bmatrix} 1 \\ x \\ y \end{bmatrix} \tag{4}$$

$$\begin{aligned} h_L &= h_L(x_L, y_L) = f_L(t_1, t_2, t_3) \\ h_R &= h_R(x_R, y_R) = f_R(t_1, t_2, t_3) \end{aligned} \tag{5}$$

$$h = \frac{h_L \cdot \bar{P}_L + h_R \cdot \bar{P}_R}{\bar{P}_L + \bar{P}_R}$$

3.3. HIERARCHICAL MODELLING AND INTEGRATION

This algorithm suggests the division of the DTM models' mutual coverage area into homogeneous separate hierarchical working levels (Dalyot and Doytsher, 2006). A two-stage monitoring process involving spatial registration and matching is implemented. First, a registration is carried out on a large region within the overlapping area, and only then a constrained matching process is implemented independently and separately on local parts within each of these regions. This enables to properly define, model and store the complete spatial local interrelations of the entire data presented in both models – without coercing a single global one on the entire area. The suggested algorithm consists of the following three steps.

3.3.1. Registration

The registration process (i.e., initial hierarchical level) on both models is carried out while relying on sets of unique selective conjoint features. Distinctive interest points in the topography were identified according to a novel extraction mechanism of surface-derived geomorphologic maxima features. This mechanism used four perpendicular second degree polynomials {i} with coefficients {$a_{(i)}$, $b_{(i)}$, and $c_{(i)}$} around each grid-point within a threshold distance {L} – as depicted in Eq. (6). Calculating the area in the vertical dimension of each polynomial and validating its three coefficients in relation to a certain threshold gives an adequate topologic criterion regarding its behaviour in respect to its surroundings.

$$Z_{(i,j)} = a_i + b_i \cdot L_{(i,j)} + c_i \cdot L^2_{(i,j)} \tag{6}$$

The registration process implemented on the extracted sets of homologues points relies on the Hausdorff distance algorithm (Huttenlocher et al., 1993). Given two sets of points A = {a_1,…, a_m} and B = {b_1,…, b_n}, the forward Hausdorff distance – h – measures the degree of mismatch between the two sets, as defined in Eq. (7). This equation identifies point a ∈ A that is farthest from any point in B, and then measures the distance from a to its nearest neighbour b in B. This value is later statistically evaluated by the correspondence it obtains between the remainder points in sets A and B. This Euclidean spatial distance gives an initial estimation of the global reciprocal working reference frame, i.e., systematic discrepancy modelling value. The output is a vector-set of preliminary registration values for the entire area chosen, which is used as a-priori data for the second hierarchical level – the matching process.

$$h(A,B) = \max_{a \in A} \min_{b \in B} \| a - b \| \tag{7}$$

3.3.2. Matching and modelling

The registration value enables the implementation of an adequate local matching process between the two models. An Iterative Closest Point (ICP) (Besl and McKay, 1992) matching is implemented on homologous corresponding local data frames, i.e., sub-regions, which are divided from the complete mutual coverage area. It is obvious that by matching small frames it is possible to achieve more effective monitoring and modelling of local random discrepancies, since inherent ‘errors’, exist between the models. Monitoring – and then modelling – these errors is achieved by minimizing the target function, i.e., extracting the best possible correspondence between the sub-regions. The geometric target function is defined by a spatial six-parameter transformation model: three translations and three rotations.

A geometrically constrained ICP algorithm between two homologous local frames is implemented, which assures that the nearest neighbour search criterion is correctly achieved. In addition, they verify that each of the paired-up points – one in each model's frame – is the closest one exists, as well as having the same relative topography surroundings. It is worth noting that this algorithm is compatible in matching gridded databases – as well as non-gridded ones (such as in the case of datasets acquired by ALS).

Implementing local matching processes on zonal data frames results in an output that consists of matching parameters sets, which are equivalent to the number of matched frames. Each set includes six geo-registration parameters that best describe the relative spatial geometry of the mutual homologous frames matched. Since this process yields better localized geo-registration definition, it ensures matching continuity on the entire area (as opposed to matching the entire data in a single matching process). These geo-registration sets can be described as elements stored in 2D matrix: each set is stored in the cell that corresponds spatially to the frame it belongs to, as depicted in Figure 7. This matrix is actually analogues to a 'geo-registration DTM', where each grid node (cell) corresponds to the geometric centre of local frames. This 2D matrix will comprise as the bases for implementing precise geo-oriented qualitative analysis capabilities between these DTM models.

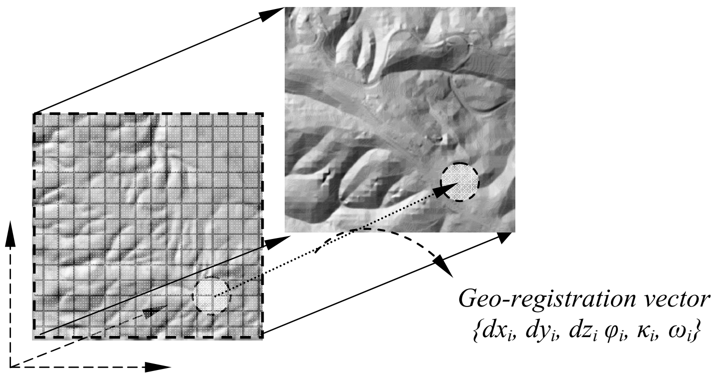


Figure 7. Geo-registration matrix (superimposed on-top the left source DTM) where each cell stores the geospatial relations, i.e., transformation, between mutual coverage frames.

3.3.3. Integration

An integration process involves interpolation on the values stored in the geo-registration matrix in order to achieve the source models given resolution. An integration process is designated to produce a new (integrated) model that is derived from the data stored in the source models as well as from their spatial correlations. The integrated model has to preserve both models morphology and topology. Compared to coercing single global transformation estimation, using localized interpolation yields more reliable and correct parameters calculation that describe both models' local mutual correlations.

Conceptually, the integrated dataset is spatially located 'between' the models used for its calculation. Thus, two interpolation 'directions' are implemented: (i) Horizontal – between the matrix cells values. This calculation is needed to calculate the exact six-parameters required for transforming each point stored in one model to its analogous location in the other. The horizontal interpolation uses novel interpolation concept that uses quaternion domain on the rotation values (Shoemake, 1985), and bi-directional 3rd degree parabolic interpolation on the translation values (Doytsher and Hall, 1997); (ii) Vertical – the six-parameters calculated via the horizontal interpolation represent the correlation of a certain point in one model to its location in the other. As mentioned before, the integrated dataset 'lies' between the given models. So, a weighted interpolation on these six-parameters is therefore needed. The weight is derived from the mutual accuracy of both models. This means that the integrated database will 'lay' closer to the more accurate database. The vertical interpolation uses SLERP interpolation on the rotation values (Shoemake, 1985), and linear interpolation on the translation values. Consequently, for each node in the model a new height value is calculated, which takes into account local trends and inter-relations that exist among the models, which are modelled (and stored) in the geo-registration matrix. Figure 8 depicts a shaded-relief representation of a DTM, which is a result of integration according to two approaches: left – the common *Copy & Paste* mechanism; right – the proposed hierarchical modelling. It is clear that while the left DTM presents clear truncated morphological entities on both sides of the seam line, the right one is continuous and complete within the coverage area.

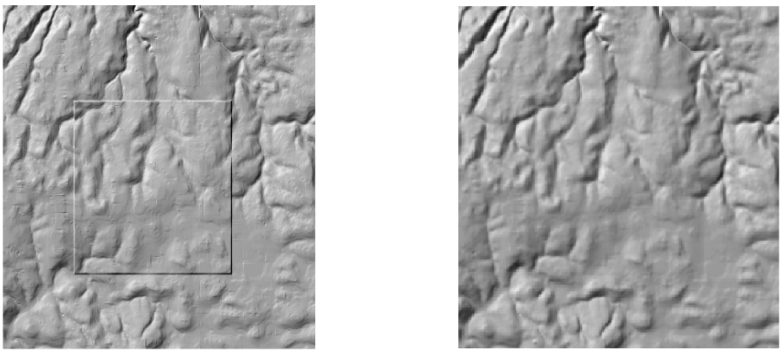


Figure 8. Integrated DTM that is the result of two approaches: common *Copy & Paste* mechanism (left), and hierarchical modelling (right).

4. Establishing Reliable and Qualitative Environmental Control Processes

In the previous section, the survey of several novel integration processes was presented. Several examples were also given in that section, which further validates their correctness, qualities, robustness, and above all – analysis resolutions to the problems discussed in Section 2. In this section additional examples will be given, which further validate the algorithms' potential capabilities in monitoring environmental processes.

4.1. LANDSLIDE DETECTION

A 25 × 25 km test area near Mt. Carmel in the north of Israel was chosen. One source model was a 25 m resolution DTM produced by digitizing 1:50,000 contour maps 20 years ago. The other source model was an ALS simulated model, which used a photogrammetric DTM produced 5 years ago, representing a density of approximately 0.2 points per 1 m^2, while covering an area of approximately 2 × 2 km. This simulation enables to compare sparse grid DTM versus dense TIN, with each describing the test area topography at different epochs (approximately 15 years apart).

A landslide simulation based on a 3rd degree polynomial was implemented on the ALS simulation model on the east-south side of the ridge covering more than 400 × 600 m. Landslides are categorized by the topography and its derived geotechnical constraints (soil type, surface shear strain, and more). The landslide's failure mechanism simulated here is classified as a "generalized translation failure", where the critical clip surface is a single straight line with deep or shallow failure (Baker, 2003).

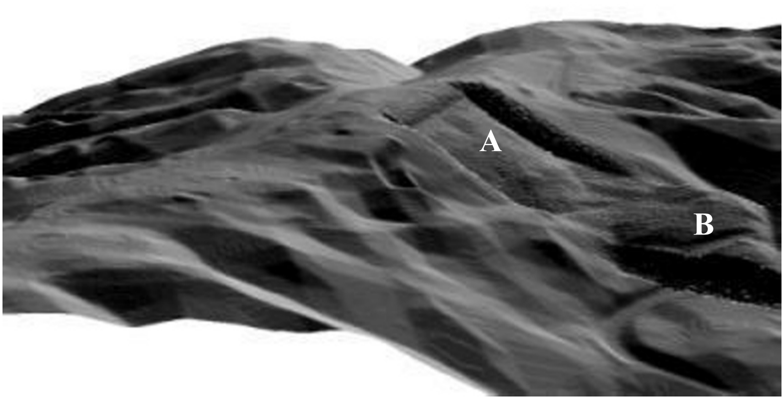
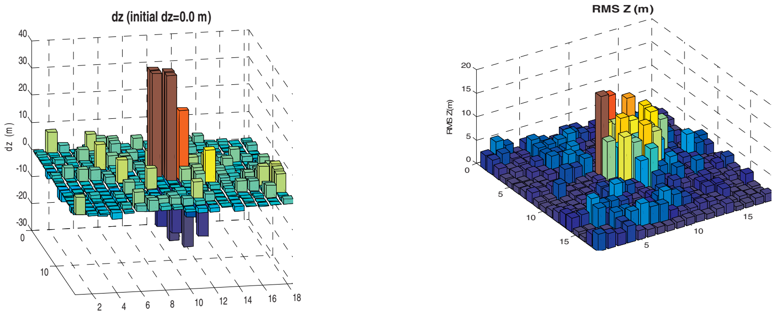


Figure 9. Shaded relief representation of the translation landslide simulation implemented on the ALS model: A denotes displaced area; B denotes accumulated debris area.

The maximal height change in the displaced area is approximately 30 m, while the maximal height change value in the accumulated debris area is approximately minus 40 m. A noise matrix was added as well. The outcome of this landslide simulation is depicted in Figure 9.

The hierarchical modelling and integration algorithm was implemented (Dalyot et al., 2008a). The mutual coverage area was divided to frames of 100 × 100 m, in which the ICP matching process was implemented on each one separately and independently. The assumption is that all mutual frames should be matched accurately, except for frames affected by the landslide. This is validated by the six-transformation values extracted for the frames. Figure 10 is a 3D representation of the dz values extracted, and a statistical evaluation value (rms-z) of the complete six-transformation values extracted, in which the affected landslide region can be identified clearly by the high bar values within the low ones.



Translation in dz

rms-z statistical analysis

Figure 10. 3D representation of dz and rms-z values for each frame (all values in Z axis are in meters).

4.2. CHANGE DETECTION

Two DTMs were used to evaluate the effectiveness of the hierarchical modelling in identifying morphological changes (Figure 11). The DTMs

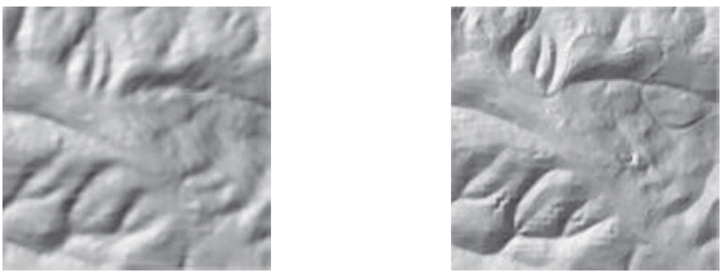


Figure 11. DTMs used for the change detection analysis: digitized 25 m – presented here in a 5 m interpolation (left), and photogrammetric 4 m (right).

covered approximately 2 × 2 km, were produced 20 years apart from each other, and presented resolution differences. The mutual coverage area was divided into frames of 100 × 100 m, in which the ICP matching process was implemented on each one separately and independently.

Figure 12 depicts the outcome of the proposed procedure (left) – as well as the outcome of the default mechanism that is based solely on the mutual coordinate reference frames, i.e., super-imposition (right). The figures depict a statistical evolution value – rms-z (mentioned in Section 4.1). As can be seen, rms-z identifies precisely areas with morphological changes (high values).

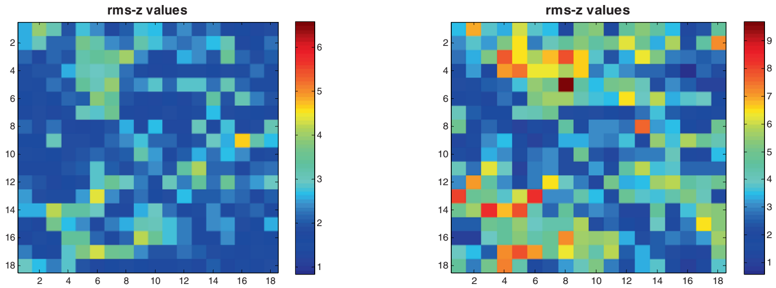


Figure 12. Statistical value rms-z for all frames calculated via the hierarchical modelling (left), and via a super-imposition mechanism (right). Colour bar values in meters.

The rms-z values calculated via the proposed modelling presents better correspondence: around 1–2 m with a maximum value of 5 m, whereas in the default mechanism it reaches 10 m. Close inspection of Figures 11 and 12 shows that high rms-z values correspond to morphologic inconsistencies, whereas the default mechanism presents more noise with no exact correspondence. For example this is noticeable in the channel area on the low-left corner, where several channels appear only in the 4 m DTM. Similarly this is noticeable in the mountainous area in the upper-part of the area modified in the 4 m resolution DTM as a result of a new paved road.

4.3. HYBRID MULTI-GEOSPATIAL TERRAIN MODELLING

Figure 13 (right) depicts a shaded-relief representation of a hybrid DTM, which is a result of integrating two models: one is a grid DTM produced 15 years ago presenting 25 m resolution and covering approximately 25 × 25 km. The other is an irregular ALS campaign (after filtering) produced 2 years ago covering proximally 2 × 2 km (Dalyot et al., 2008b). The ALS model is situated on the lower-left corner of the DTM. With minor modifications the ICP matching process can be used to any data structure and data resolution – as implemented here: DTM and ALS models. The shaded relief representation of the integrated dataset shows continuous, unified and complete terrain relief representation. Moreover, it is clear that no seam line is visible, while the hybrid model preserves the topology and morphological entities – as presented in the DTM and ALS models.

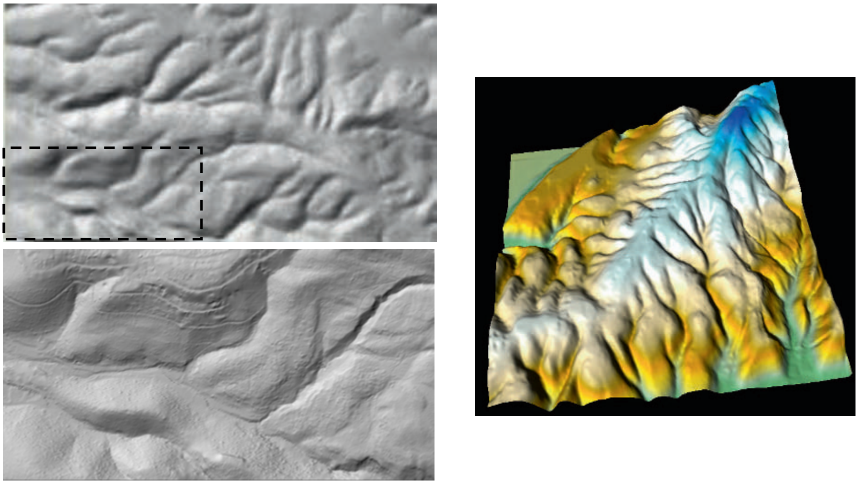


Figure 13. DTM (top-left) and ALS (bottom-left) models showing distinctive differences in level of detailing and accuracy (mutual coverage area is denoted by a dashed rectangle). The hybrid model (right, rotated 90° counter clockwise) produced by integrating these models (mutual coverage region on lower-right area).

5. Conclusions

Standard on-the-shelf GIS software packages, which are designed for geo-spatial modelling and visualization of two or more terrain relief models, mostly use those models' mutual coordinate reference systems for these tasks. In contrast, three integration and comparison algorithms were introduced, suggesting novel modelling mechanism that are based on the topologic and morphologic information stored in those models. These algorithms used the existing mutual local correlations between the models – instead of coercing a singular global one. These models can be implemented on models that are adjacent to each other – or having mutual overlapping coverage area.

Several experimental analysis results were presented: change detection, comparison and integration. All proved to be accurate, robust, effective, and relatively fast, introducing new geospatial analysis capabilities to be carried out on digital terrain models of various sources. In all three algorithms reviewed, the terrain relief representation of the integrated model was unified and continuous. The terrain preserved the inner geometric characteristics and topologic relations (morphology) thus, preventing any representation distortions. Moreover, these algorithms have no dependency on the source models' resolution, density, datum, format and data structure. These new approaches present a step toward merging terrain data from diverse sources into a single, coherent DTM, enabling the creation of a seamless DTM database. Furthermore, it was shown that these novel algorithms can be used for various geo-spatial tasks that demonstrated their usefulness and applicability for establishing a reliable, qualitative and robust tool for environmental control processes.

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ADVANCED CLUSTERING ANALYSIS FOR ENVIRONMENTAL INDICATORS

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Abstract. Maps are used in many application areas to support the visualization and analysis of geo-referenced data. The geometry used in those maps is usually associated with the administrative subdivisions of the regions, disregarding the purpose of the analysis. Another common drawback is that traditional classification methods for data analysis, used for example in Geographic Information Systems, divide the data in a pre-defined number of classes. This can lead to a situation where a class integrates values that are very different from each other and that do not allow the identification of the main differences that can exist between regions. This chapter presents a different approach for geo-referenced data analysis that is based on clustering analysis. Through a clustering process it is possible to analyse a specific data set with a map, employing a Space Model, which suits the purposes of such an analysis. Space Models are new geometries of the space that are created to emphasize particularities of the analysed data.

Keywords: Clustering, Data Mining, Environmental Indicators, Space Models.

1. Introduction

Clustering is the process of grouping a set of objects into clusters so that objects within a cluster have high similarity with each other, but are as

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dissimilar as possible to objects in other clusters (Han and Kamber, 2001). Clustering has been used in a wide range of applications, like grouping sets of clients, products or patients that present a similar behaviour attending to some characteristics. This chapter presents another use of clustering techniques, namely in the creation of Space Models.

Space Models represent divisions of the geographic space in which the several geographic regions are grouped according to their similarities with respect to a specific indicator. Space Models represent natural divisions of the geographic space based on some geo-referenced data.

This chapter addresses the analysis of data, in this case environmental indicators, by the Space Models identified by the STICH (*Space Models Identification Through Hierarchical Clustering*) algorithm. The identified Space Models, which integrate several clusters, point out particularities of the analysed data, like regions that significantly differ from one another.

The following sections, in outline, include: (i) a brief overview of the concept of environmental security and the associate environmental indicators; (ii) an overview of clustering, its methods and techniques, and the proposed STICH algorithm; (iii) Space Models and their characteristics; (iv) the analysis of indicators using the proposed Space Models; (v) a conclusion with some remarks about the proposed approach.

2. Environmental Security and Environmental Indicators

There is no simple and broadly recognized definition of the term "environmental security" (cf. Barnett, 2001). We will refer to "environmental security" meaning the complex of concerns that relate environmental factors to threats to peace.

The visualization of environmental indicators is a major issue of environmental security, i.e., of properties of the environment that may indicate a threat to peace. Typical geo-referenced environmental indicators are related to the supply of fresh water, deforestation and desertification, waste disposal, energy, food, health protection factors, and population density (King, 2000). According to King (2000), there is a strong statistical correlation between such indicators and political stability. Therefore, it is of crucial importance to be able to see on maps the concrete distribution and levels of environmental indicators of regions where security is endangered.

However, we will present our clustering approach with examples from stable European regions, since we will focus on the clustering methodology, and do not pretend to provide an independent security analysis of any region.

3. Clustering Analysis

Clustering is the process of grouping a set of objects into clusters so that objects within a cluster have high similarity with each other, but are as dissimilar as possible to objects in other clusters. Thus, clustering is a discovering process that identifies homogeneous groups of segments in a dataset (Zaït and Messatfa, 1997; Jain et al., 1999; Grabmeier, 2002). Dissimilarities are measured based on the attribute values describing the objects (Han and Kamber, 2001). Clustering, as a data mining technique (Cios et al., 1998), has been widely used to find groups of customers with similar behaviour or groups of items that are bought together, allowing the identification of the clients' profile (Berry and Linoff, 2000). This chapter presents another use of clustering techniques, namely in the analysis of environmental indicators through the creation of Space Models.

3.1. PRINCIPLES

Two of the well-known types of clustering algorithms are based on partitioning and hierarchical methods. These methods and two corresponding algorithms are presented next.

3.1.1. Partitioning methods

A partitioning method constructs a partition of n objects into k clusters where $k \leq n$. Given k, the partitioning method creates an initial partitioning and then, using an iterative repositioning technique, it attempts to improve the partitioning by moving objects from one cluster to another. The clusters are formed to optimize an objective partitioning criterion, such as the distance between the objects. A good partitioning must aggregate objects such that objects in the same cluster are similar to each other, whereas objects in different clusters are very different (Han and Kamber, 2001).

One of the well-known partitioning clustering algorithms is the *k-means* algorithm, where each cluster is represented by the mean value of the objects in the cluster. The *k-means* algorithm takes as input a parameter k that represents the number of clusters in which the n objects of a dataset will be partitioned. The obtained division tries to maximize the *Intracluster* similarity (a measurement of the similarity between the objects inside a cluster) and minimize the *Intercluster* similarity (a measurement of the similarity between different clusters), which means a high similarity between the objects inside a cluster and a low similarity between objects in different clusters. This similarity is measured looking at the centres of gravity (centroids) of the clusters, which are calculated as the mean value of the objects inside them.

Given the input parameter k, the *k-means* algorithm works as follows (MacQueen, 1967). Randomly select k objects, each of which initially represents the cluster centre or the cluster mean. Assign each of the remaining objects to the cluster to which it is the most similar, based on the distance between the object and the cluster mean. Compute the new mean (centroid) of each cluster.

After the first iteration, each cluster is represented by the mean calculated in step 3. This process is repeated until the criterion function converges. The squared-error criterion is often used, which is defined as:

$$E = \sum_{i=1}^{k} \sum_{j=1}^{l} o_j \in C_i \left| o_j - m_i \right|^2 \tag{1}$$

where E is the sum of the square-error for the objects in the dada set, l is the number of objects in a given cluster, o_j represents an object, and m_i is the mean value of the cluster C_i. This criterion intends to make the resulting k clusters as compact and as separate as possible (Han and Kamber, 2001).

One of the disadvantages of this method is the necessity for users to specify k in advance. This method is also not suitable for discovering clusters with non-convex shapes or clusters of very different sizes (Han and Kamber, 2001).

3.1.2. Hierarchical methods

Hierarchical methods perform a hierarchical composition of a given set of data objects. It can be done bottom-up (Agglomerative Hierarchical methods) or top-down (Divisive Hierarchical methods). Agglomerative methods start with each object forming a separate cluster. Then they perform repeated merges of clusters or groups close to one another until all the groups are merged into one cluster or until some pre-defined threshold is reached (Han and Kamber, 2001). These algorithms are based on the inter-object distances and on finding the nearest neighbours objects. Divisive methods start with all the objects in a single cluster and, in each successive iteration, the clusters are divided into smaller clusters until each cluster contains only one object or an end condition is verified (Karypis et al., 1999).

An important example of an agglomerative method is the *k-nearest neighbour* algorithm. Each step of this clustering algorithm merges the k records that are most similar into a single cluster.

The *k-nearest neighbour* algorithm uses a graph to represent the links between the data objects. This graph allows the identification of the several k objects most similar to a given data item. Each node of the *k-nearest neighbour* graph represents a data item. An edge exists between two nodes p and q if q is among the k most similar objects of p, or if p is among the k

most similar objects of q. Figure 1 presents the *3-nearest neighbours* graph of several data items[1].

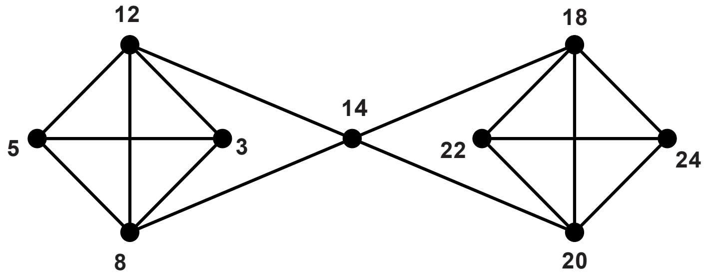

Figure 1. An example of the *k-nearest neighbour* algorithm.

3.2. THE STICH ALGORITHM

The *Space Models Identification Through Hierarchical Clustering* (STICH) algorithm (Santos et al., 2005) is based on the *k-nearest neighbour* algorithm. However, the principles defined for STICH try to overcome some of the limitations of the *k-nearest neighbour* approach, namely the need to define a value for the input parameter k. This value imposes restrictions to the maximum number of members that a given cluster can have.

STICH uses an iterative process in which no input parameters are required. Another characteristic of STICH is that it produces several usable Space Models (explained in more detail in next section), one at the end of each iteration of the clustering process. As a hierarchical clustering algorithm with an agglomerative approach, STICH starts to assign each object in the dataset to a different cluster. The clustering process begins with as many clusters as objects in the dataset, and ends with all the objects grouped into the same cluster.

The approach followed in STICH is:

1. For the dataset, calculate the Similarity Matrix of the objects, which is the matrix of the Euclidean distances between every pair of objects in the dataset.
2. For each object, identify its minimum distance to the dataset (the value that represents the distance between the object and its 1-nearest neighbour).

[1] Note that the central node has four neighbors, because of the identical distances of two of them.

3. Calculate the median[2] of all the minimum distances identified in the previous step.
4. For each object, identify its k-nearest neighbours, selecting the objects that have a distance value less or equal than the median calculated in step 3. The number of objects selected, k, may vary from one object to another.
5. For each object, calculate the average c of its k-nearest neighbours.
6. For each object, verify in which clusters it appears as one of the k-nearest neighbours and then assign this object to the cluster in which it appears with the minimum k-nearest neighbours' average c. In case of tie, an object that appears into two clusters with equal average c, the object is assigned to the first cluster in which it appears in the Similarity Matrix.
7. For each new cluster, calculate its centroid.

This process is iteratively repeated until all the objects are grouped into the same cluster. Each iteration of STICH produces a new Space Model, with decreasing number of clusters, which can be used for different purposes. For each Space Model, a quality metric is calculated based in the difference of the Intracluster and Intercluster similarities (Equation 2).

$$ModelQuality = \left|Intracluster - Intercluster\right| \quad (2)$$

The *Intracluster* indicator is calculated as the sum of all distances between the several objects in a given cluster (l represents the total number of objects in a cluster) and the mean value (m_i) of the cluster (C_i) in which the object (o_j) reside. The total number of clusters identified in each iteration is represented by t (Equation 3).

$$Intracluster = \sum_{i=1}^{t}\sum_{j=1}^{l} o_j \in C_i \left|o_j - m_i\right| \quad (3)$$

The *Intercluster* indicator is calculated as the sum of all distances existing between the centres of all the clusters identified in a given iteration (Equation 4).

[2] The median is used instead of the average, since the average can be negatively influenced by outliers.

$$Intercluster = \sum_{i=1}^{t} \left(\sum_{\substack{j=1 \\ j \neq i}}^{t} \left| m_i - m_j \right| \right) \tag{4}$$

The *ModelQuality* metric can be used by the user in the selection of the appropriate Space Model for a given task. However, it is on the minimum value of this metric that we found the STICH outliers model, in the case outliers exist in the dataset (Figure 2). In the beginning of the clustering process the *Intracluster* similarity value is low, because of the high similarity between the objects inside the clusters, and the *Intercluster* similarity value is high, because of the low similarity between the several clusters. As the process proceeds, the *Intracluster* value increases and the *Intercluster* value decreases. The minimum difference between these two values means that the objects are as separate as possible, considering a low number of clusters. After this point, the clustering process forces the aggregation of all the objects into the same cluster (the stop criterion of agglomerative hierarchical clustering methods).

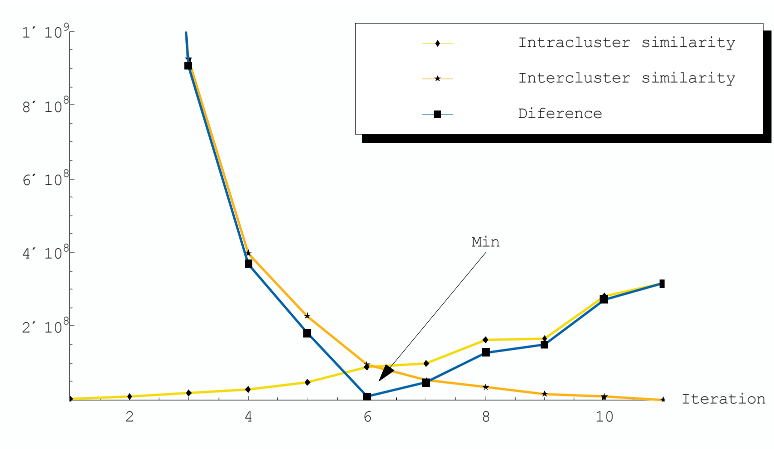

Figure 2. Intracluster similarity vs. *Intercluster* similarity.

One example of the use of STICH, step by step, is presented in Figure 3 for a data set including the values 3, 5, 8, 12, 14, 18, 20, 22 and 24.

1st. Iteration

K-nearest neighbours

		C1	C2	C3	C4	C5	C6	C7	C8	C9
		3	5	8	12	14	18	20	22	24
C1	3	0	2	5	9	11	15	17	19	21
C2	5	2	0	3	7	9	13	15	17	19
C3	8	5	3	0	4	6	10	12	14	16
C4	12	9	7	4	0	2	6	8	10	12
C5	14	11	9	6	2	0	4	6	8	10
C6	18	15	13	10	6	4	0	2	4	6
C7	20	17	15	12	8	6	2	0	2	4
C8	22	19	17	14	10	8	4	2	0	2
C9	24	21	19	16	12	10	6	4	2	0
Min. Distance		2	2	3	2	2	2	2	2	2
Median										2
Average		2	2		2	2	2	2	2	2

Identified Clusters

C1	3	5	
C2	5	3	
C3	8		
C4	12	14	
C5	14	12	
C6	18	20	
C7	20	18	22
C8	22	24	
C9	24	22	

Resulting Clusters			*Centroid*	*IntraCluster*	*InterCluster*
C1	3	5	4	2	66
C3	8		8	0	50
C4	12	14	13	2	40
C6	18	20	19	2	40
C7	22		22	0	46
C8	24		24	0	54
				6	**296**
				ModelQuality	**290**

2nd. Iteration

K-nearest neighbours

		C1	C2	C3	C4	C5	C6
		4	8	13	19	22	24
C1	4	0	4	9	15	18	20
C2	8	4	0	5	11	14	16
C3	13	9	5	0	6	9	11
C4	19	15	11	6	0	3	5
C5	22	18	14	9	3	0	2
C6	24	20	16	11	5	2	0
Min.Dist.		4	4	5	3	2	2
Median							3,5
Average					3	2,5	2

Identified Clusters

C1	3	5		
C2	8			
C3	12	14		
C4	18	20	22	
C5	18	20	22	24
C6	22	24		

Resulting Clusters			*Centroid*	*IntraCluster*	*InterCluster*
C1	3	5	4	2	47
C2	8		8	0	35
C3	12	14	13	2	30
C4	18	20	19	2	36
C5	22	24	23	2	48
				8	**196**
				ModelQuality	**188**

3rd. Iteration

K-nearest neighbours

		C1	C2	C3	C4	C5
		4	8	13	19	23
C1	4	0	4	9	15	19
C2	8	4	0	5	11	15
C3	13	9	5	0	6	10
C4	19	15	11	6	0	4
C5	23	19	15	10	4	0
Min.Dist.		4	4	5	4	4
Median						4
Average		4	4		4	4

Identified Clusters

C1	3	5	8	
C2	8	3	5	
C3	12	14		
C4	18	20	22	24
C5	22	24	18	20

Resulting Clusters					*Centroid*	*IntraCluster*	*InterCluster*
C1	3	5	8		5,3	5,3	23,3
C2	12	14			13,0	2,0	15,7
C3	18	20	22	24	21	8,0	23,7
						15,3	**62,7**
						ModelQuality	**47,3**

4th. Iteration

K-nearest neighbours

		C1	C2	C3
		5,3	13	21
C1	5,3	0	7,7	15,7
C2	13	7,7	0	8
C3	21	15,7	8	0
Min.Dist.		7,7	7,7	8
Median				7,7
Average		7,7	7,7	

Identified Clusters

C1	3	5	8	12	14
C2	12	14	3	5	8
C3	18	20	22	24	

Resulting Clusters						*Centroid*	*IntraCluster*	*InterCluster*
C1	3	5	8	12	14	8,4	18,4	12,6
C2	18	20	22	24		21,0	8,0	12,6
							26,4	**25,2**
							ModelQuality	**1,2**

5th. Iteration

K-nearest neighbours

		C1	C2
		8,4	21
C1	8,4	0	12,6
C2	21	12,6	0
Min.Dist.		13	13
Median			13
Average		13	13

Identified Clusters

C1	3	5	8	12	14	18	20	22	24
C2	18	20	22	24	3	5	8	12	14

Resulting Clusters										*Centroid*	*IntraCluster*	*InterCluster*
C1	3	5	8	12	14	18	20	22	24	14,0	56,0	0,0
											56,0	**0,0**
											ModelQuality	**56,0**

Figure 3. An example of the clustering process using the STICH algorithm.

4. Space Models

Human beings mentally use space models to simplify reality and to perform spatial reasoning more effectively. When we look at the birth rate of several countries and try to analyse the data, our first thought is to group countries with similar birth rate. This procedure allows us to create a Space Model.

Space Models are new geometries of the space that are created to emphasize particularities of the analysed data. A Space Model integrates groups of regions that present similar behaviour with respect to a specific characteristic. Each group represents a cluster aggregating regions that are similar regarding the analysed characteristic. Regions in different clusters must be as dissimilar as possible. Besides the role of Space Models in data analysis, their creation also allows their use as a means for data visualization, since new space geometries are created.

4.1. PRINCIPLES

The main characteristic of a Space Model lies in the identification of groups of regions that emerge from the analysed data, in contrast to groups of regions that are limited to a predetermined number of classes or to any other constraint specified by the user.

The identification of Space Models follows a set of principles (Moreira et al., 2005), which are implemented by the STICH algorithm presented in the previous section. The principles are:

1. Space Models must be identified from the data values available for analysis, and no constraints can be imposed on their identification.
2. The obtained Space Models must be the same, independently of the order by which the available data is analysed in the clustering process.
3. Space Models can include clusters of different shapes and sizes.
4. Space Models must be independent of specific domain knowledge, like the specification of the final number of clusters.

4.2. IDENTIFICATION OF SPACE MODELS

Following the clustering process implemented by the STICH algorithm it is possible to identify Space Models that allow data analysis and the creation of new space geometries that point out the particularities of the analysed data.

This subsection presents an example of the use of the STICH algorithm for the identification of Space Models. In this example we have nine regions, each one of them characterized by a specific value. The values are 3, 5, 8, 12, 14, 18, 20, 22 and 24. The process of identification of Space Models using the STICH algorithm is shown in Figure 4 (following the iterations presented in the example of the previous section).

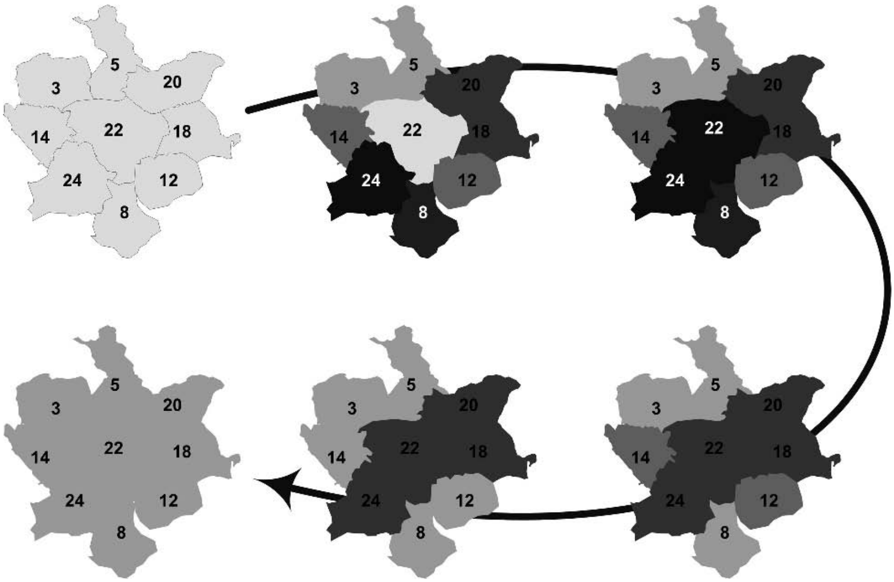

Figure 4. An example of the process of creation of Space Models.

5. Analysis of Environmental Indicators Using Space Models

This section will illustrate the analysis of several indicators, including environmental indicators, in order to distinguish the different approaches that were mentioned along this chapter: the analysis of data over traditional classification processes using a Geographic Information System (GIS), the use of a clustering algorithm like the *k-means* algorithm, and the use of the STICH algorithm for clustering geo-referenced data.

We start with the analysis of the population density values for 15 European countries. This example will demonstrate the analysis of this indicator using the results obtained with the *k-means* algorithm, and the results obtained using the STICH algorithm and the Space Models produced for the analysis of the data associated with the population density indicator. Table 1 lists the data[3] available for analysis.

[3] All the data for the fifteen countries of Europe analysed in this chapter were collected within the EPSILON Project (funded by the European Commission, IST-2001-32389). STICH is a result achieved within the context of this project. The project has contributed to a better understanding of the European Environmental Quality and Quality of Life, and has developed tools aimed at generating environmental sustainability indices.

TABLE 1. Data available for the population density indicator.

Country	Population Density	Country	Population Density	Country	Population Density
Finland	17.0	Austria	96.7	Italy	191.7
Sweden	21.6	France	108.3	Germany	230.2
Ireland	53.9	Portugal	111.1	U. Kingdom	240.5
Spain	79.1	Denmark	123.9	Belgium	335.9
Greece	82.9	Luxemburg	169.2	Netherlands	470.2

The analysis of the data using the *k-means* algorithm was carried out in a manual way, using Microsoft® Excel, in order to show each step of the clustering process. After six iterations the clustering process reaches a stable state, and the process comes to an end. Figure 5 shows the several steps and the corresponding values. The results were obtained using a *k* value equal to 3 in order to enable the comparison with another Space Model of 3 clusters. The values shown in Figure 5 are: the identification of the three clusters (C_1, C_2, and C_3), the mean value of each cluster (*m*), the distance of each value to the mean value of the clusters (*dist_C1*, *dist_C2* and *dist_C3*) and the squared-error calculated (*E*) at each step.

1

		m
17.0	C_1	17.0
21.6	C_2	21.6
53.9	C_3	176.4
79.1	C_3	
82.9	C_3	
96.7	C_3	
108.3	C_3	
111.1	C_3	
123.9	C_3	
169.2	C_3	
191.7	C_3	
230.2	C_3	
240.5	C_3	
335.9	C_3	
470.2	C_3	

2

dist_C1	dist_C2	dist_C3		m	E
0	4.6	159.4	C_1	17.0	0.0
4.6	0	154.8	C_2	66.84	2.046.7
36.9	32.3	122.5	C_2		167.4
62.1	57.5	97.3	C_2		150.3
65.9	61.3	93.5	C_2		257.9
79.7	75.1	79.7	C_2		891.6
91.3	86.7	68.1	C_3	220.11	12.501.7
94.1	89.5	65.3	C_3		11.883.4
106.9	102.3	52.5	C_3		9.256.6
152.2	147.6	7.2	C_3		2.591.9
174.7	170.1	15.3	C_3		807.2
213.2	208.6	53.8	C_3		101.8
223.5	218.9	64.1	C_3		415.7
318.9	314.3	159.5	C_3		13.407.1
453.2	448.6	293.8	C_3		62.544.5
					117.023.8

3

dist_C1	dist_C2	dist_C3		m	E
0	49.84	203.1	C_1	19.3	5.3
4.6	45.24	198.5	C_1		5.3
36.9	12.94	166.2	C_2	93.7	1.584.0
62.1	12.26	141.0	C_2		213.2
65.9	16.06	137.2	C_2		116.6
79.7	29.86	123.4	C_2		9.0
91.3	41.46	111.8	C_2		213.2
94.1	44.26	109.0	C_2		302.8
106.9	57.06	96.2	C_2		912.0
152.2	102.36	50.9	C_3	273.0	10.764.1
174.7	124.86	28.4	C_3		6.601.6
213.2	163.36	10.1	C_3		1.827.6
223.5	173.66	20.4	C_3		1.053.0
318.9	269.06	115.8	C_3		3.962.7
453.2	403.36	250.1	C_3		38.907.6
					66.477.8

4

dist_C1	dist_C2	dist_C3		m	E
2.3	76.7	256.0	C_1	30.8	191.4
2.3	72.1	251.4	C_1		85.3
34.6	39.8	219.1	C_1		532.1
59.8	14.6	193.9	C_2	110.17	965.4
63.6	10.8	190.1	C_2		743.7
77.4	3	176.3	C_2		181.5
89.0	14.6	164.7	C_2		3.5
91.8	17.4	161.9	C_2		0.9
104.6	30.2	149.1	C_2		188.5
149.9	75.5	103.8	C_2		3.484.4
172.4	98.0	81.3	C_3	293.7	10.404.0
210.9	136.5	42.8	C_3		4.032.3
221.2	146.8	32.5	C_3		2.830.2
316.6	242.2	63.0	C_3		1.780.8
450.9	376.5	197.3	C_3		31.152.3
					56.576.1

17.0
21.6
53.9
79.1
82.9
96.7
108.3
111.1
123.9
169.2
191.7
230.2
240.5
335.9
470.2

5

dist_C1	dist_C2	dist_C3		m	E
13.8	93.2	276.7	C_1	30.8	191.4
9.2	88.6	272.1	C_1		466.6
23.1	56.3	239.8	C_1		2.905.2
48.3	31.1	214.6	C_2	120.36	1.702.6
52.1	27.3	210.8	C_2		1.403.4
65.9	13.5	197.0	C_2		559.9
77.5	1.9	185.4	C_2		145.5
80.3	0.9	182.6	C_2		85.8
93.1	13.7	169.8	C_2		12.5
138.4	59.0	124.5	C_2		2.385.1
160.9	81.5	102.0	C_2		5.089.0
199.4	120.0	63.5	C_3	319.2	7.921.0
209.7	130.3	53.2	C_3		6.193.7
305.1	225.7	42.2	C_3		278.9
439.4	360.0	176.5	C_3		22.801.0
					52.141.6

6

dist_C1	dist_C2	dist_C3		m	E
13.8	103.4	302.2	C_1	30.8	191.4
9.2	98.8	297.6	C_1		85.3
23.1	66.5	265.3	C_2		532.1
48.3	41.3	240.1	C_2	120.36	1.702.6
52.1	37.5	236.3	C_2		1.403.4
65.9	23.7	222.5	C_2		559.9
77.5	12.1	210.9	C_2		145.5
80.3	9.3	208.1	C_2		85.8
93.1	3.5	195.3	C_2		12.5
138.4	48.8	150.0	C_2		2.385.1
160.9	71.3	127.5	C_2		5.089.0
199.4	109.8	89.0	C_3	319.2	7.921.0
209.7	120.1	78.7	C_3		6.193.7
305.1	215.5	16.7	C_3		278.9
439.4	349.8	151.0	C_3		22.801.0
					49.387.2

Figure 5. An example of the use of the *k-means* algorithm.

The analysis of the results allows the verification of the constitution of each cluster:

C_1 = (17.0 – 21.6 – 53.9)

C_2 = (79.1 – 82.9 – 96.7 – 108.3 – 111.1 – 123.9 – 169.2 – 191.7)

C_3 = (230.2 – 240.5 – 335.9 – 470.2)

Using the STICH algorithm and its process of identification of Space Models, Figure 6 shows the Space Model obtained at the 5th iteration. It is a Space Model with three clusters. The clusters' mean values are presented in the map legend. This Space Model shows a high level of region aggregation, pointing out the lowest and the highest values of the indicator in analysis. In this model one of the clusters contains only one region, the Netherlands with its 470.2 of population density, distinguishing this region from all the others. As can be also seen in Figure 6, in the creation of a Space Model the borders of the analysed regions are dissolved in order to create new space geometries. The new space geometries reveal the geometries of the identified clusters.

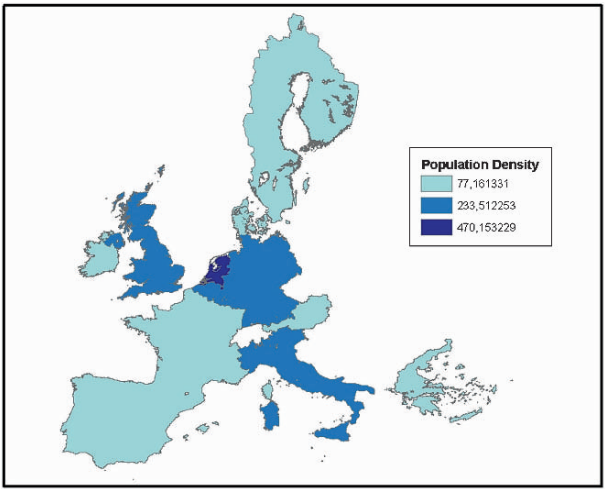

Figure 6. A Space Model for the analysis of the population density indicator.

Let us now analyse an environmental indicator. This indicator is the *Soil Toxicity Index* for 15 countries of Europe at NUTS I level. For this administrative subdivision level, for these 15 countries, 74 values are available. The analysis is undertaken using a thematic map generated using a GIS, on the one hand, and one of the Space Models produced by the STICH algorithm, on the other.

The analysis of data using a thematic map consists of a classification task in which the several regions are associated to a specific class. The number of classes is provided by the user and the GIS identifies the limits of each class. This means that the class limits do not emerge from the data but are imposed in the beginning of the classification process. Figure 7 presents a thematic map for the *Soil Toxicity Index* using four classes.

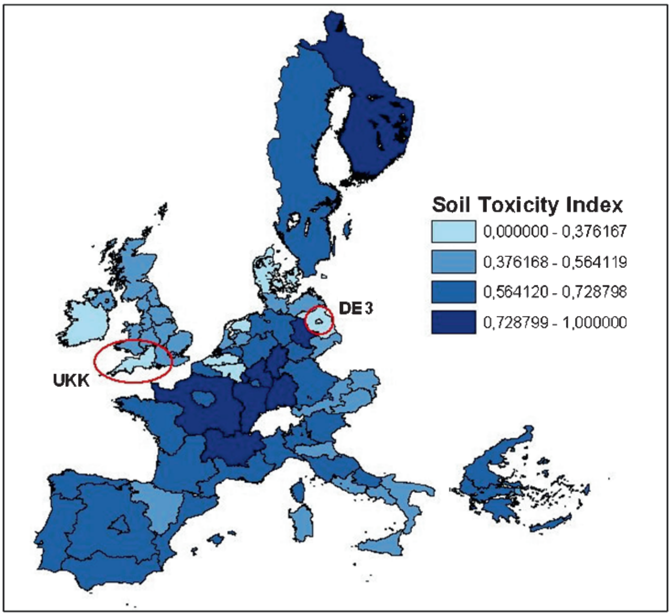

Figure 7. A thematic map for the analysis of the *Soil Toxicity Index.*

By the analysis of Figure 7 we can see that the classification process joined regions with values as different as 0 and 0.376167. It is very dissimilar a region that presents a value of 0 in the *Soil Toxicity Index*, like *DE3* marked in the Figure 7 with a circle, and a region that presents the value of 0.376167, like *UKK* also marked in the map. With this classification, some important information is lost and the best and worst cases are difficult to identify.

Using the STICH algorithm and a Space Model with four clusters, Figure 8 presents the obtained model. In this model the limits of the clusters are completely different from the ones obtained in the classification process. This example shows that the Space Model obtained by the STICH algorithm highlights a region (the one formed by two NUTS I regions, *DK0* and *DE3*, marked with two circles) where the average value of the *Soil Toxicity Index* is much lower than the mean value in all other regions. This allows the easy and immediate identification of the areas that perform much better than all others in terms of this indicator.

To conclude this section, we show the analysis of another environmental indicator, *Groundwater Quality*. This example gives an idea of the several Space Models that are identified in a clustering process with the STICH algorithm and the main differences between them in terms of analysis. Each iteration of the clustering process generates a Space Model that reflects a more detailed or a more general analysis over the data. More general analyses are obtained reaching the end of the clustering process and usually in those iterations outliers in data are revealed.

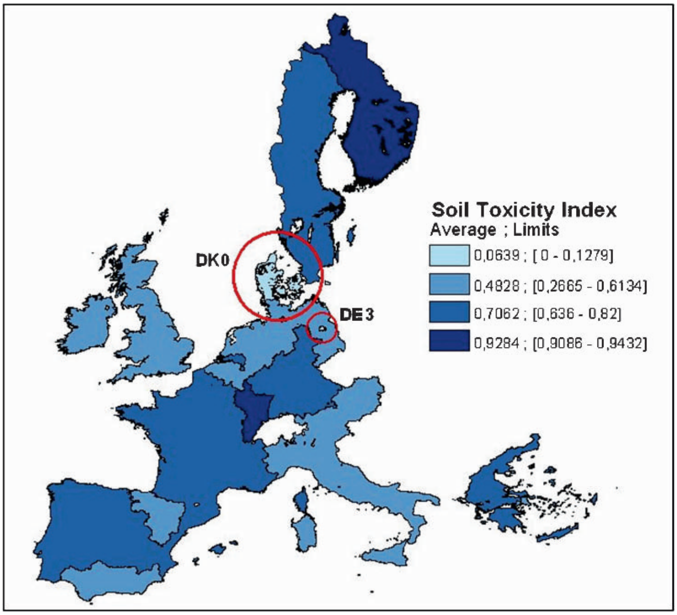

Figure 8. A Space Model for the analysis of the *Soil Toxicity Index*.

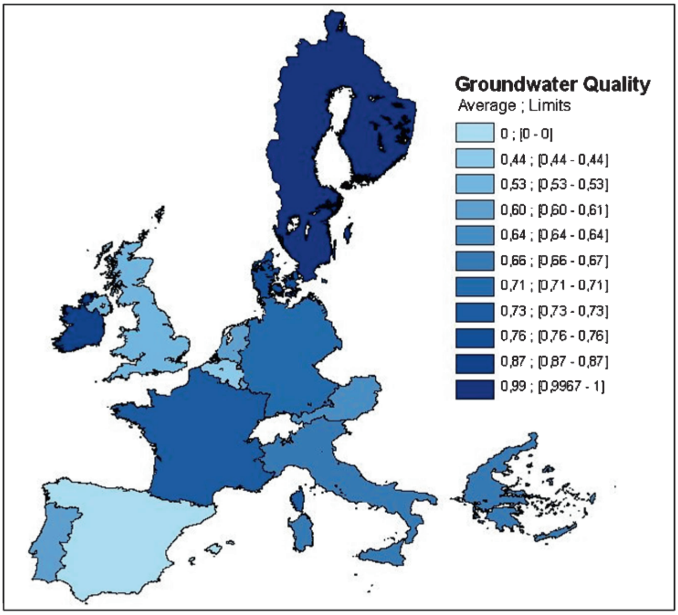

Figure 9. Analysis of the *Groundwater Quality* indicator (2nd iteration).

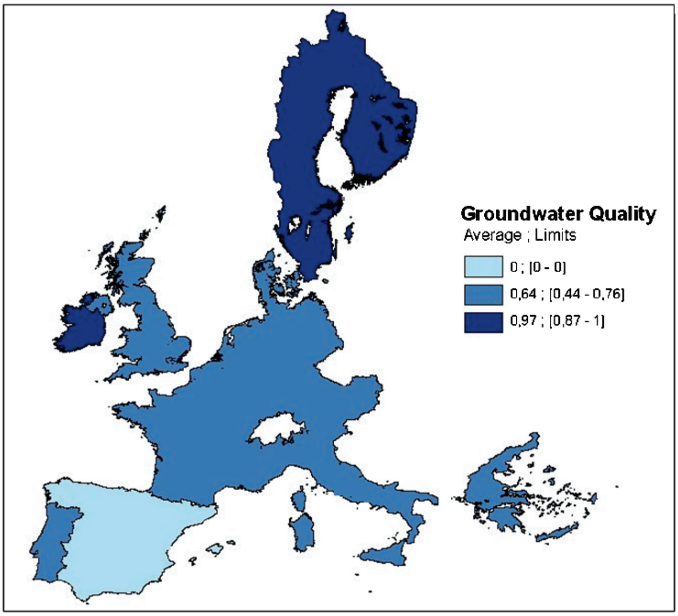

Figure 10. Analysis of the *Groundwater Quality* indicator (9th iteration).

For the *Groundwater Quality* indicator, Figure 9 presents the Space Model obtained at the 2nd iteration of the clustering process. At this stage, the Space Model integrates 11 clusters, while at the 9th iteration the Space Model integrates three clusters (Figure 10).

By choosing the appropriate iteration of the clustering process, the user has the opportunity to analyse the same data at different levels: from a very detailed analysis to a broad view of the data. Moreover, with this approach, the regions that fall apart from the others are not hidden by the choice of a small number of clusters. Note that, in this example, Spain is still highlighted, even when only three clusters are considered.

6. Conclusions

This chapter addressed the analysis of geo-referenced data through clustering processes. The objective was to point out the advantages of the use of the STICH algorithm in the analysis of such type of data. The creation of Space Models as a result of the clustering process allows the identification of new geometries of the space that can be used not only to understand the similarities among regions, but also as a basis for the analysis of other indicators, instead of employing traditional administrative subdivisions.

The implementation of the STICH algorithm, the SM-Tool, is available for download at http://ubicomp.algoritmi.uminho.pt/epsilon/. As future work, the STICH algorithm shall be implemented in an open-source GIS platform, in order to enable a broader use of the tool. The current implementation still requires the ESRI© ArcGIS software.

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SOKNOS – AN INTERACTIVE VISUAL EMERGENCY MANAGEMENT FRAMEWORK

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Abstract. Emerging Spatial Data Infrastructures and non-spatial Web Service environments allow new approaches to dynamically integrate information sources. The ability for dynamic information integration provides the basis on which an emergency management system should allow its users to create spatial, temporal and structural views on the emergency situation. Furthermore, dynamic information aggregation and generalization should allow tailoring the presented information to the users' requirements. In combining a SOA-based information processing approach with a user-centric perspective on information visualization and handling, we introduce the approach taken in the SoKNOS project to develop a new generation of emergency management systems.

Keywords: Emergency Management, Collaborative Work Environments, Semantics-Based Web Service Integration, Visual Analytics.

1. Introduction

In everyday situations, the Web 2.0 and Web Service-based environments such as Spatial Data Infrastructures (SDI) have changed the way we interact with information. Information is not only consumed but also collaboratively created and used. Even more important, a big proportion of the population of the European countries has acquired the skills to efficiently use these new means of dealing with information. The question arises how these new

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skills in combination with further developed technology can be leveraged in emergency management systems.

However, if compared to the consumer space, emergency management poses a number of additional challenges that must be tackled. Among these are high reliability, high availability and accuracy of information, secured access to information and ease of use, even in stressful situations.

In this chapter we introduce the approach taken in the SoKNOS project to leverage the emerging technologies in order to arrive at a new generation of emergency management systems. We first list the central requirements, an efficient and easy to use emergency management system has to fulfil, then introduce the steps taken in the SoKNOS project to meet these requirements.

1.1. MOTIVATION AND GOAL

SoKNOS is motivated by the vision of seamlessly integrated, heterogeneous information sources that enable emergency organizations to collaborate in an efficient way. The SoKNOS vision is to enable decision makers

- To quickly find and integrate information from heterogeneous and distributed environments while keeping the integrated information accessible to other emergency organizations
- To visually explore the situation at hand, individually or in collaboration, by combining different visual analysis, aggregation and generalization methods that work on an entirely consistent information basis
- To create new information such as commands or requests, but also new geo-spatial objects, plans and documentation of the situation in an intuitive, collaborative and consistent way
- The tasks of integrating, aggregating and generalizing as well as creating information has to be facilitated by a considerably improved usability of the system.

1.2. CHALLENGES AND BACKGROUND

We observe abundance in distributed and heterogeneous information, which could potentially be used for emergency management. Finding potentially useful information sources and assessing their accuracy and reliability is a challenge. Especially in emergency situations unreliable or incorrect information integration can lead to erroneous decisions that could even exacerbate the emergency. The challenge of assessing the semantic interoperability is paramount to information integration that is not performed in a hard-wired fashion.

In parallel to the increasing number of potentially available information sources, we observe an increase in visual analysis methods. However, in many cases, different analysis methods come with different and hence not interconnected tools. Therefore switching the views easily and tracking a particular object across different visualizations are not supported. Further on, using several tools in parallel decreases the usability of the overall system since the user has to cope with different interaction metaphors.

To sum up, one could say decision makers are, at the moment, not supported in *dynamically* finding the appropriate information sources to get an *integrated information basis* visualizing the current emergency situation. The emerging SDIs (Wagner et al., 2005) are heading in the right direction to provide integrated geospatial information. Additionally the ability to integrate non-spatial information sources is needed.

Even when assuming that an integrated view on the current situation may be achieved, decision makers are not supported in getting an *aggregated view* by adding information from different sources to the same object. For example, in a visualized object such as a hospital, information on its location, available staff, number of free beds, number of expected patients, status of electricity and water supply and many more can be aggregated. The challenge is, that the aggregation is performed in such a way that the aggregated object shows precisely the subset of additional information that the particular user needs for solving the task at hand only to prevent information overload. This in turn requires user models and suitable visualization techniques.

In SoKNOS, we focus on emergencies that exceed the response capabilities of local emergency organizations in such a way that a higher command level is required in order to manage the emergency. In this sense, the emergencies that are supposed to be managed with a SoKNOS system can be considered disasters according (Turner and Pidgeon, 1997) who define a disaster as a disruptive event that is large-scale, costly, public, or unexpected. SoKNOS systems will be employed when the common reaction plans are not sufficient or, due of the unexpected nature of the event, do not exist. (Ryoo and Choi, 2006) provide a classification framework of disaster information management systems in which a SoKNOS system would be seen as a system that supports the response and the recovery from natural and socio-technical disasters.

In the remainder of this chapter we will identify the requirements for an emergency management system that employs the emerging possibilities of Web Service environments from an information processing perspective. We then introduce the approach taken in the SoKNOS project to fulfil these requirements, leading to the development of a user-centric Web Service-based emergency management system.

2. Requirements from an Information Processing Perspective

Based on user studies made in the SoKNOS project, we list the requirements we consider essential in order to achieve a new generation of user-centric, Web Service-based emergency management systems.

2.1. REQUIREMENTS CONCERNING VISUALIZATION AND USER INTERACTION

(Carver and Turoff, 2007) identify and emphasizes the central role of intuitive interface and interaction design in an emergency management system. The SoKNOS system embraces this conclusion and offers homogeneous user interaction and visualization metaphors as well as it supports collaborative work in and between emergency management teams.

Ease of use. Large emergencies are exceptional events, therefore familiarity with a specialized user interface which needs thorough training cannot be assumed. Furthermore, in the management of large incidents, stress is a crucial factor. The supporting software system should therefore minimize the user's cognitive load. The system should effectively avoid the "thread rigidity syndrome" where additional stress is caused because of a loss of control over the situation or reduced understanding of reality, discussed in context of emergency management by (Turoff et al., 2004).

Tracking objects across views. Solutions to this requirement introduce the possibility to visualize the same objects in parallel in spatial, temporal and organizational views. Physical objects like roads, buildings or rescue teams are involved in processes. This can be passively, as a building is involved in a fire, or actively such as rescue teams are involved in rescuing or protecting. The option to track an individual entity in parallel across these different spatial, temporal and organizational views enables the user to get a holistic and highly realistic picture of the situation at hand.

Personalization of system functionality. The system should take the needs of the various users and the roles they have when engaged in handling the incident into account. This includes the easy access to needed and frequently used functionality as well as supporting personal preferences for the level of complexity the systems offers.

Adjustment of the level of detail. To reduce the cognitive load the visualization should initially present the level of detail the user's role requires, but also support to get more detailed information or to present more coarse grained information if necessary.

Collaboration support. Emergency management is teamwork. In some situations, the team members require the ability to quickly exchange views (i.e., how they see situation's representation on their screen) between each other. In other situations, the ability to collaboratively work on the same screen is required. In this case the personalization should be kept as far as possible, i.e., the toolset should adapt to the user who currently operates the screen.

2.2. REQUIREMENTS CONCERNING INFORMATION SERVICE INTEGRATION

This set of requirements focuses on acquisition of up to date information regarding the incident. The goal is to get a common operational picture of the incident which is consistent across organizations.

Information integration. A central requirement of emergency management systems is the ability to integrate new and heterogeneous information services from various providers, such as traffic and weather information, flood warnings, yellow pages, news or the resource availability of other organizations. This in turn requires an intuitive search functionality enabling to find particular information services quickly. The found services need to be easily added to the existing information base. Therefore, the support of data harmonization and the ability to assess semantic interoperability[1] in order to facilitate the semi-automated integration of newly found services is essential.

Semantic annotations. Organizations, even when operating in the same region or country often use slightly different vocabulary. The semantic annotation of Web Services and the underlying information sources is necessary to prevent inconsistencies in the information flow.

Reliability and security. Reliability and security are intrinsic requirements for a system aimed to support the management of large incidents. Therefore information services need to be replaced quickly and securely in case of a failure.

2.3. REQUIREMENTS CONCERNING INFORMATION AGGREGATION AND GENERALIZATION

This set of requirements combines those which arise from the need to avoid an information overflow because of the vast amount of incoming information with the need to efficiently visualize and compare information which is relevant to support decisions.

Information aggregation describes the possibility to *place aggregated information in a single object* by adding information from different sources.

[1] "The capacity of information systems or services to work together without the need for human intervention" (Francis et al., 1999).

The challenge is to perform the aggregation in such a way that the aggregated object shows only the additional information that a particular user needs for solving the task at hand. This requires user models and suitable visualization techniques.

Information generalization is about the possibility to generate generalized views based on the previously aggregated information. While the aggregated objects have a precise location, in generalized spatial views the goal is to reduce the number of single objects in generalized objects that represent a number of objects with similar characteristics. For example, for a general view on the resources available at a place of action, it is not of interest to see the individual rescue teams but symbols that aggregate the resources according to a certain property.

Information consistency is paramount for enabling the previous requirement. Incidents develop quite fast. Therefore, the current status each participating organization has differs naturally, furthermore information might get lost and inconsistencies arise which might finally lead to wrong decisions. Therefore, functionality is needed which enables to track and eliminate information inconsistency across organizational borders.

2.4. REQUIREMENTS CONCERNING INFORMATION CREATION

This set includes all requirements regarding the creation of information during the management of a particular incident.

Digitizing information. Important are easy-to-use methods to turn analogue information into digital information. In an emergency, information from all types of non-digital sources needs to be turned in to digital information. While in the previous sections we focused on the integration of digital sources, here the focus in on turning information that arrives via radio messages, analogue text messages and spoken messages into digital information.

Creating new information objects. Making plans, giving orders and documenting incoming messages creates new information that does not originate in previously existing sources. This new information needs to be stored efficiently and must be accessible to all team members in a consistent way.

Simulation, interpolation, risk analysis. Making plans relies on the ability to imagine how the situation may develop. This can be supported by the ability to perform simulations and interpolations. Obviously, generating new information of this type relies on information integration and aggregation beforehand.

3. The SoKNOS Approach

In the following sections, we present how the SoKNOS approach tackles the requirements identified above. Central aspects of the approach are presented along the general research questions: "*how to improve the usability of the system*?" (visualization and user interaction), "*how to get information into the system?*" (information integration), "*how to get from the integrated information basis just the information required for a certain task?*" (information aggregation and generalization), "*how to facilitate the creation of new information within the system?*" (information creation).

Figure 1 presents a general view[2] of the SoKNOS architecture, illustrating how the above mentioned aspects are reflected in the SoKNOS system design.

3.1. VISUALIZATION AND USER INTERACTION

Plug-in approach. The flexibility of the SoKNOS user interface is based on individually configurable plug-ins, framed into the SoKNOS portal. Plug-ins are self-contained units, which communicate via well-defined interfaces. Three central plug-ins provide three perspectives on the current situation. The spatial perspective is provided by a Geospatial Information Plug-in, the temporal perspective is provided by a Mission Diary Plug-in and the structural-organizational perspective is provided by a Mission Account Plug-in. Other plug-ins support particular fields of responsibility, for example provisioning of forces and materials, planning or finding suitable information sources.

Tracking objects across views. To offer a contiguous visual perspective across all plug-ins, the workspace provides support for synchronized selection, i.e., simultaneous highlighting of selected objects (per workspace).

Personalization I. Depending on the user's needs, plug-ins can be selected, (re-)arranged and individually configured. This leads to a working environment in which the user is exposed only to those system elements and interaction possibilities that suit his task at hand as well as his experience level with IT systems.

Modelling the users. Emergency management is commonly carried out by a group of domain experts (for example experienced officers of the fire brigade or the police) that take a number of roles with different responsibilities and therefore different perspectives on the situation. SoKNOS adapts to these different operating procedures by first modelling the roles and then tailoring the user interface to these roles.

[2] Concentrates on core elements for reasons of clarity.

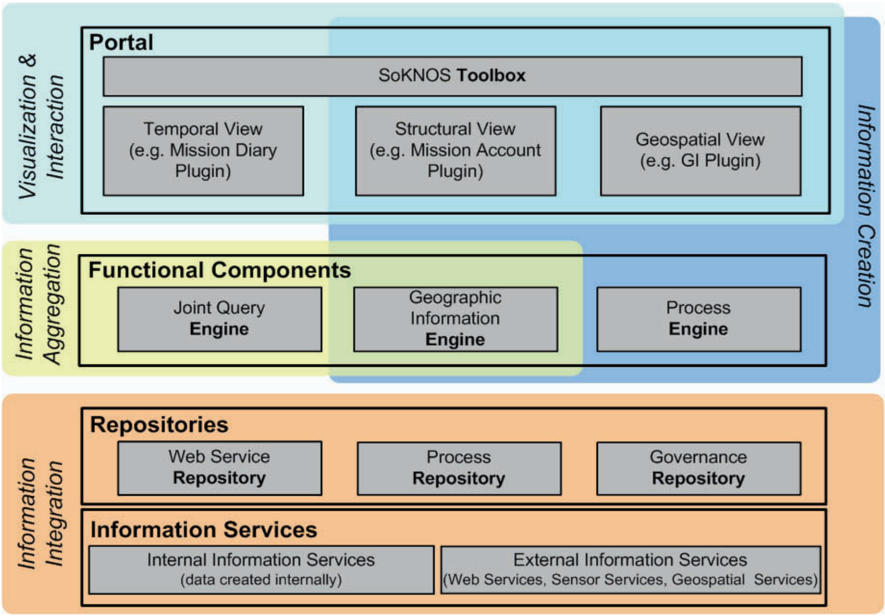

Figure 1. The figure shows the simplified SoKNOS architecture with respect to information creation, aggregation, integration and visualization. In SoKNOS, the user interacts via plug-ins with the system. The functionality of the plug-ins is provided by functional components, while the entire data management is handles via web services.

Toolbox. To provide a homogenous user experience, interaction with the front-end is not performed via menus or buttons in the plug-ins, but via a toolbox that adapts to the users role and current task (i.e., the active plug-in).

Personalization II. Working styles differ from organization to organization and from individual to individual. Thus, in a SoKNOS system, the user can customize the toolbox to fit his or his organizations preferences. Pre- and user-defined preference templates help to quicken this customization process.

Local collaboration. Emergency management is by nature a collaborative task based on the capabilities of the individual experts. Thus it seems reasonable to assume that an integrated emergency management system like SoKNOS will significantly benefit from adapting approaches from the Computer Supported Cooperative Work (CSCW) area. In SoKNOS, the separation of users from each other is significantly weakened, allowing users to easily push and pull information to and from other workspaces. Furthermore, awareness on other users' activities is created to enable and foster collaboration. This is mainly done by:

- Locking currently edited objects and visual indication of these edits.
- A collaboration plug-in that allows the users to pull and push information between workspaces.

- The personalized toolbox which can be migrated to another workspace, enabling shared space cooperation between users that need to discuss issues in detail. Thus, a user has always the same set of tools available, independently from the workstation he currently works at.

3.2. INFORMATION SERVICE INTEGRATION

Web services. In a SoKNOS system, all information sources, internal as well as external, are accessible only via Web Services. SoKNOS distinguishes services into external services and system-internal services.

Semantic annotations. Web Services are made available via a Web service repository that facilitates finding and accessing information sources. Central for finding information suitable for the task at hand is the ability to clearly specify its content. SoKNOS requires that Web Services are semantically annotated. That is, the structure of a Web Service as well as its underlying information source is described using ontologies. Capturing the domain knowledge in ontologies allows accounting for differences in the vocabulary used by emergency organizations while still enabling the discovery and use of information sources from different organizations. This approach enables interoperability between organizations without requiring a difficult to reach, unified data schema (or universal emergency data standard) to which all organizations have to commit.

Consistent information basis. Each SoKNOS system has one unified set of information sources which is accessible to all users. This common set of information sources ensures a consistent view on the situation. Pessimistic locking on a very fine granular level prevents inconsistencies due to simultaneous and conflicting edits.

Collaboration across SoKNOS systems. Large disasters require co-operation not only inside an organization, but also across organizations. Assuming each organization runs its own SoKNOS system, with the Web service approach SoKNOS takes, there is already the foundation for a shared view on the situation: publicly available services (e.g., weather information) can be accessed by all involved organizations and internal information can be exposed to other organizations by setting corresponding access rights. This enables users to compare information of the same type, e.g., missing person or casualties. Since each organization usually generates its own information in the field, this information is by nature likely to be inconsistent. Here, “subscribing” to services of another organization offers the great advantage of parallel visualization of the same information. This allows identifying discrepancies between organizations.

Cross-organizational information integration. New plug-ins can be developed to account for particular needs of an emergency management organization. For example, the police may develop a plug-in that serves a particular police-related task, leading to a specific visualization of the situation. These newly created plug-ins can be stored in a (SoKNOS) global repository and deployed to other organizations (e.g., fire workers) at emergency time. This collaborative approach allows a highly dynamic adaptation to new emergency situations.

3.3. INFORMATION AGGREGATION AND GENERALIZATION

Entity aggregation. The vision of a large number of integrated and semantically interoperable information sources will allow the so far unknown possibility of aggregating information related to a particular object. Information on this object can be retrieved by jointly querying several information sources. The results are then aggregated in a detailed view on that object. The basis for this approach is laid by the previously mentioned semantic annotation of the integrated services based on an ontology that covers key domain concepts.

Visual generalization. To prevent a mental overload that may occur due to the available information from various sources, the SoKNOS system offers semantic zooming into visualizations of the situation on different levels of generalization.

3.4. INFORMATION CREATION WITHIN THE SYSTEM

Semantically annotated information. Apart from integrating external information in the system, creating consistent information within the system is an important issue in emergency management system. Orders are created, new spatial objects are drawn in the map, actions are planned or units are managed. All these tasks create new information. Within a SoKNOS system each new information object is automatically assigned to a category in the SoKNOS ontology. This allows keeping track of individual objects and supporting the identification of misconceptions in organizational diagrams. For example reassigning a unit to another task may reassign automatically a new commander to it.

Analysis, prediction and simulation. SoKNOS provides a set of visual analysis, simulation and prediction tools. This results in new information on the situation that was not available beforehand.

Planning support. Large disasters require that commonly used plans are altered or re-combined. SoKNOS supports the creation of plans that finally lead to actions. In combination with the information created by

Visual Analytics and simulations, plans form the essential type of information created within the system.

4. Related Work

Emergency management has become a matter of increased significance (Witty and Morency, 2008) during the last few years resulting in a rising number of research projects.

The SHARE project (Koch et al., 2005) also analyzed large emergencies, but focused on the development of a mobile push-to-talk communication system. Besides, information services for forces in the field are provided and an ontology-based database allows for storing knowledge acquired during the event. As the SHARE architecture is also based on SOA, services developed for it can be integrated into SoKNOS.

The ORCHESTRA project (Board, 2005) defines a disaster and risk management architecture for a common approach to disaster and risk management on a European scale, covering the four phases: prevention & mitigation, preparation, response and recovery. SoKNOS adopts the SOA and semantic interoperability approaches outlined in ORCHESTRA, but concentrates on the response phase.

5. Conclusion

The goal in SoKNOS is to develop an easy to use, highly adaptable working environment where internal and external collaboration is seen as a key factor for successful emergency management.

This is realized by an architecture that follows rigorously the paradigm of service orientation. Yet service orientation alone is not sufficient. Information integration and collaboration between organizations, even if they all are engaged in the same domain, requires to bridge differences in the used vocabulary. This demands methods that allow the assessment of semantic interoperability of the collaboratively used information sources. SoKNOS requires a precise semantic annotation of each information source that is made available across the systems. Furthermore, reliability and security are important cross cutting concerns, where SoKNOS is going to develop mechanisms enabling the secure and reliable access to necessary information while keeping the required usability.

Next to information integration and aggregation, the third line of development that carries the SoKNOS vision is the development of flexible adaptation of the user interfaces to the user's needs by providing new interaction and visualization techniques. The user-centric approach in SoKNOS enables the predefinition of user roles that can further be adapted to the expertise of the individual user. This results in a tightly tailored working environment that optimizes the performance of the individual organization member. Based on this personalization, SoKNOS increases the efficiency of collaboration between users with different expertise in both, actual domain knowledge and experience with complex IT systems.

In this chapter we have outlined the approach taken in SoKNOS that further specifies and implements (parts of) the architecture developed in ORCHESTRA (Board, 2005). It will significantly improve the work in the control rooms of all kinds of emergency organizations.

6. Disclaimer

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VISUAL ANALYTICS

GEOSPATIAL VISUAL ANALYTICS

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Abstract. In the context of spatial planning, environmental management and monitoring a number of geospatial technologies allow operators and experts to capture, store, process and display an unprecedented amount of information about the environment and a wide variety of phenomena. However the extremely wide range of data available poses a critical challenge to operators that need to extract key pieces of knowledge from very large and heterogeneous sets of geospatial information. Within this scenario the domain of GeoVisual Analytics (GVA) can provide effective solutions to ensure better environmental control and to prevent environmental crisis. This paper presents the current challenges that GVA needs to face in the context of environmental protection, highlighting current technological, infrastructural, economical and legal implications at the international level. Finally the chapter shows how these issues have been tackled by the authors presenting the results of their current research activities.

Keywords: GeoVisual Analytics, Spatial Data Infrastructure, Environmental Protection, Geographic Information.

1. Context

Pollution resulting from extended use of fossil fuels, large fires and chemical substances released as consequence of industrial accidents or terrorist attacks may be the triggering factors of an environmental crisis with major consequences in terms of public health, economical as well as social security.

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Several accidents have tragically demonstrated the consequences of poor attention to environmental security. Inadequate preparation to unexpected events can have disastrous effects. One the most remarkable example is the accident which occurred in Bhopal, India on 1984, one of the worst industrial disasters ever recorded (Bhopal Information Center, 2009). The accident was a dramatic example of large-scale effects of an environmental disaster occurring in the proximity of an urban area. The industrial accident caused the release into the atmosphere of 40 ton of Methyl Isocyanate (MIC) gas from the Union Carbide India Limited (UCIL) plant. This created a killer cloud which quickly spread through the nearby city of Bhopal, killing 3,800 and leaving several thousand permanently or partially disabled.

Within developed countries the complexity of controlling the territory is further amplified by the extent of available infrastructures, often made of an articulated cross-border "network of networks". The latter are considered a strategic asset of a country since they ensure transportation, power transmission and communication. Infrastructural networks. Transportation and energy infrastructures are often extremely vulnerable to natural or man-made disasters which may potentially expose the population to very serious risks. In the specific context of Europe, for instance, free exchange of people and goods, together with a relatively efficient infrastructure network, is resulting in a continuous increase in the transport of goods which is expected to grow of 55% by 2020. If on the one hand the increasing mobility of goods and people across different EU countries through interconnected transport networks is the "*sine qua non*" (ASECAP, 2006) to sustainable regional and international socio-economic growth, on the other hand, this yields increasingly higher congestions, pollution and, potentially, more significant threats to the environment.

The number of accidents in the last few years has dramatically demonstrated that the chance for a major environmental crisis caused by transport systems is far from remote. The European Alpine area, for instance, regarded as one of the most environmentally sensitive region in Europe, is crisscrossed by some of the most important and busiest transport networks of the continent. The high level of environmental risk caused by high traffic is testified by the 80,000+ vehicles per day transiting on 2005 through Brenner pass alone (El-Araby, 2007) resulting in 33.6 Mill. Tons of goods transiting as road freight traffic (EU, 2006). The real possibility of environmental crisis within such an environmentally sensitive area is testified by the rail accident occurred on 13/12/2006 near Avio, a village in the Italian Alps along the Brenner corridor (Repubblica, 2006). The accident caused a spill of Methylene Diphenyl Diisocyanate (MDI) from one of the four 25-ton carriages. Low air temperatures at the time of the accident prevented the creation of the environmental conditions that could have triggered a disaster of similar nature to the accident in Bhopal.

This highlights why providing adequate support to crisis management in case of major events is one of the first top priority actions at the EU level (AISCAT, 2006). Security concerns on public strategic infrastructures has been given high priority in the EU agenda (EC, 2007a,b) since the 9/11 events and following attacks to Madrid and London (BBC News, 2004, 2005). Initiatives such as the proposal for an EU Directive on "the Identification and Designation of European Critical Infrastructure and the Assessment of the Need to Improve their Protection" clearly show how security is high on the agenda at EU level (EC, 2006a,b).

2. The Role of GeoVisual Analytics

The aforementioned scenario highlights the importance of being able to react to critical events during an environmental crisis. This is a crucial skill for crisis managers who need to be supported by proper tools and comprehensive training. Operators typically need to be capable to access, distribute and process a wide range of Geographic Information (GI) and to have access to tools supporting tactical actions within large-scale decision-making processes. This information needs to be augmented with information retrieved from real-time sensors and monitoring systems. The fast growth of available information, the widespread access to technologies to access and process GI, the availability of increasingly precise localization technologies (e.g., GALILEO) and the ubiquitous access to wireless communication infrastructures (Wi-Fi, WiMax, H3G, etc.), create a new scenario requiring new techniques that can maximize the benefit of such data-rich context, avoiding potential information overloads. Such a fast growth in fact requires new approaches that can maximize the advantages of what otherwise could become a potential information overload (Keim et al., 2008).

An ideal system should support operators with the largest possible set of automatic or semi-automatic processes and it should be capable to support them to interpret specific data patterns potentially triggering early warnings. Crisis managers need to be supported by simulation systems capable to respond interactively to the managers' actions. Through a complex iterative process the operators need to move from data to information, to awareness, to knowledge, turning raw data into understandable pieces of intelligence.

The domain of Geo-Visual Analytics (GVA) (Thomas and Cook, 2005, 2006) provides an answer to the aforementioned scenario through the development of techniques and tools capable to identify relevant data or information pattern within a vast information flow made of multidimensional geographical data coming from databases, as well as from traffic, pollution or environmental sensors. The strategic importance of the domain of Geo-Visual Analytics (GVA) is proved both by the large number of initiatives a the EU level and by the increasing funds made available by the US government to centers operating in the field of VA[1] (Kohlhammer, 2007).

However, in the context of environmental security, GVA needs to face a number of challenges, which will be discussed in the following sections:

1. The importance of harmonization of environmental data access and processing
2. The role of GI-based technologies for a sustainable development and protection of the environment
3. Advanced Interactive Visualization and Analysis for environmental security
4. International, regional and national legal frameworks and constraints
5. Political, economical and social factors in the protection of the environment

Each of these five issues echoes a challenge tackled during the NATO Advanced Research Workshop (ARW) corresponding to a section within this book. Within each section a number of different contributions provide an overview of the state of the art, they present current limitations, leading-edge research activities as well as best practices.

3. The Importance of Harmonization of Environmental Data Access and Processing

The availability of information on the environment has significantly increased over the last few years. Today digital information includes high-resolution satellite imagery, digital maps, economic, social, and demographic information. Popular software solutions such as Microsoft Virtual Earth, NASA WorldWind, Google Maps and Google Earth have exposed to the wide public an extremely large set of data with global coverage. Citizens today can easily get access to an unprecedented amount of information at global scale related to the environment. This information is constantly increasing both in terms of resolution and quality. The widespread diffusion of geo-databases containing information on the environment, as well as technological developments in the field of sensor networks, have made it possible to access a significant amount of real-time or near-real-time measurements of a number of indicators of environmental interest.

[1] US investments in the VA field have raised, between 2004 and 2007, from 4 to 40 Mil. US$ (Kohlhammer, 2007).

The availability of such a vast range of publicly available information is being used to provide citizens with a variety of new services. This in turn is causing a profound evolution in the way people access environmental information, as testified by the number of web applications and mash ups using geospatial data. In fact today people can have ubiquitous access, through a simple web browser, to Petabytes[2] of imagery and vector information at global scale. However the uncontrolled exposition of such a vast amount of data to the public is raising serious concerns, as this provides an extremely rich source of information which can be potentially misused to plot actions threatening the environment.

This fact unveils a paradoxical scenario in that, while common citizens have gained easy access to high-resolution global information, operators engaged at different level in the process of environmental control, face an increasing decentralization of the information available at the public administration level, which prevents them from get fast access to the wide set of additional information required to ensure the highest level of environmental control.

One of the main causes of this is related to the fact that environmental management is not carried on by a single unit but it typically involves a wide range of geographically distributed departments and public administrations, each maintaining their own repository specifically designed for their mission. As a result information of environmental relevance is often stored within repositories created and maintained by different institutions, whose IT systems are typically made of independent and heterogeneous components, often deployed through combinations of proprietary as well as open source software solutions. IT infrastructures are often tailored to the specific needs of the owner, be this an administration or security corps, with the sole purpose of ensuring access, management, and processing of their data. Further lack of common guidelines has brought, as result, to the adoption of different, often incompatible, data formats, protocols and data models.

This scenario poses serious limitations to the level of control that administrations have over the environment since they heavily rely on having efficient access to the widest range of information and on monitoring and processing of very heterogeneous spatial indicators.

Moreover efficient environmental management has inevitable cross-border implications, as demonstrated during a number of large scale natural environmental disasters affecting areas far beyond national borders. The

[2] Microsoft has recently launched a 15 Petabytes data centre in Boulder (USA) for its software Virtual Earth solution.

complex economical and social interlinking between different countries further amplifies the effects of a potential environmental crisis. At the wider international level the complex decision processes, following a large scale environmental crisis, may involve a large set of competences within different units at different levels, from EU, to national, to the regional authorities.

The aforementioned scenario shows how ensuring harmonized and interoperable access to environmental data, regardless of regional or national borders, is of vital importance. Harmonization and standardization at data, infrastructural and protocol level is essential to avoid the creation of non-interoperable "information islands".

International bodies such as Open Geospatial Consortium, Inc.®, the International Organization for Standardization and the European Committee for Standardization have played a key role through a significant standardize-ation effort in the field of geospatial information, resulting into a vast corpus of standards both in terms of data model and protocols. The relevance paid, at the international level, to the adoption of common standards, protocols, and architectures for the management of spatial information is testified by the large number of initiatives, on both sides of the Atlantic, fostering harmonized access to GI to increase environmental security. At EU level a number of initiatives have been promoted by the European Environmental Agency (EEA), which plays a major role promoting sustainable development at the EU level through the Environmental Action programs. The EEA contributes to the European Environment Information and Observation Network to support the collection and organization of environmental spatial data. Further EEA supports the European Environmental Information System as well as the Shared Environmental Information System to produce and manage software components which will contribute to the forthcoming creation of European Spatial Data Infrastructure – ESDI. The importance of environmental monitoring is also emphasized by the other major actions such as Global Monitoring for Environment and Security, which represents the EU initiative within the Global Earth Observation System of Systems. The latter is promoted by the U.S. Environmental Protection Agency, aims at producing a global infrastructure to support access and transformation of environmental data.

At the EU level environmental protection is being further supported by an international legal framework which promotes harmonization of GI of environmental relevance. At the heart of this framework there is the EU directive for the Infrastructure for Spatial Information in Europe, also known as INSPIRE (2009), in force since May 2007. The legally binding nature of INSPIRE proves the commitment of the EU towards the harmonization of geospatial information. The directive will enforce member states to create highly interoperable infrastructures sharing common data models and adopting common standardized technologies to better support environmental monitoring and planning.

4. The Role of GI-Based Technologies for a Sustainable Development and Protection of the Environment

The aforementioned scenario has been the main driver for a significant research effort from the authors which has brought to the development of reference architecture, to be deployed by public administrations, in order to ensure fast and interoperable access to a vast range of information of environmental relevance.

The need for standardization and interoperability has brought the authors to the development of an architecture supporting the convergence of technologies, policies and procedures necessary to ensure access and fruition of Geographical Information (GI). This convergence, which goes beyond the deployment of a simple technological infrastructure, follows the paradigm often referred to with the term Spatial Data Infrastructures or SDI. The reference architecture developed creates the basis for use of spatial information by the wide community, creating the technological pre-conditions for a number of applications of environmental interest, essential to governmental institutions, to industry, to citizens.

The architecture has been designed to work through a federation of web-service and it has been engineered to be compliant to a number of standards and common data models, in line with forthcoming and legally binding regulations set by INSPIRE. This choice ensures that the system can interoperate with other SDIs regardless of their geographical location and specific software platform.

From a more technical perspective the SDI has been deployed as Service Oriented Architecture (SOA) (W3C, 2004), through the exposition of a variety of different geographical Web-Services (WS) arranged according to the multi-level structure illustrated in Figure 1. Most WS have been developed to ensure compliancy with OGC® Web-service standards, and therefore they shall be referred to as OWS (OGC® Web-service).

The lowest logical level (data level) of the infrastructure ensures the provision of data which is aggregated, processed and then exposed through a middleware which operates as mediator with the highest application level, where applications are deployed. At the data level the complexity typical of the GI available, together with the requirements in terms of reliability, scalability, robustness, data recovery and integrity has required the adoption of an articulated approach. This has included the adoption of Database Management Systems (DBMS) and Geo-Databases based on both proprietary enterprise solutions (e.g., Oracle Database 11g Enterprise Edition) and Free and Open Source Software (FOSS) technologies. To be able to perform 3D analysis the data level has been developed to provide support for 3D data structures including point clouds and Triangle Irregular Network (TIN). The data level has been also designed to support access to real-time or near real-time information coming from environmental sensors.

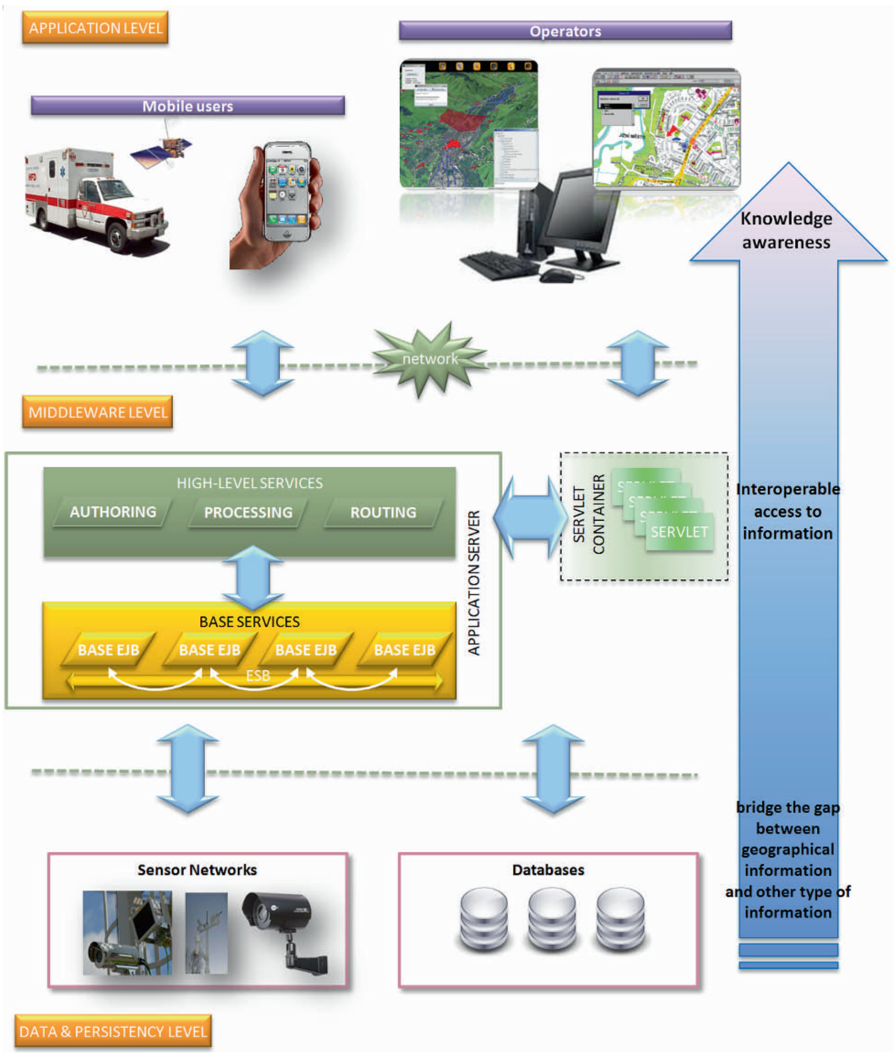

Figure 1. The multi-level architecture developed.

At higher logical level, a set of OWS make a complex middleware capable to expose a large number of functionalities, exposing both low level and high level services. Low level services have been developed to provide access and update of GI in line with national and international standards. More specifically, in line with INSPIRE directive[3] the infrastructure developed features discovery services, including Catalog Services for the Web (CS-W); view services including Web Map Service (WMS), Web Map Tiling Service (WMTS) and Web Feature Service (WFS-T); download services and transformation services. The middleware features services capable provide interoperable access to information coming from sensors, providing support to a number of standards belonging to OGC® Sensor Web Enablement (SWE) initiative, including Sensor Observation Service (SOS), to cluster and expose sensor data, Sensor Alert Service (SAS), to define alert conditions, and SensorML, describing the formalism necessary to describe sensors. Moreover a number of high-level services have been developed to expose complex processing functionalities as Web Processing Service (WPS) as detailed in the following sections.

Each middleware component has been developed on top of the web-oriented Enterprise platform Java Enterprise Edition (JEE) where the business logic of each component of the middleware has been deployed as an Enterprise Java Bean (EJB). EJB can communicate with other components at various levels that is through an Enterprise Service Bus (ESB) thus providing a communication infrastructure that removes any direct connection between service consumers and providers, through Remote Method Invocation (RMI) as well as through a messaging system based on Java Message Service (JMS) based on Message Driven Beans (MDB).

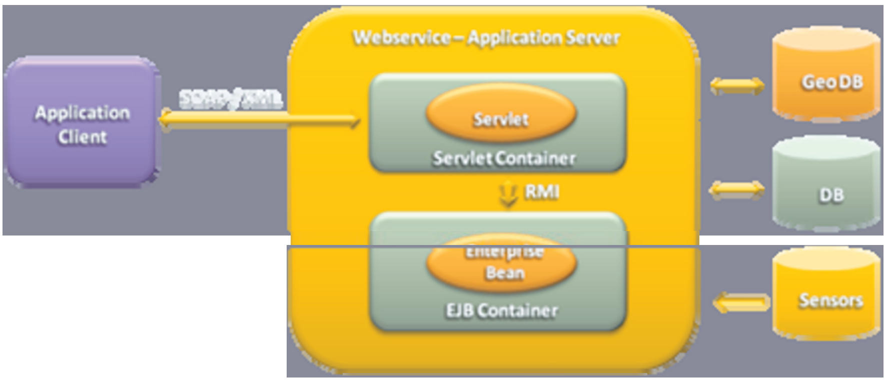

Figure 2. A diagram illustrating how an EJB is coupled to a Java Servlet to expose business logic functionalities via web service.

[3] Cfr. INSPIRE directive, Article 11 (EC, 2007b).

Finally, as illustrated in Figure 2 it is possible to access functionalities of each EJB via web-service by coupling each EJB to a Java Servlet, exposed on the network through a servlet container (e.g., Apache Tomcat), which in turn communicates with the EJB via RMI.

5. Advanced Interactive Visualization and Analysis for Environmental Security

At the highest logical level of the software infrastructure illustrated in Figure 1, there are a number of applications engineered to support decision making and improve preparedness among cross-department teams dealing with different aspects of environmental management.

The challenge faced by the authors was to develop a single interactive 3D environment capable to provide support to monitoring and planning activities which could ensure access, process, filtering and representation of large geographical repositories characterized by high dimensionality and variability over time, embedding complex relationships related to different territorial factors.

The resulting application allows ubiquitous access to GI and to processing tools through the services exposed by the SDI. To maximize accessibility, the application has been developed as Java multi-platform solution, deployable as standalone client as well as web-based application thus ensuring integration with existing web portals. The application provides the user with a number of GVA functionalities to help them reduce complexity present within the information flow and to help them formulate theories and conclusions in an interactive manner.

To do so the authors have adopted an integrated approach between advanced visualization technologies, human–computer interaction, data processing, indexing, intelligent extraction and filtering of data thus ensuring that information, results of simulations and specific conditions can be connected through formal logic relationships. This approach has been useful to support operators to gain both a global comprehension of the environmental phenomena as well as to be able to focus on specific data patterns and their relevant attributes.

The application benefits from the software framework previously described, in that the SDI becomes the core of a GeoVisual Analytics (GVA) solution capable to provide ubiquitous access to GI and to processing services. The latter become the building blocks of an interactive GVA application capable to ensure a better understanding the environment, to increase prediction of disasters and to reduce risks of environmental threats.

5.1. USER-CENTERED DESIGN

The specific solution developed has been engineered to ensure user-friendly access to analytical tools, through an interactive application capable to ensure access, update, process and analyze GI within a single interactive environment.

Delivering user-friendly solutions was considered of high priority, as an essential pre-condition was to facilitate exchange and dissemination of spatial information among different stakeholders, each with different professional background, who need to access a vast set of heterogeneous data within a mission critical context.

The challenge taken up by the authors has been to develop a platform for GVA capable to ensure the convergence of tools for analysis and synthesis, by addressing, in an epistemological manner, the typical problems of decision-making within the environmental process. As a result the development had to deliver interaction metaphors capable of explicitly supporting the methodology at the basis of decision making process.

This approach has required addressing the problem from both theoretical and methodological point of view. For this reason a first detailed analysis of the domain and user requirements has been carried on, with the purpose of understanding the language, culture and processes typical of the different operators involved in environmental management. The analysis then followed an approach typical of operational epistemology, by identifying, for each of the vertical domains progressively addressed, the most appropriate strategy to be adopted to ensure the best possible support to the process of knowledge acquisition typical of each group of operators.

The final result of the analysis was the modeling – as workflow – of the different operators' activities. Eventually for each of these a set of automatic and/or semi-automated procedures, designed for a given segment of the workflow, were developed and used as the basis of the GeoVisual Analytics capabilities featured by the system.

The different building blocks of a typical workflow had to ensure processing, filtering and representation of large geographical repositories characterized by high dimensionality and variability over time, embedding complex relationships related to the different territorial factors. This approach has resulted in an interaction metaphor capable to blend with the users' typical working activities, thus significantly reducing their cognitive load, enabling operators to focus on the task to be performed rather than on the function to be deployed to accomplish it.

Components of the workflow can be used to access a variety of spatial information and to provide support for complex analytical tools through the composition of elementary processing units connected by formal logic relationships.

As illustrated in Figure 3 the interface uses a graph-based visual metaphor to represent processing components directly within the 3D scene. This is used to guide the entire analytical process, from data access and integration, to the presentation of the results of the analysis.

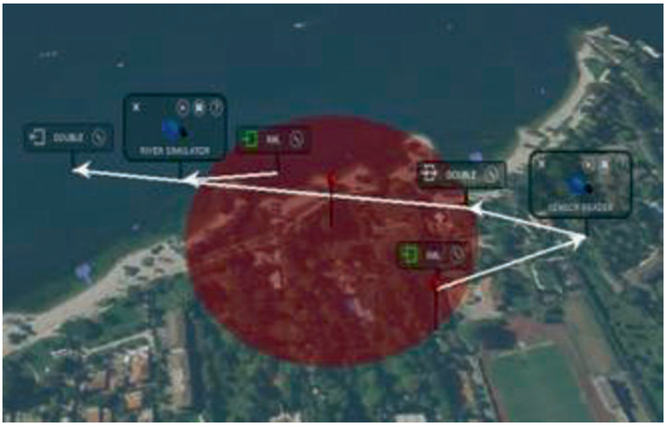

Figure 3. An example of process chaining.

Taking advantage of the service oriented nature of the SDI, the GVA application ensures interactive access to automatic or semi-automatic process-sing functionalities which are exposed across the network as web-services. Processing services can be used by operators to access information, to perform simulations and to identify specific conditions or data patterns. Services can be used to expose both low level processes, e.g., to ensure pre-processing or geo-reference data, as well as high-level processes, necessary for instance to provide automatic feature recognition, to ensure extraction of thematic maps, to assess risks, etc.

To ensure maximum interoperability, processing services have been built on top of standard WPS (OGC®, 2009e) protocol and can be interfaced to other standard-compliant web services available within the SDI (e.g., WMS and WFS). WPS is a standard service supporting asynchronous processing over the network which can be used to expose both new and existing functionalities which can be made interoperable through the SOA. This approach ensures that computational functionalities necessary to run simulations of environmental interest are accessible in a fully interoperable manner.

The client application provides automatically an interactive graphical representation of the processing functionalities available across the SDI, providing access through a 3D pie or a graph-based interface (see Figure 4).

Figure 4. Processing functionalities available are rendered as 3D pie or a graph.

The type and name of each process is automatically retrieved from the WPS server through the relevant metadata. When a process is dragged from the interface onto the 3D scene, this is represented as a 3D icon (see Figure 5), with an additional set of commands used to execute the process or to retrieve all the information available as metadata. A process can be composed up to three distinct types of components, the process controller, one or more input slots and one or more output slots.

Figure 5. The representation of a process.

As visible in Figure 5 the process controller has four distinct commands (from left to right) used to remove the process and all associated results, to execute the process together with all dependent processes, to stop the process (whenever possible) and, finally, to display information available about the process. This can be used, depending on the data type, to save the XML content as a file, to visualize text in a window, to represent a 3D shape or to render an image on the terrain.

With regard to how data are processed, every process can be considered as a black box that can receive input and transmit results to a further process. Each input and an output slot is automatically created through a process description exposed by the WPS. The only information visible to the user is the information required as input and the resulting output represented by different icons rendered on each slot.

Figure 6. Creation of a connection between WPS.

Figure 7. Breaking a connection between WPS.

The exchange of information among process is possible through the adoption of formal logic relationships. This can be done by composing several elementary processing units into process chains that can be used to perform complex functionalities. Input slots can be connected to compatible output slots as well as to results of user's commands (e.g., a selection identifying a specific area within the environment). To create a connection the operator drags the input slot over the output slot (or vice-versa) as illustrated in Figure 6. When the user drags an in-slot next to an out–slot – if of compatible data type – they snap together as visible in Figure 7, creating a logical bridge which can be interrupted by the user if required. When this is done the process chain is broken and the original structure is replaced.

As each block of the chain represents a processing service operators can perform very articulated web-service orchestration in a completely transparent way. This approach has proved to be extremely user-friendly and it allows performing complex processing tasks with very little training.

Furthermore, specific processing functionalities can be constrained to specific areas of the territory, for instance in case of localized simulations. For this the user can interactively select, directly within the 3D scene, a specific area defining the area of interest.

This approach has a number of advantages in terms of usability and scalability as illustrated in previous works of the authors (De Amicis et al., 2009; Encarnação et al., 2008). This approach allows, from the technical point of view, to operate, in a very user friendly way, complex web-service orchestration. When a process is invoked, the communication across the relevant corresponding web services is established, and all the input/output values are encoded and transmitted as soon as these are available.

Such a modular approach, applied to the context of GVA, is extremely flexible in that processing functionalities reside at the server side, allowing for unlimited scalability, and it is suited to a wide range of solutions including but not limited to:

- **Remote sensing technologies**: through the development of processes using information captured by sensors or through active and passive earth observation technologies.
- **Processing technologies**: through the development of tools capable to transform raw data (signals and images) into geo-referenced, geometrically correct, pre-processed data at the relevant scale with all properties necessary to allow a correct visualization.
- **Automatic recognition technologies**: through the development of pattern recognition processes capable to operate automatic classification from earth observation data.
- **Data aggregation and fusion**: to merge sensed data with other available sources (ancillary data, information from ground sensors or proximal sensing, etc.) and high level components (recognition of multi-sensor/multi source data).
- **Technologies to extract information** from geometric information capable to extract information on the shape semantics relatively to a specific geographical feature.

The 3D interface is extended to other functionalities of the system and it becomes particularly useful when dealing with numeric datasets, for example, when the user needs to access real time data from a sensor station located on the terrain. This could be for instance a river water level, compound weather information (barometer, humidity, visibility, wind direction, etc.) all retrieved in real time through web services. In this case the 3D interface is used to represent the information related to the respective dataset, as illustrated in the example of Figure 8, where the height of a 3D pie is used to represent the most recent data available from the sensor whilst the close-by arrow, indicates the trend of the variation of the data set.

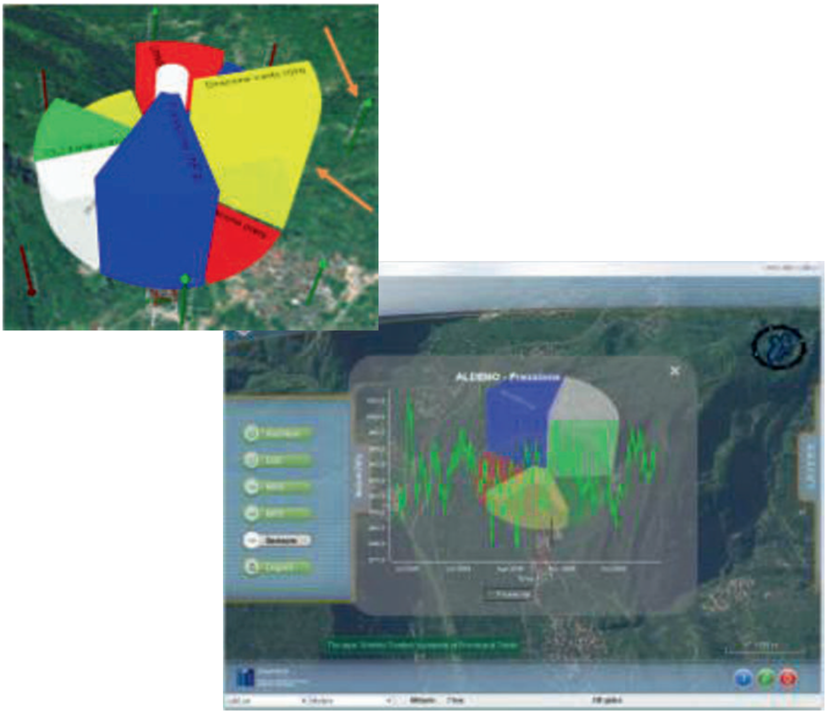

Figure 8. Example of 3D interface used to represent sensor data.

Most importantly, as illustrated in Figure 9, this modular approach can potentially benefit from the evolution, in terms of hardware and software, which has brought to new computational techniques such as Cloud or GRID computing by exposing processing functionalities as Web Processing Service GRID (WPS-G) (Baranski, 2008). Several EU initiatives such as SCIER – Sensors & Computing Infrastructure for Environmental Risk (SCIER, 2009), whose results are described in one of the following chapters, show the great potential of the use of GRID technologies in the geospatial domain.

This approach has a further advantage in that it is completely hardware transparent. This allows development of complex processing architectures capable of benefitting from the recent availability of hybrid hardware platforms combining multi-core CPU with multi-GPU (Graphics Processing Unit). The fast development of technologies such as CUDA™ (nVidia, 2009) or the recently released CUDASA (Compute Unified Device and Systems Architecture) (Strengert et al., 2008) can be all used within this framework to benefit of the adoption of GPUs to process non-graphical data,

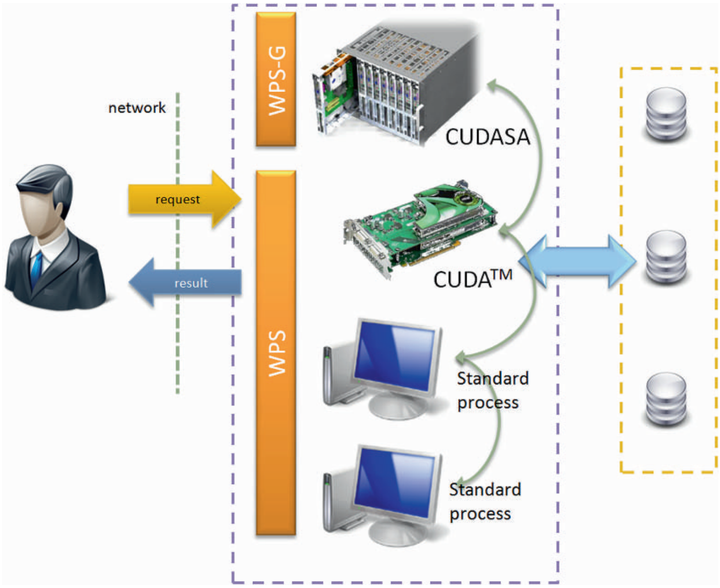

Figure 9. Overall process general mechanism based on WPS.

5.2. A CASE STUDY

A practical use case, adopted to validate the efficacy of the interface, will help us illustrate the potential of the application. In the use case described operators have been asked to use the system to simulate the effects of major floods and to identify the population to be evacuated.

As shown in Figure 10 the operator selects a number of services and creates the required process chain. The first process operates as filter, identifying those sensors available within a region selected by the user. The process, as result, identifies one sensor, which returns the river level in real time. The identified sensor is passed to the second process together with an additional input defining the simulated increased river water level (e.g., 5 m). The second sensor uses these two pieces of information, together with the area previously selected by the user, to calculate the flood within the area delimited by the selection. The output of the process is the contour of the area affected by the disaster. This information is passed as input to the final processing unit that retrieves the list of streets within the affected area from a spatial database. The process further invokes a public white-pages web-service to identify telephone numbers of those leaving on each endangered street. Their address is in turn passed to a public geo-coding web-service which returns the corresponding spatial location, used by the service to render a pin in the scene.

Figure 10. The complex process chain used to calculate the flood simulation.

After all processes are connected, the user executes the last process in the chain, that will recursively invoke all the previous process. When the processing is complete, a window appears listing names and contacts of everyone in potential danger. As this information are real names, surnames, addresses and telephone numbers for privacy concerns these are not shown in this chapter. Following a similar approach the operator can create an evacuation plan taking in account attributes like people distribution, road works, optimal paths, etc. that can be calculated in a similar manner by other processes.

5.3. APPLICATION IN REAL CONTEXT

The development illustrated in this chapter is the result of a 3 year long development. The first core system, ensuring access and fruition of geo-spatial data, was in fact developed to ensure access to the Urban Provincial Plan of Trento Province in Italy. In this context the framework was essential to provide operators and planners with a tool that could give them fast and interoperable access to the vast set of data necessary to verify the validity of the plan, at provincial scale, through cross-checking among a variety of different data sets. The sheer size of the plan and the limited time available required a new tool ensuring high performance and accuracy.

The initial set of low level OGC-compliant web-services (based on WMS) was further extended to include support to a variety of OCG standards including, but not limited to, WMS, WFS-T, WPS, etc. with the resulting infrastructure setting the basis for the development of a local SDI. Concurrently, at application level, the original geo-browser has gone through extensive re-engineering, including functionalities typical of Decision Support Systems, delivering a complete GVA application.

6. International, Regional and National Legal Frameworks and Constraints

The technological vision illustrated so far can deliver tangible results only if it is framed within a legal framework that ensures a coherent strategy from regional to national level and beyond. For this reason the choice has been to design the entire infrastructure in line with the forthcoming European legal framework set by the INSPIRE directive (EC, 2007a,b; INSPIRE, 2009). The directive, in fact, represents the most relevant EU initiative to harmonize Geographical Information of environmental relevance, obliging member states to create highly interoperable, web-service-based, Spatial Data Infrastructures (SDI), sharing common data models and adopting common standardized technologies to better support environmental monitoring.

7. Political, Economical and Social Factors in the Protection of the Environment

It is important to underline that the results of this work answer not only to technological and legal requirements clearly respond to a number of political, economical and social issues. In fact, as reported by United Nations Population Fund, since the end of 2008 for the first time in human history more than half of the planet's population is now residing in urban areas. This results in new level of insecurity as results of increased pressure on the environment. Examples of this are both visible in developing countries, where there are some of the fastest growing cities in the world (Cohen, 2006), as well as within developed countries, with one notable example being the waste crisis occurred in the south of Italy on 2008 (IEMA, 2008). Recent events have clearly shown that the political, social and economical costs of such environmental crisis can be extremely high.

The clear need for such GVA-based technologies is stressed by the steadily increasing number of natural disasters in the last 30 years. This is affecting both developed countries, as dramatically proved by recent events such as hurricane Katrina, as well as developing countries (Grasso et al., 2006, 2008) as the large part of 700+ catastrophes occurring in the world every year affect parts of the world with high poverty rate (Hernandez et al., 2004). The importance of providing fast access to environmental information such as GI, satellite imagery has proved essential to support post-event rescue operations as demonstrated in the aftermath of events such as hurricane Katrina, the Indian Ocean tsunami (Laituri and Kodrich, 2008) or the 2005 earthquake in Pakistan (Nourbakhsh, 2006). Providing fast access to environmental geospatial data has been also essential pre-condition to create Decision Support Systems (DDS).

In addition to accidents caused by man-made or major weather-related events, terrorist attacks represent today a significant environmental threat. The consequent disruption as well as social and economical costs caused by a large scale environmental crisis can be enormous. Environmental and social consequences of accidents can be devastating. As highlighted by Čišić et al. (2007) a Liquid Natural Gas (LNG) tanker, holding up to 3.3 million tons of liquefied gas, if targeted by terrorists can be used as a weapon of mass destruction. In this context ensuring an adequate level of security is increasingly more difficult.

As highlighted throughout this chapter the convergence of two traditionally different domains, Visual Analytics and Geographical Information, can deliver effective solutions to help operators better protecting the environment. The resulting discipline of GeoVisual Analytics can be in fact the key enabling technology delivering higher context awareness and a better understanding of the environment, essential to improve prediction of disasters, to better protect human lives and to reduce cost caused by environmental threats.

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GIS & VISUAL ANALYTICS ON GRID TECHNOLOGY

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Abstract. To prevent casualties both in human lives and in private/public property due to Environmental Hazards such as Floods or Forest Fires, it is required that large-scale Integrated Technological Systems are developed to detect in time an imminent event. Such Systems use highly efficient computational engines to perform simulations on natural phenomena in real time, they use web-applications to retrieve Geographic and Meteorological Information to be used as input for the aforementioned Simulation Models, they visualize simulation-output via GIS technology so that the visual result meets high quality standards in terms of information mapping. Technology, Architecture and Design of such a System is presented in this chapter.

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1. Introduction

Natural Hazards and Emergency Management Systems, EMS, (e.g., floods, wildland fires) requires utilization of large-scale computational systems based on Visual Analytics. These systems can: (i) monitor large geographical areas, assess risk-levels in real time based on environmental and meteorological data obtained from sensing infrastructures, and (ii) perform simulations aimed to predicting the spatial and temporal evolution of the imminent events. Based on simulations and real life estimates, the emergency event is managed by the authorities (e.g., Fire Brigade, Police, Forest service) via system optimization techniques indicating optimal allocation of resources (e.g., aircrafts, fire-fighters), optimal procedures and population notification, based on Visual Analytics.

Simulations and visualization are based on mathematical models and vast data input. A cornerstone of the data input is the geographical information (GI) on: (i) geomorphology and environmental parameters (e.g., climatology, land-vegetation), (ii) social and economic parameters (e.g., characteristics of human patterns in the region, social and economic parameters), (iii) regional event relayed parameters (e.g., soil fueling), and (iv) other parameters (e.g., historic record). Simulations and input-output is today based on GIS Visual Analytics.

This presentation reports on the SCIER[1] *GIS Visual Analytics* (www.scier.eu) a project supported by the European Commission. SCIER offers an Emergency Management Platform for Forest Fires and Floods (current level), based on GIS Visual Analytics operational on GRID computational technology, as of the heavy computational load and others reasons (e.g., distributed availability of models, data and technologies) emerging during a hazardous situation requiring immediate attention and security response.

2. System Overview

Environmental hazards such as forest fires and floods can cause a large number of human casualties in areas where rural and urban environments meet (e.g., forests or rivers near/along thinly populated areas). An early

[1] SCIER: Sensing & Computing Infrastructure for Environmental Risks, European Commission Contract FP6-2005-IST-5-035164, Directorate General Information Society & Media. 200 Rue de la Loi, B-1049 Brussels, Belgium, www.scier.eu

warning for a forthcoming event can prevent loss of human lives and private/public property. To this end, an emergency management system requires at least (Figure 1):

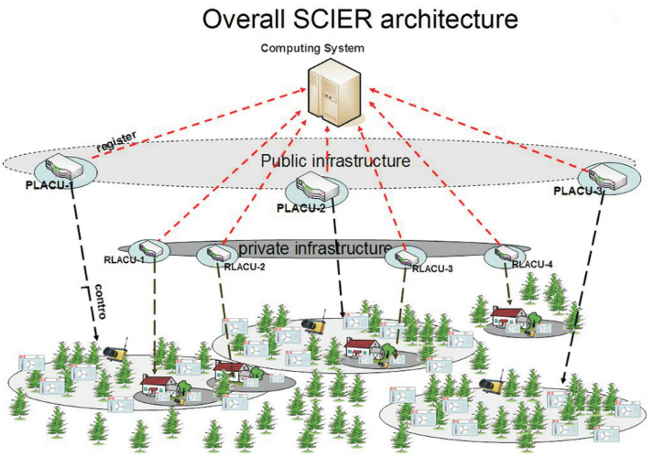

Figure 1. Sensors system architecture to managing environmental emergency (Metelka and Bonazountas, 2007).

1. A well organized, state-of-the-art wireless sensors network (WSN) deployed along the area of interest, for monitoring environmental parameters such as rain precipitation, river water levels (flood), temperature, wind speed, relative humidity, smoke-flames (e.g., via cameras/visual sensors for wildland fire) (Raghavendra et al., 2004).
2. A local area control unit (LACU) aimed to configuring and administrating the attached WSN.
3. A GIS-server-module for providing simulation-models with geodata on the area of interest, and for delivering to the end-user Visual Analytics and graphical interfaces for simulation-results visualization, making decisions easy and efficient to interact with the overall EMS.
4. A central computing system (CCS) where simulation models are executed and data from measurements are collected, stored and statistically elaborated so that the risk is assessed. The architecture of such as system is depicted in Figure 2.

Computational complexity in environmental modeling is high for both floods and forest fires. On the other hand, such Emergency Management Systems receive a large volume of input-data, execute simulations, and must deliver results in real time at a high speed.

To meet the above demand, systems of high computational power with GIs and Graphic User Interfaces (GUIs) are employed, and public authorities are provided with tools capable to respond fast to hazards and inform/

protect citizens. GRID and Visual Analytics technologies meet such computational requirements, and SCIER is one example offering such technology.

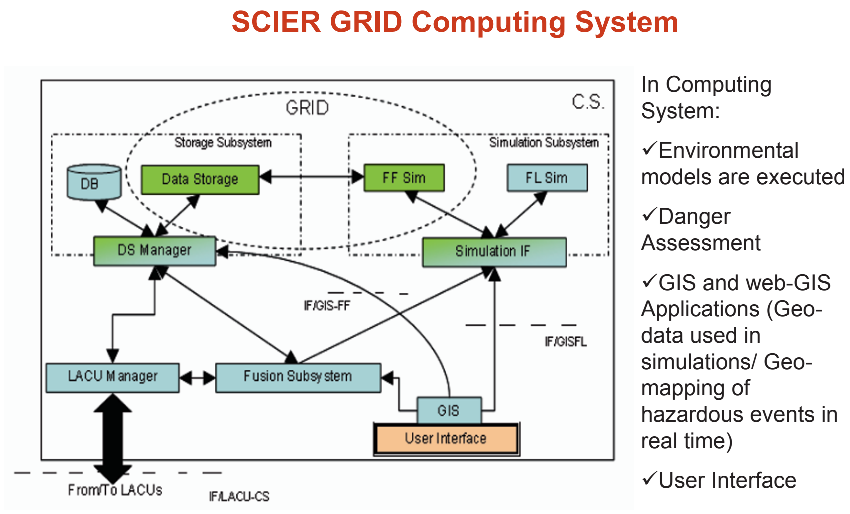

Figure 2. SCIER GIS and visual analysis on GRID Technology (www.scier.eu).

3. GRID Technology

GRID consists from a cluster of computationally efficient machines. Computational tasks are distributed accordingly along the cluster so that calculations speed up. All operations and protocols for distributed computing are transparent to the end-user. This is remarkable, since no change in the s/w code is required, i.e., the user simply uploads a source code developed for an ordinary computing machine on the GRID and after tasks are executed, an output is obtained. The SCIER GIS technology on GRID is depicted in Figure 3.

3.1. GRID COMPUTATIONAL COMPLEXITY IN CASE OF WILDLAND FIRE SIMULATION

A vast part of physical–empirical–mathematical models has been developed the last decades (Frandsen, 1971; Rothermel, 1972), etc.; let us leave aside the *minor differences between models* and say that *more or less*, all forest fire models simulate the spatiotemporal evolution of a fire given some specific meteorological conditions (e.g., temperature, wind speed, wind direction) and a specific terrain geomorphology with its on-ground-vegetation (i.e., fuel maps). In addition: (i) on the one hand, computational burden of the aforementioned models rises with input-data volume, namely, either with larger areas under surveillance or with higher spatial resolution, and (ii) on the other hand, it is customary that simulations are not triggered for just one static scenario of meteorological conditions.

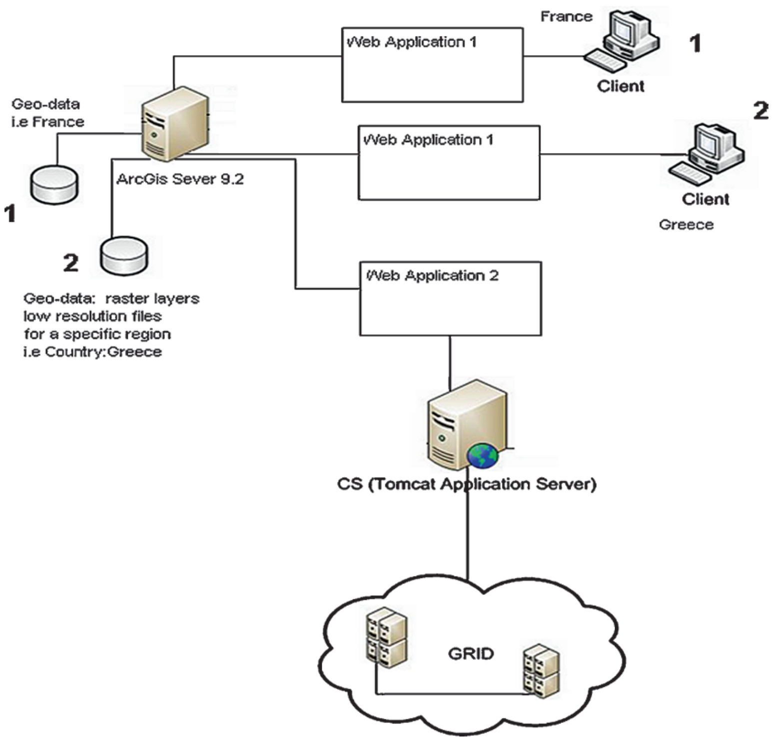

Figure 3. Integration of GI System via Web applications (www.scier.eu).

Thus, several dynamic scenarios are usually generated: on the wind field for instance along the area of interest (i) an initial scenario is generated by extrapolating in space, both measurements from sensors and short-time predictions from meteorological services, (ii) then, this scenario is replicated into *N* versions which are perturbed compared to the initial scenario; as a result, N-meteo-scenarios lead to N-simulations; (iii) this set of simulations generates in turn a set of possible disaster scenarios, and finally (iv) all scenarios get a score as the event evolves and the most unrealistic of them are filtered.

3.2. GRID ARCHITECTURE AND INTEGRATION

The above-mentioned task demands a highly efficient computational system based on GRID (Foster et al., 2003). To collaborate with the rest of the System, the GRID has an interface which receives all tasks and then distributes them in the cluster. This particular the interface makes the internal operations transparent to the user while it handles all requests for simulations: usually a simple schema is preferred such as a First-In-First-Out (FIFO) queue for all incoming requests.

4. GRID GIS Module

The GRID-GIS and Visual Analytics module is the core of the application. Next, this is presented according to its operation for wildland and flood simulations.

4.1. GRID GIS FOR WILDLAND FIRE SIMULATION

Within the context of a fully integrated system for managing environmental emergencies due to wildland fires, the user (e.g., Civil Protection Authority) should be able to monitor in real time the area of interest and interact with the rest of the system (e.g., GRID, Simulation Models) via a friendly GIS interface: information concerning the WSN (e.g., measurements, type of sensor, coordinates) should be visualized in real-time on a reference-map while the user should be able to select on the map a sub-area of interest by a simple crop-procedure, then define a number of fire-ignition points and finally trigger a simulation. In case that an event actually occurs, results on the spatiotemporal evolution of the fire should be visualized on the map. The SCIER web application portal is shown in Figure 4.

We distinct two web applications:

- *Web application 1*: the GIS module (server) provides the user with a friendly GIS Interface. The user, can visualize the area of interest, trigger a simulation and then watch the results.
- *Web application 2*: the GIS module communicates with the rest of the System through the CS. This application is more complex: it implements all necessary protocols between the two components. For instance, it makes sure that the user's requests for simulations are received at the GRID, input/output geo-files are delivered and received safely in both directions, the WSN is monitored and it is visible to the user through the map in real time.

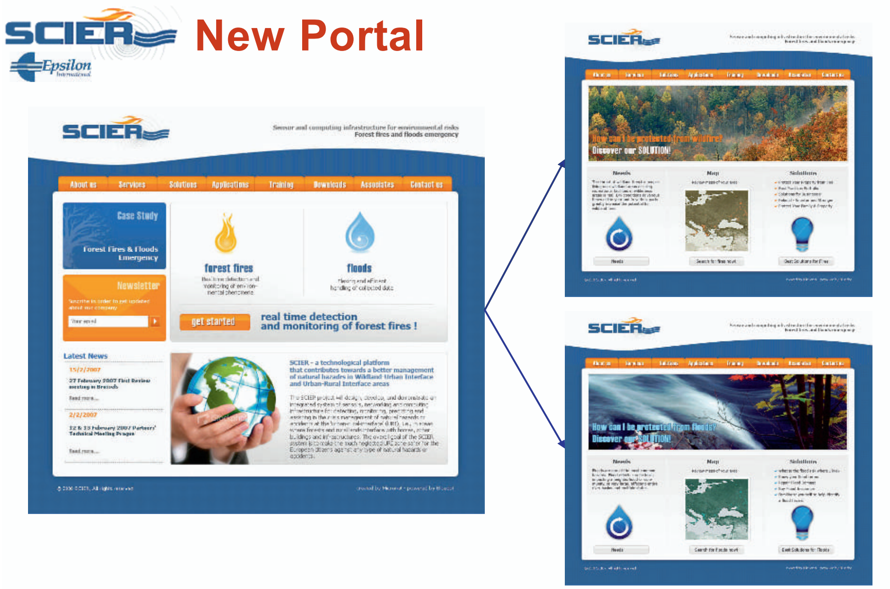

Figure 4. The SCIER GIS and visualization portal (www.scier.eu).

It is worth mentioning that a small set of raster files containing GI is necessary to run the fire simulation model. In fact, only a few files are necessary, precisely those containing information on the aspect and the slope of the particular terrain, as well as information on the use of land and the vegetation (fuel maps). All other input are files of similar format, they contain though meteorological data. Besides, they are not stored in the GIS-database but are created in-real time according to measurements received from sensors and short-term forecasts received from meteo-services.

All above-mentioned files contain information in a low spatial resolution since there is no need to feed the model with details. Otherwise, for a full set of GIS-files with high resolution, it would have been impossible to transfer via the web such a large volume of data in real-time.

Notice however, that a full set of GIS raster files contained in the database of the system is used to set a reference map. On this map the spatio-temporal evolution of a fire event is visualized. Modern GIS technology can deliver on-map visualizations of high-quality standards.

The simulations are validated in Gestosa, Portugal (Figure 5).

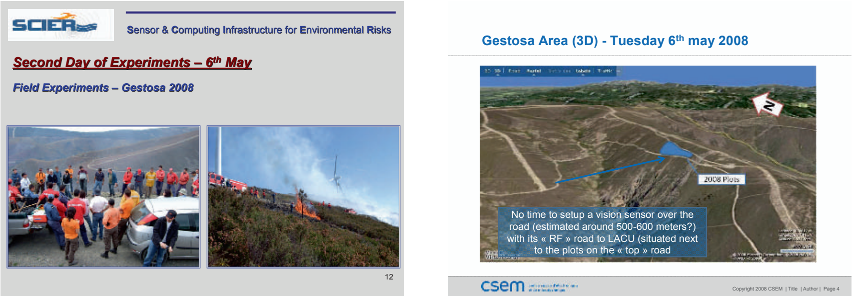

Figure 5. Field validation experiments: 6 May 2008, Gestosa, Portugal (www.scier.eu).

4.2. GRID GIS AND VISUAL ANALYTICS FOR FLOOD SIMULATION

Flood simulation requires as well GI for the morphology of the river basin, the terrain layout for areas along river side, etc. This information is *empirically* embodied in the mathematical simulation model during set-up and configuration procedures (MIKE 11, 2000).

Measurements on the water-level coming from sensors as well as measurements and forecasts on Rain Precipitation are used as initial conditions for the model. Simulation results to a scenario on water level. This particular level generates a flood map. This map is visualized via the GIS module. These maps are usually pre-calculated and stored inside the GIS module. So when a simulation returns a prediction on a water level, the corresponding map appears on screen (Figure 6).

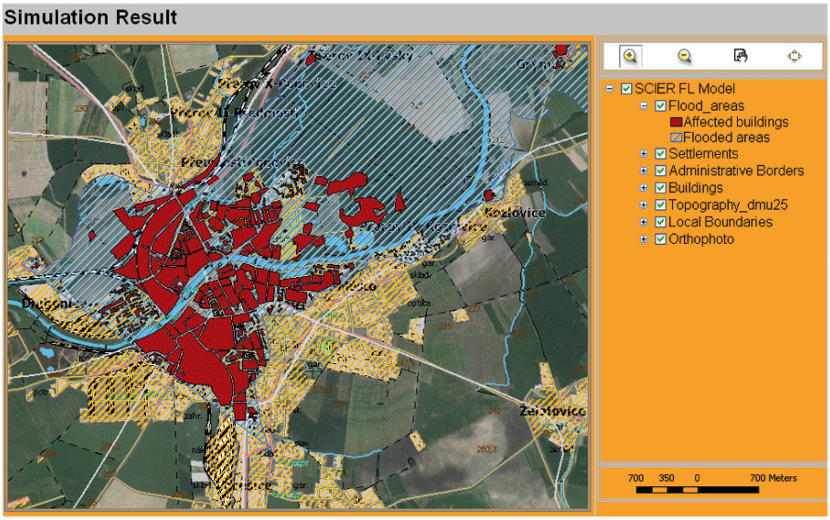

Figure 6. Visualization of a flood scenario, Czech Republic (www.scier.eu).

5. The SCIER GIS and Visualization Platform

SCIER stands for Sensing and Computing Infrastructure for Environmental Risks. It is developed by a consortium of 14 European partners and is co-funded by the European Commission (EC). SCIER's design and architecture reflects all specifications described above. The SCIER GIS and visualization infrastructure is operational on www.scier.eu, Figure 4.

A WSN network is used which carries sensors for measuring environmental parameters such as temperature, humidity, wind speed, wind direction, rain precipitation as well as vision sensors – cameras – which monitor the area of interest and they are "trained" to detect fire/smoke by using pattern recognition algorithms.

A computing infrastructure which receives and elaborates data from measurements, assesses the risk-level and it triggers simulations or, informs the user on the imminent danger. The grid is a sub-component of this infrastructure and it is supported by the GRNET, the Hellenic GRID Network.

The GIS module is delivered on ESRI, Inc.™ technology. GI is stored in a database in Munich, and both web applications described above are implemented via an ArcGIS server 9.2. This particular s/w has embedded libraries which support a variety of data-file formats and graphics implementations.

For example, Figure 5 shows the GUI in case of flood simulation. Through this interface the user is able to access all recent simulations indexed according to starting/ending time. He/she can choose which simulation to visualize. An example of a flood event for a city in Czech Republic is depicted.

For flood simulation, a 1-dimensional mathematical model for river hydraulics is used. The model has been developed by DHI (www.dhi.dk), the MIKE 11 HD (MIKE 11, 2000). For forest fire simulation, a slightly modified version of "BEHAVE" (Rothermel, 1972; Andrews, 1986) model is used.

An important aspect when developing management platforms based on modeling and GIS visualization platforms is the systems validation. SCIER validations are performed into the laboratory, via field experiments (Figure 5) and via field trials (Figure 7).

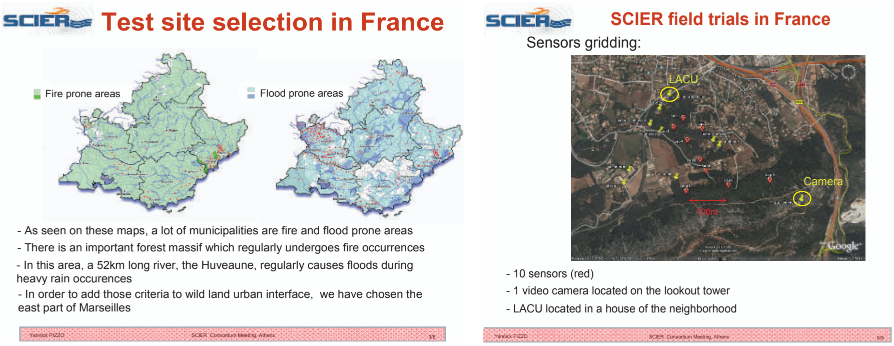

Figure 7. SCIER field trials in France (www.scier.eu).

6. Conclusions

Reference citation is by name and year, the text citation may take one of the technological innovation in GIS and computational systems, can deliver integrated technological platforms which can monitor a large geographical area, receive measurements and short-term forecasts on environmental parameters, run simulation models on physical disasters and return to the user crucial information via a user-friendly, graphical-map interface. Specifically, new s/w products for GIS and web-GIS applications can handle a variety of data, can ensure inter-operability between different GIS technologies – Google, Microsoft, ESRI – and can deliver graphical and map services of high quality.

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VISUAL ANALYTICS FOR THE STRATEGIC DECISION MAKING PROCESS

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Abstract. The collection and storage of huge amounts of data is no longer a challenge by itself. However, rapidly growing data repositories are creating considerable challenges in many application areas. Visualizations that worked well with a few data items now produce confusing or illegible displays. Decision-makers struggle to act based on a severely restricted understanding of the situation. The goal of Visual Analytics is to overcome this information overload and create new opportunities with these large amounts of data and information. The key challenge is to intelligently combine visualization techniques and analytic algorithms, and to enable the human expert to guide the decision making process. This chapter covers interesting and relevant previous work on situation awareness, naturalistic decision making, and decision-centred visualization. These concepts are put into the context of Visual Analytics research and are further illustrated by application examples.

Keywords: Visual Analytics, Decision Making, Applications.

1. Introduction

In many application areas, vital decisions depend on the right information being available at the right time. Nowadays, the acquisition of raw data is no longer the driving problem: it is the ability to identify methods and models, which can turn the data into reliable and comprehensible knowledge.

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Any technology, that claims to overcome the information overload problem, has to provide answers to the following challenges:

- Who or what defines the "relevance of information" for a given task?
- How can inappropriate procedures in a complex decision making process be identified?
- How can the resulting information be presented in a decision- or task-oriented way?

With every new application, procedures are put to the test possibly under circumstances completely different from the ones under which they have been established. Fully automated search, filter and analysis only work reliably for well-defined and well-understood problems. The path from data to decision is typically quite complex.

The overarching driving vision of Visual Analytics is to turn the information overload into an opportunity: just as *information visualization* has changed our view on databases, the goal of Visual Analytics is to make *our way of processing* data and information transparent for an analytic discourse. The visualization of these processes will provide the means of communicating about them, instead of being left with the results. Visual Analytics will foster the constructive evaluation, correction and rapid improvement of our processes and models and – ultimately – the improvement of our knowledge and our decisions.

2. Overview on Visual Analytics

On a grand scale, Visual Analytics provides technology that combines the strengths of human perception and electronic data processing. Visualization becomes the medium of a semi-automated analytical process, where humans and machines cooperate using their respective distinct capabilities for the most effective results. The diversity of the analytical tasks can not be approached with a single theory. Visual Analytics research is highly interdisciplinary and combines various related research areas such as visualization, data mining, data management, data fusion, statistics and cognitive science (among others). Visual Analytics builds on a variety of related scientific fields. At its heart, Visual Analytics integrates information and scientific visualisation with data management and data analysis technology including spatio-temporal data research, as well as human perception and cognition research (see Figure 1). For effective research, Visual Analytics also requires an appropriate Infrastructure in terms of software and data repositories, and to develop reliable evaluation methodology.

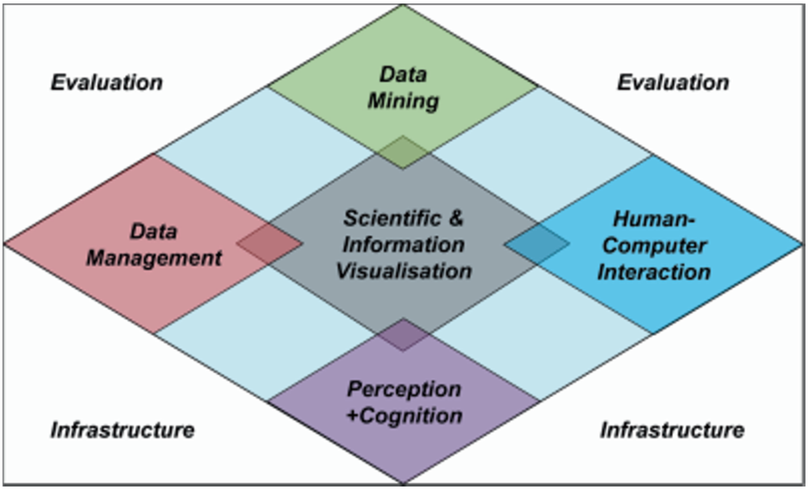

Figure 1. Visual Analytics integrates scientific and information visualization with core adjacent disciplines: data management and analysis, spatio-temporal data, and human perception and cognition.

Information Visualization during the last decade has developed methods for the visualization of abstract data where no explicit spatial references are given (Card et al., 1999; Unwin et al., 2006). Typical examples include business data, demographics data, network graphs and scientific data from, e.g., molecular biology. The data considered often comprises hundreds of dimensions and does not have a natural mapping to display space, which renders standard visualization techniques such as bar-charts ineffective.

An efficient *management of data* of various types and qualities is a key component of Visual Analytics as it typically provides the input of the data that are to be analyzed. Generally, a necessary precondition to perform any kind of data analysis is an integrated and consistent data basis. Finding integrated representations for different data types such as numeric data, graphs, text, audio and video, semi-structured data, and semantic representations is a key challenge of modern database technology.

Data Mining and Analysis researches methods to automatically extract valuable information from raw data by means of automatic analysis algorithms (Maimon and Rokach, 2005) and to approve existing models about the data. It has recently been recognized that visualization and interaction are highly beneficial in arriving at optimal analysis results. In almost all data analysis algorithms a variety of parameters needs to be specified, a problem which is rarely trivial and often needs supervision by a human expert. Visualization is also a suitable means for appropriately communicating the results of the automatic analysis, which often is given in abstract representations, like decision trees. Visual Data Mining methods (Keim and Ward, 2002) try to achieve exactly this.

While many different data types exist, one of the most prominent and ubiquitous data types is data with references to time and space. The importance of this data type has been recognized by a research community which formed around *spatio-temporal data* management and analysis (Andrienko and Andrienko, 2005). In *geospatial* data research, data with geographical references in the real world is considered. Finding spatial relationships and patterns among this data is of special interest, requiring the development of appropriate management, representation and analysis functions. Visualization often plays a key role in the successful analysis of geospatial data.

Effective utilization of the powerful *human perception* system for visual analysis tasks requires the careful design of appropriate human–computer interfaces. Psychology, Sociology, Neurosciences and Design each contribute valuable results to the implementation of effective visual information systems. Research in this area focuses on user-centred analysis and modelling, the development of principles, methods and tools for design of perception-driven, multimodal interaction techniques for visualization and exploration of large information spaces, as well as usability evaluation of such systems (Dix et al., 2003).

3. Decision Making and Visualization

The amount of information a human being can process at any given point in time is rather limited. In this direction, research in psychology and human factors has provided many insights and facts to guide user interface design and information visualization and to help adhere to these human constraints. One particular thread of research, human-centred computing, focuses on how knowledge about the strengths and weaknesses of humans can enhance overall human–machine system performance. This area is important for Visual Analytics and for visual decision support. Human and machine can be seen as two parts of a collaborative system that solves problems and reacts to its environment (Hoffman et al., 2002). From this point of view, the computer is best at fulfilling tasks that are data-intensive but deterministic, while the human is predestined for creative tasks and ambiguous situations. A central challenge is to define a common representation of the situation and to provide for effective and efficient communication between the two. Both sides, human and computer, can influence each other.

Several theories from research in human factors and cognitive science demonstrate different approaches to explain how humans actually come to conclusions and decisions. One of these theories is naturalistic decision making (NDM) that describes how experts make decisions in their natural environments. Studies on situation awareness claim that decision-makers have to be well informed about the current situation on certain awareness levels to increase the probability of a good decision. Both NDM in general and situation awareness in specific have been guiding approaches for decision-centred visualization (Kohlhammer and Zeltzer, 2003). The next sections will introduce these topics and will describe their implications on the current efforts in the area of Visual Analytics.

3.1. VISUALISATION FOR DECISION SUPPORT

It is important for visual decision support and Visual Analytics to understand how humans process information, in particular how people make decisions in real-world environments. Decisions are allocations of resources pursuing some objective. The decision-maker will make decisions consistent with his or her values and preferences, i.e., things important to the decision-maker, especially those relevant to the decision. Decision making is the process of sufficiently reducing uncertainty and doubt to allow the reasonable choice of a course of action (Harris, 1998). The decision environment is defined as all information, values, and preferences available at the time of the decision. Major challenges of decision making are uncertainty and information overload. The more relevant information can be processed, the larger the decision environment will be, and the better the chance for a good decision.

Decision support and training systems have been built in the past to augment human decision making based on models of rational decision making that features the following steps: analyze the situation, find out about alternatives, and select an alternative by certain criteria. These models of decision making assume, that decisions can be broken down into a selection of alternatives by pre-defined criteria, and that the human decision-maker in this process is rational and competent at all times. They are also mainly concerned with deductive logical thinking, analysis of probabilities, and statistical methods. Most importantly though, they downplay human abilities to learn to make good decisions over time, to make decisions under high stress and workload, and to make decisions with ambiguous, incomplete and uncertain data (Zsambok and Klein, 1997).

One specific descriptive theory that explains human decision making is *naturalistic decision making* (NDM), which concentrates on decision making in natural settings. The purpose of NDM research is to describe the decision making strategies people really use, rather than developing mathematical decision models or prescribing the strategies they ought to use. Several NDM models have been developed, e.g., the recognition-primed decision making model by Klein (1999). All of these models have in common that they evaluate experts, i.e., system users who bring expert knowledge into the analysis that is beyond the system capabilities. This makes it an interesting theory for Visual Analytics despite the fact that each expert has his or her own way of "behaving expertly" (Mosier, 1997).

3.2. SITUATIONAL AWARENESS

Situation awareness can be defined as the human user's internal conceptualization of a situation. A formal definition by Endsley (2000) defines three levels of situation awareness (see Figure 2): the perception of the elements in the environment within a volume of time and space (Level 1), the comprehension of their meaning (Level 2), and the projection of their status in the future (Level 3).

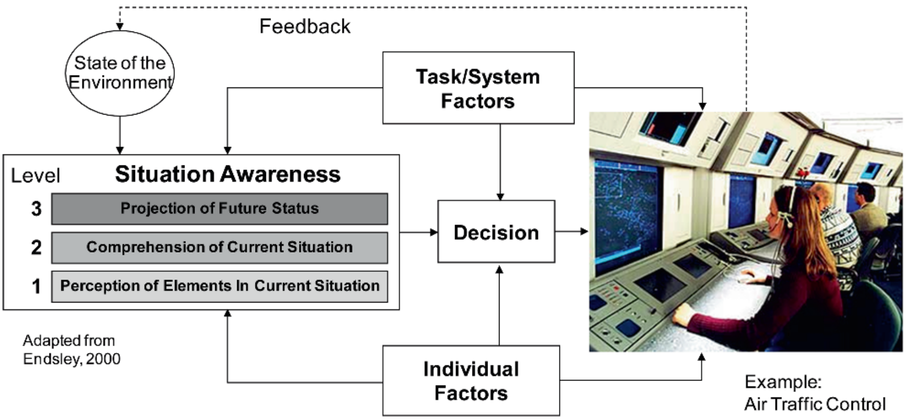

Figure 2. Situation awareness can be described as the human user's internal conceptualization of a situation, which is a critical element for effective decision making.

This first level of situation awareness is about perceiving the status, attributes, and dynamics of relevant elements in the environment. A pilot, e.g., has to perceive important elements such as other aircraft, elevations, or warning lights along with their relevant characteristics. The comprehension of the situation (level 2) is based on a synthesis of disjoint level 1 elements to form a holistic picture of the environment, including a comprehension of the significance of objects and events. In such an environment, a novice decision-maker may be capable of achieving the same level 1 situation awareness as more experienced human decision-makers, but may fall far short of being able to integrate various data elements along with pertinent goals in order to comprehend the situation in the same way as experts. The third level of situation awareness is the ability to project the future actions of the elements in the environments (at least in the near term). For example, an air traffic controller needs to put together various traffic patterns to determine the available runways as well as potential collisions.

Situation awareness, therefore, involves far more than perceiving information in the environment. It includes comprehending the meaning of that information in an integrated form compared to one's goals, and providing projected future states of the environment. These higher levels of situation awareness are particularly critical for effective decision making in many environments. Each level in Endsley's model builds upon the previous level. Thus, a system has to store and provide access to information on the essential elements in the current environment (Level 1) to be able to support the perception of the current situation (Level 2).

3.3. DECISION-CENTERED VISUALIZATION

For several years now there has been research on information visualization from a decision-centred perspective (Kohlhammer, 2005). The general idea of the Decision-Centred Visualization (DCV) approach is the integration of knowledge representation and aspects of human-centred computing into information visualization solutions for time-critical and information-intensive domains. DCV was designed as a scalable solution for filtering and prioritizing of time-critical information to be visualized.

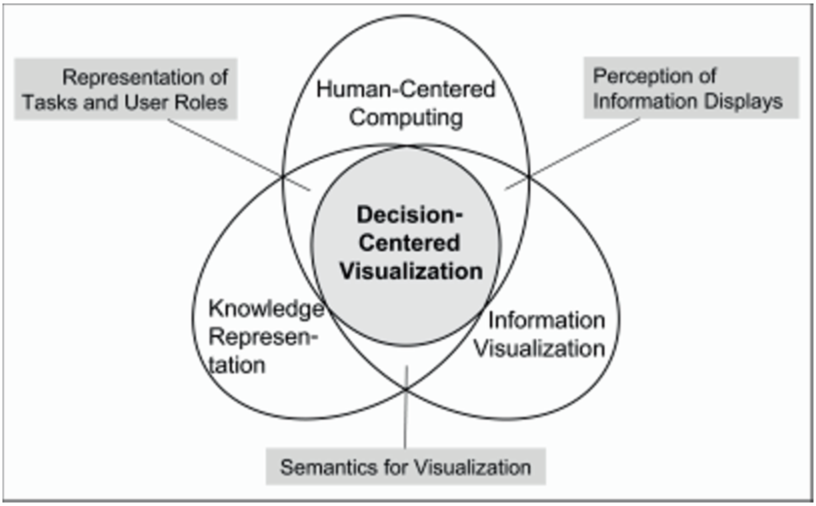

Figure 3. The concepts of DCV are not only influenced by knowledge representation research but also by human-centred computing and information visualization.

DCV is an approach to adaptive, interactive visualization at the intersection of knowledge engineering and information visualization. DCV suggests the use of decision and task models as well as knowledge of the information environment in an application domain to guide the human–machine interface and the visualization system in order to produce knowledge-based presentations. The objective is to reduce the information workload and to provide information visualization that enables decision-makers to quickly achieve situation awareness during their tasks and to make informed decisions under time pressure. To achieve this, a DCV system relies on machine-readable representation of knowledge of a domain to present to the human user filtered information specific to the current task. While the approach originated from problem areas in the emergency management domain, the most recent developments also form a valuable building block of Visual Analytics.

3.4. DECISION SUPPORT THROUGH VISUAL ANALYTICS

DCV is not the only approach that supports users in information-intensive environments (see comparison by Kohlhammer (2005) with concepts in the areas of context awareness, agent-based systems, and others). The uniqueness of DCV stems from the focus on information-intensive applications and a specific view on decision support that does not intend to replace human decision making. While expert systems and automated diagnosis tools are typically built to take over certain decisions from the user, DCV is focused on context-sensitive visualization to enhance decision making abilities for the user.

The emerging field of Visual Analytics integrates results of a large number of research areas (see Section 2). Thomas and Cook (2006) propose a research agenda for the next decade which covers a broad spectrum of different topics. The chapter by Keim et al. (2008) presents research which centres on the development of appropriate visualization systems that satisfy the demands in different application areas, such as financial analysis, emergency management, engineering, and many more. Representative for the novelty of this research in Visual Analytics is the adaptation of Shneiderman’s mantra “Overview first, Filter and zoom, Details on demand”, which is focused on the visualization tasks in Visual Analytics. Keim extends this mantra to focus on Visual Analytics: “Analyze first, Show the important, Zoom, filter and analyze further, Details on demand”. This vision can only be achieved through innovative combinations of analytical approaches and advanced visualization techniques.

Thus, the new core of a system supporting decisions through Visual Analytics is neither the analytical intelligence built into its algorithms (as it is the case in these days’ business intelligence tools) nor is it the specific visualization techniques built into the system. Rather, the centre of interest is the interactive dialog between visualization approach and analytical approach that relies on the novel application of knowledge from data management, data mining, and cognitive science. Thomas and Cook (2006) call this concept the analytic discourse, which should be supported by novel sense-making methods (or knowledge crystallization methods). Sense-making involves analytical reasoning, which includes gathering information that is re-represented in a form that aids the decision-maker to develop insight by manipulating this representation.

Now we return to situation awareness research and DCV. In a situation of information overload, the user would be confronted with too many level 1 elements to become aware of the entire situation. Following the DCV approach, based on the represented knowledge, a decision support system can filter the level 1 elements to bring only relevant information to the visual attention of the user. Through manipulation of such a visual representation, the decision-maker (or the team of decision-makers) can build situation awareness on level 2 and 3. This process has to be supported by analytical techniques to process the complexity or the sheer size of the level 1 data and information pool. At the end of a successful sense-making process we have a decision-maker who can make informed decisions, and who can communicate his or her insights to other relevant groups.

4. Application Example

The approach described above, i.e., selection of relevant information based on knowledge representation and task-centred visualization following the DCV approach, has been applied to several show cases. In 2003, one application case was the support of command and control, and sensor exploitation and tasking, which are complex task domains in which watch-standers must make time-critical, high-risk decisions, often under conditions of high workload. DCV was applied to the interactive information presentation that uses knowledge about naval missions, tasks, and decisions, to classify and prioritize incoming C4ISR and operational data in a real-time simulation environment supported by HLA/RTI. The visualization has later been adapted for emergency management support with visualization support for a commercial GIS, as depicted in Figure 4.

Within the project SoKNOS (see related chapter within this book) we develop new visualization methods and concepts to support the work of decision-makers in emergency management situations. This work is in line with previous work on emergency management supported by the DCV approach. Major tasks are the integration of large distributed data sources for the visualization and the development of user friendly interfaces. New concepts are introduced to support a fast and detailed overview of the current situation in a catastrophe or emergency situation.

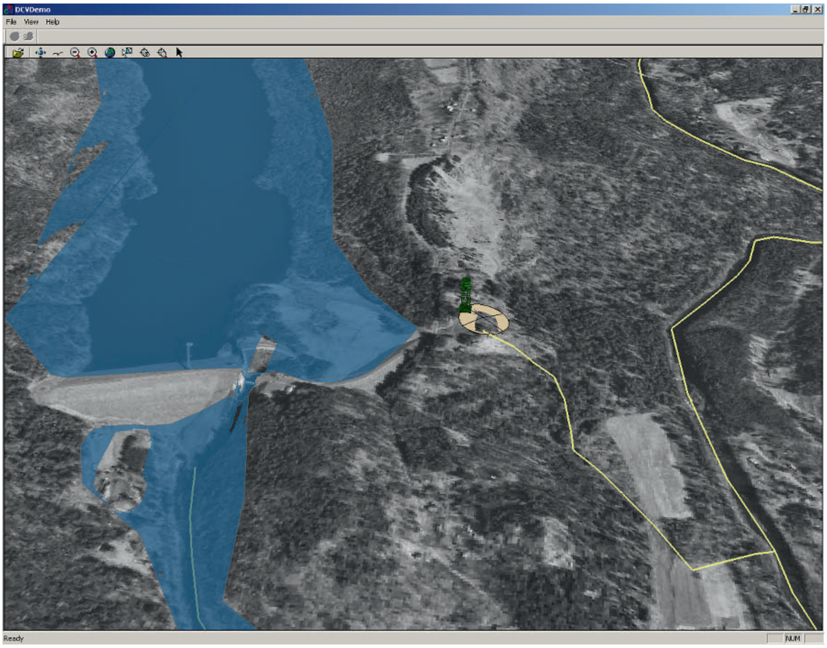

Figure 4. A decision-centred visualization implementation based on a commercial GIS product feature combining 2D map and 3D terrain visualization with additional data and information for situation awareness and decision making.

These new visualization concepts support different views with a number of toolsets and configurable aspects of data visualization techniques. Collaboration between the different users with different roles and sharing different views on the same data sets on different work stations is central for the development. A generic visualization framework is developed to support communication and view sharing inside the framework as well as inter-framework communication.

All these visualization and tracking tools are developed under strong security aspects. Not every user will have access to all resources. Only the users that have a specific role will be able to release actual commands to deploy resources or to make decisions. The others can track those decisions and commands to have the latest information as fast as possible but will generally not be able to change decisions or resource deployment. For later analysis, it is important to have system that allows a transparent view on what has been done during an emergency situation and who decided what to do when and where.

5. Summary and Outlook

Visual Analytics research has created a new focus within the field of visualization. The goal is to turn decision-makers from passive observers of visual representations to active users of visual analysis tools. Visual Analytics relies on work in cognitive science that investigates how people actually make decisions. One theory in this field, situation awareness, highlights the mechanism of information understanding and sense-making as a prerequisite to make informed decisions. These results are used in the authors' previous work on decision-centred visualization, which aims at filtering large amounts of data and information based on knowledge representation and semantics. This chapter shows how these insights apply to the growing research area of Visual Analytics.

The use of semantics and the exploitation of represented knowledge for Visual Analytics have not yet been addressed sufficiently. It is part of the active work of the authors to create new results in this direction. Another focus will be a stronger interweaving of visualization techniques and analytic algorithms. First results have recently been published by May and Kohlhammer (2008). Fraunhofer IGD is the coordinator of a recently started European coordination action called VisMASTER. Its goal is to join European academic and industrial R&D excellence from several individual disciplines, forming a strong Visual Analytics research community. Decision support will be strong area of interest within the project.

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VISUAL ANALYSIS OF PUBLIC DISCOURSE ON ENVIRONMENTAL ISSUES

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Abstract. The public discourse on environmental issues employs the news media and the emerging consumer generated media as its primary communication channels. Analyzing the use of these channels by the various discourse participants yields valuable insight into the status of opinion formation on environmental problems. This chapter outlines common methods for the monitoring and visualization of public discourse in the news media and it proposes requirements for the application of such methods to environmental discourse. The integration of geospatial visualizations with semantic dimensions and numeric data is identified as the key challenge in visualizing public discourse on environmental issues. A showcase application which addresses this challenge is briefly presented.

Keywords: Public Discourse, Environmental Issues, Visualization.

1. Introduction

Public discourse refers to the process of collaborate opinion formation and decision making which enables consensual problem solving on a societal level. In practice, the media serve as the prime communication channel for this process. The role of the news media and of consumer generated media is particularly pronounced in public discourse on environmental issues, as outlined in Section 2.

The observation of public discourse in the news media relies primarily on automated media monitoring. Information retrieval techniques and

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content analysis methods are applied to process news content into quantitative results, as discussed in Section 3. Several visualizations of media attention, issue coverage and other results of content analysis are presented in Section 4. Public discourse on environmental issues shows several peculiarities which require modification and extension of these standard visualizations. Section 5 formulates some requirements for visualizations of environmental discourse and presents a showcase application.

2. Public Discourse on Environmental Issues

Considering common definitions of political discourse (Johnson and Johnson, 2000), public discourse on environmental issues can be understood as the communication process which enables collaborative opinion formation and decision making with regard to environmental problems. Pragmatic environmental discourse is conducted by domain experts, as for instance environmental scientists, by representatives of economic interest and by affected citizens and their representatives. (Dryzek, 2005)

Public discourse on environmental issues is characterized by the exchange of views between these agents through the news media and, recently, through consumer generated media. The role of the media in this process is emphasized by the international nature of issues, which restrains agents from assessing matters based on personal experience, and by the complexity of the decision basis, which requires elaboration and explanation in order to be comprehensible to non-experts.

In the wake of the United Nation's Agenda 21 programme for sustainable development, many nations and international organizations have adopted regulations which ensure free access to environmental information. Such legislation is intended to provide all actors of the environmental discourse with a consistent decision basis. For example, individuals and organizations have the right to access environmental information generated by public authorities in the European Union.

Considering the outlined role of the media in the environmental discourse, such legislation is insufficient if the media fail to communicate relevant information to the general public in a comprehensible way (Bell, 1994) or (set agendas which do not reflect the real-world priority of environmental problems (Nas, 2000).

The constant monitoring of media coverage by means accessible to the general public is therefore in the best interest of all participants of the public discourse on environmental issues.

3. Monitoring Public Discourse

First attempts to gauge informal public discourse using polls date from the early 19th century. A firm statistical basis for opinion research has been developed in the 20th century. Opinion polls yield explicit, quantitative information on the state of opinion formation for a specific set of questions. Results can immediately be analyzed and visualized. However, opinion polls are less suitable for monitoring the formal exchange of views in the media which precedes and affects opinion formation. It is interesting to note that recent trends towards consumer-generated media, as, for instance, blogs and discussion forums, have opened an alternative window into informal public discourse.

Public discourse in the news media has been monitored by dedicated agencies since the end of the 19th century, when “clipping services” started to collect and process news articles. In the second half of the 20th century, content analysis has been developed as a standard methodology for the analysis of news articles (Holsti, 1969). Content analysis relies on quantitative, statistical properties of large text corpora, as for instance the frequency of keywords, to identify patterns and structures in communication. This approach has been criticized for excessive emphasis upon quantification, and alternatives focusing on qualitative features have been proposed (Goffman, 1974). Content analysis continues to provide the basis for the automated processing of large corpora because it is comparably easy to realize using information technology.

Modern automated media monitoring systems collect and merge content from dedicated news databases and online sources as, for instance, websites or blogs, into a single, large text corpus which is annotated with metadata like author, date and source. Information retrieval methods as, for instance, lexical analysis, stopwords removal, stemming and indexing are applied to facilitate searching the corpus and to prepare the corpus for further processing (Baeza-Yates and Ribeiro-Neto, 1999). Named entity recognition based on linguistic patterns or statistical models is performed to identify entities as, for instance, organizations, persons and geographical references. Once named entities have been identified for a corpus, classical content analysis can be applied and results can then be visualized as outlined in the next section.

It is interesting to note that the processing steps described so far can be executed in near-real-time for a typical search result set which contains several thousand news articles. Therefore, it is possible to interactively obtain media monitoring results for arbitrary issues as long as the formulation of an adequate search query is feasible.

4. Visualizing Public Discourse

The term visualization commonly refers to the use of visual representations to support communication and comprehension of complex information. Applications of visualization techniques in the context of public discourse can be traced back to the 19th century. The development of real-time computer graphic systems in the late 20th century has enabled the creation of dynamic and interactive visualizations. Information visualization has emerged as the scientific field investigating the use of computer-supported visual representations to aid understanding of abstract data (Card et al., 1999). Findings in Information Visualization have soon been applied to the visualization of news articles (Renisson, 1994; Andrews et al., 2002). Today, a plethora of web-based visualization systems backed by automated media observation systems provides visual analysis of public discourse to a wide audience.

Attention analysis investigates the frequency and extent of media coverage allocated to specific concepts (as, for example, individuals or products). The visual representation of media attention towards public actors (as, for example, election candidates) constitutes a prime application area of public discourse visualization. For small, coherent sets of actors, attention values are often displayed using bar charts, pie charts or line graphs, which are supplemented with descriptive labels and graphics. The United States presidential election of 2008 provides a number of examples, for instance (US Election, 2008 Web Monitor). For large, diverse sets of actors, attention values are often displayed using figurative graphical representations which place actors in a visual context designed to ease comprehension and interpretation (compare Figure 1).

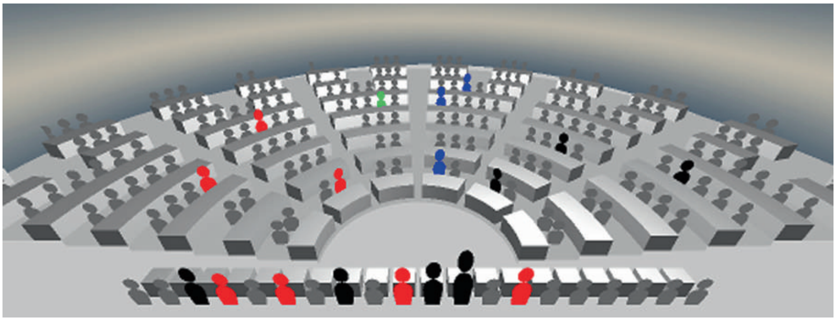

Figure 1. Visualizing media attention towards members of the Austrian parliament: each Member of Parliament is represented by an icon which is correctly positioned within a stylized model of Austria's National Council. Icon size indicates relative attention value and icon colour indicates party affiliation (Kienreich et al., 2008).

Issue analysis extends the idea of attention analysis by investigating the context of the media coverage allocated to specific concepts. From a technical point of view, issue analysis amounts to a co-occurrence analysis of concepts. One prominent application in the domain of public discourse is the visualization of the issues most often associated with a public actor (compare Figure 2). Again, the United States presidential election of 2008 provides a number of examples, for instance (Washington Post, 2008).

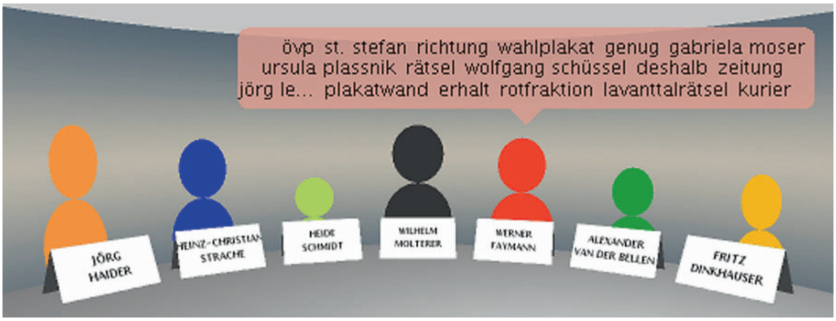

Figure 2. Visualizing issues associated with the top candidates for the Austrian Parliamentary Election of 2008: each candidate is represented by an icon and a place card. Icon size indicates relative attention value and icon colour indicates party affiliation. A tag cloud displays issues associated with the selected candidate (Kienreich et al., 2008).

To enable the use of domain-specific visual representations, the results obtained from issue analysis can be restricted by narrowing the investigated type of context. Limiting the context to geographical references facilitates a geospatial visualization revealing geographical patterns in public discourse (compare Figure 3). Recursive analysis within the context of public actors yields a directed graph of individuals which can be displayed using social network visualization techniques (Freeman, 2000).

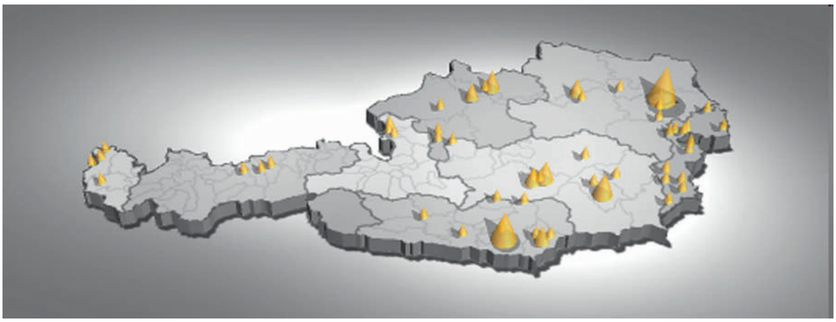

Figure 3. Visualizing geographical references associated with one of the top candidates for the Austrian Parliamentary Election of 2008: Each geographical reference is represented by yellow cone located on a stylized map of Austria. The size of each cone indicates relative association frequency (Kienreich et al., 2008).

Sentiment analysis investigates the attitude of media coverage allocated to specific concepts by ranking references to a concept on a scale ranging from positive to neutral to negative. Reliable detection of sentiment is problematic because intricate language structures (as, for instance, irony or double negatives) are often used in relevant text segments. Successful applications of sentiment analysis to the domain of public discourse have been based on heuristics and term dictionaries (Scharl and Pollach, 2003). Suitable visual representations are analogous to those described for attention and issue analysis. In the absence of a focus set of concepts, global surveys of public discourse yield massive amounts of relevant information. Corresponding visualizations usually present an initial overview and provide interactive facilities for zooming and filtering, in accordance with the "mantra of visual information seeking" (Shneiderman and Plaisant, 2004). Adequate visualization strategies include, for instance, tree maps (Bederson et al., 2002), night sky metaphors (Andrews et al., 2002) and tag clouds (Seifert et al., 2008) (compare Figure 4).

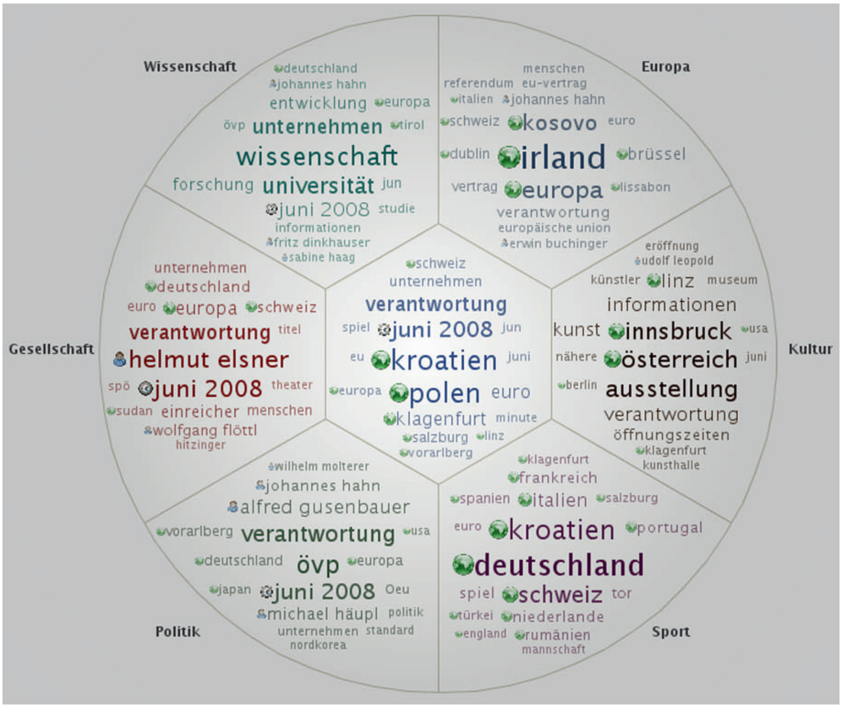

Figure 4. Visualizing an overview of public discourse: named entities have been extracted from news articles and arranged into areas representing topics. Each area contains a tag cloud of entities. Each entity displays an icon denoting entity type and a descriptive label. Label size denotes entity frequency in the corpus (Seifert et al., 2008).

5. Visualizing Environmental Discourse

The visual representations discussed in the previous section required significant modification and extension in order to yield comprehensible and helpful visualizations of public discourse on environmental issues. In particular, environmental concepts subjected to attention and issue analysis must be presented in a (visual) context which enables correct interpretation and verification.

For instance, an issue analysis of the concept "ozone" yields a large number of geographical references, which have to be presented in a geospatial visualization to enable recognition of patterns. The analysis also yields a large number of technical terms, which have to be explained and put into context for non-experts, for instance by using a semantic graph. Attempts to retrace arguments about "ozone" involve numeric data which has either been present in the media articles or has to be acquired from scientific literature. This data has to be visualized, too.

Some requirements for the design of comprehensible visualizations of environmental discourse can be devised from peculiarities of the domain as outlined in the presented example:

- A geospatial visual representation should be provided if at all possible. Geospatial services are readily available. It is estimated that at least 20% of all web pages contain accessible geographic references (Delboni et al., 2005). Most news articles contain at least one geographic reference. Thus, this requirement should be easy to implement.
- Semantic (visual) representations should be employed to present the problem domain a consistent way (as opposed to presenting separate, unrelated issues). Domain ontologies are available for many areas of environmental information. However, implementing this requirement may demand advanced analysis methods (for instance, ontology extraction and ontology alignment) in the monitoring process.
- Supplemental information (as, for instance, numeric data) should be integrated into the primary visual representation or presented in separate views, which should be coordinated with the primary visualization.

Partial solutions have been presented for some of the formulated requirements in related research areas. Design principles and applications of multiple coordinated views have been documented in information visualization and Visual Analytics. The integrated visualization of multidimensional data and geospatial information has recently been addressed in architectural heritage visualization (Blaise et al., 2006).

The Media Watch on Climate Change (Scharl et al., 2007) provides a showcase for some of the formulated requirements. This automated media monitoring system collects news articles relevant to the domain of climate change from 150 online sources. It extracts geographic references from article content and gradually generates a geospatial knowledge base. The results are presented in a rich internet application which employs multiple coordinated views. Available visualizations include a geographic map, a semantic map, a graph-based ontology view and a tag cloud.

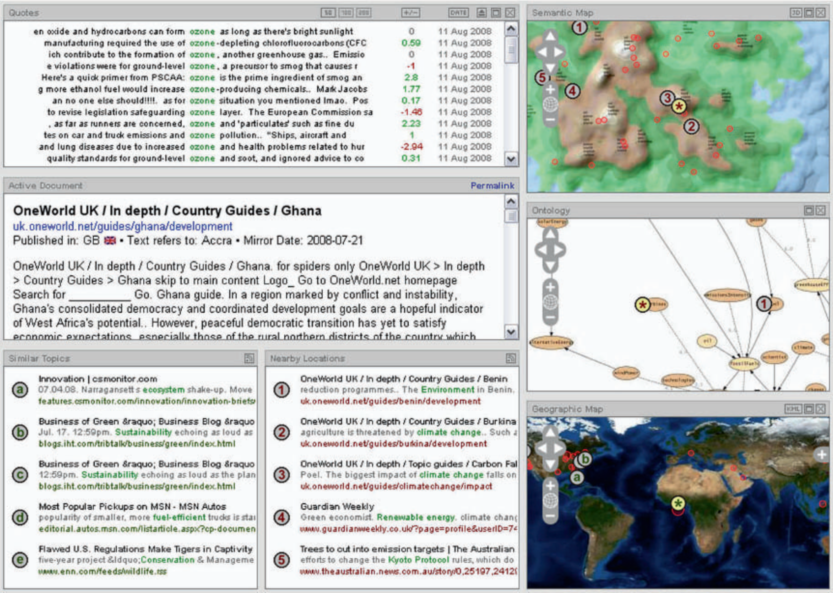

Figure 5. Visualizing public discourse on climate change: similar topics and locations (bottom left) are presented for a news article (centre left) selected from a list of search results (top left). Three synchronized visualizations present the search results as a semantic map (top right), an ontology graph (centre right) and a geographical map (bottom right). The visualizations have been centred on the location of the selected article (Scharl et al., 2007).

6. Conclusions

We have described properties of public discourse on environmental issues and outlined common techniques for monitoring and visualizing public discourse in the news media. Based on the particular properties of environmental discourse, we have proposed some requirements for automated media monitoring and visualization systems targeting the environmental domain and presented a showcase system.

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EXPLORING ENVIRONMENTAL NEWS VIA GEOSPATIAL INTERFACES AND VIRTUAL GLOBES

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Abstract. Users of online news services have discovered geospatial interfaces as an effective platform to identify and access relevant information. An increasing number of applications therefore use maps to specify queries and present results. This chapter discusses such applications with a special focus on integrating geospatial and semantic reference systems. It outlines how geospatial context can be extracted automatically from large repositories of unstructured text and presents the *Media Watch on Climate Change*, a public Web portal that aggregates, filters and visualizes environmental Web content from 150 Anglo-American news media sites. Among the key components of the Web portal are *Knowledge Planets* – Java applets that generate three-dimensional topographies based on semantic similarity and thereby demonstrate how the NASA World Wind platform can be used as a generic image rendering engine to project various types of imagery.

Keywords: Geospatial Web, Media Monitoring, Annotation, Document Enrichment, User Interface, Environmental News, Climate Change.

1. Introduction

For true media innovation to have human impact, it must affect the imagination and create an associated magic "behind the eyeballs" that changes people's behaviour in their commercial, academic and personal environments (Stapleton and Hughes, 2006). In the words of McLuhan, media as an extension of ourselves provide new transforming vision and awareness (McLuhan, 1964). In the early 1940s, the first images of Earth from space

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eroded limitations to human perception, triggered profound self-reflexive experiences (DeVarco, 2004) and revitalized public desire to preserve a beautiful but vulnerable planet (Biever, 2005). Thanks to human space exploration, therefore, users will instantly recognize our planet and find it an intuitive and effective metaphor to access and manage geotagged information: "There it is, that good old pale blue dot in all its Earthly glory, right there on your computer screen. It's a familiar sight, even from a sky-high perspective experienced only by astronauts and angels" (Levy, 2004, 56).

International media have recognized the huge potential of geobrowsers such as NASA World Wind, Google Earth and MS Virtual Earth – for example, when web and television coverage on Hurricane Katrina used interactive geospatial projections to illustrate its path and the scale of destruction in August 2005. Yet these early applications only hint at the true potential of geospatial technology to build and maintain virtual communities and to revolutionize the production, distribution and consumption of environmental news. After the successful introduction of three-dimensional geobrowsers, achieving the vision of a Geospatial Web (Scharl and Tochtermann, 2007) seems more realistic than ever. Dubbed the "holy grail of mapping" (Levy, 2004), geobrowsers project layers of metadata onto scale-independent spherical globes. They are an ideal platform to integrate cartographic data such as topographic maps and street directories, geotagged knowledge repositories aggregated from public online sources or corporate intranets, and environmental indicators such as emission levels, ozone concentrations and biodiversity density.

2. Annotating Environmental News Archives

Concentrated efforts are under way to annotate existing environmental resources with geospatial metadata (Scharl et al., 2008). The process of assigning geospatial context information is referred to as geotagging. Different sources of geospatial context information often complement each other in real-world applications (Daviel and Kaegi, 2003; McCurley, 2001):

- Annotation by the author, manually or through location-aware devices such as car navigation systems, RFID-tagged products and GPS-enabled cellular handsets. These devices geotag information automatically when it is being created. Within small virtual communities, collaborative manual tagging is still prevalent.
- Determining the location of the server – e.g., by querying the *Whois* (www.whois.net) database for domain registrations, analyzing the domain of a Web site for additional cues (e.g., www.wwf.org.uk), or

by using dedicated services such as the *Geo IP Tool* (www.geoiptool.com), which returns longitude and latitude of specific IP addresses.

- Automated annotation of existing documents. The processes of recognizing geographic context and assigning spatial coordinates are commonly referred to as *geoparsing* and *geocoding*, respectively.

Once geospatial context information becomes widely available, any point in space will be linked to a universe of commentary on its environmental, historical and cultural context, to related community events and activities and to personal stories and preferences. At present, however, many metadata initiatives still suffer from the chicken and egg problem, wishing that existing content was retrofitted with metadata (McCurley, 2001). This "capture bottleneck" results from the beneficiaries' lack of motivation to devote the necessary resources for providing a critical mass of metadata (Motta et al., 2000). Geotagging initiatives in the environmental domain are no exception. Acknowledging calls to automate the semantic annotation of documents (Benjamins et al., 2004; Domingue and Motta, 2000). The following sections focus on the third category, the automated geoparsing and geocoding of existing environmental resources.

2.1. GEOPARSING

Environmental news articles contain metadata as explicit or implicit geographic references. This includes references to physical features of the Earth's surface such as forests, lakes, rivers and mountains, and references to objects of the human-made environment such as cities, countries, roads and buildings (Jones et al., 2001). Addresses, postal codes, telephone numbers and descriptions of landmarks also allow us to pinpoint exact locations (Ding et al., 2000; McCurley, 2001).

At least 20% of Web pages contain easily recognizable and unambiguous geographic identifiers (Delboni et al., 2005). Environmental news articles are particularly rich in such identifiers, since they usually discuss the location where an event took place, or where it was reported from (Morimoto et al., 2003). The New York Times article "Brazil, Alarmed, Reconsiders Policy on Climate Change" (Rohter, 2007), for example, has a target geography of SOUTH AMERICA/BRAZIL/ MANAUS and a source geography of NORTH AMERICA/UNITED STATES/NEW YORK.

Identifying and ranking spatial references by semantically analyzing textual data is a subset of the more general problem of named entity recognition, which locates and interprets the names of people, organizations and places (Cowie and Lehnert, 1996; Weiss et al., 2005). As with most named entity recognition tasks, false positives are inevitable – e.g., documents that quote addresses unrelated to the their actual content (Morimoto et al., 2003). Ambiguity, synonymy and changes in terminology over time further complicate the geoparsing of Web documents (Amitay et al., 2004; Kienreich et al., 2006; Larson, 1996). Identical lexical forms refer to distinct places with the same name (VIENNA refers to the capital of Austria as well as a town in Northern Virginia, USA) or have geographic and non-geographic meanings: TURKEY (large gallinaceous bird; bi-continental country between Asia and Europe), MOBILE (capable of moving; city in Alabama, USA), or READING (processing written linguistic messages; town in Massachusetts, USA). Geoparsers also need to correctly process references to identical or similar places that may be known under different names, or may belong to different levels of administrative or topographical hierarchies (Jones et al., 2001).

2.2. GEOCODING

Once a location has been identified, precise spatial coordinates – latitude, longitude and altitude – can be assigned to the documents by querying structured geographic indices (gazetteers) for matching entries (Hill et al., 1999; Tochtermann et al., 1997). This process of associating documents with formal models is also referred to as document enrichment (Domingue and Motta, 2000; Motta et al., 2000).

While simple gazetteer lookup has the advantage of being language-independent, advanced algorithms consider lexical and structural linguistic clues as well as contextual knowledge contained in the documents; e.g., dealing with ambiguity by removing stop-words, identifying references to people and organizations (Clough, 2005) and applying contextual rules like "single sense per document" and "co-occurring place names indicate nearby locations". Each identified reference is assigned a probability *P(name, place)* that it refers to a particular place (Amitay et al., 2004). The location that receives the highest probability is then assigned a canonical taxonomy node such as EUROPE/AUSTRIA/VIENNA; 48°14′ N, 16°20′ E.

3. Media Watch on Climate Change

Environmental news should be organized, indexed, searched and navigated along multiple dimensions: (i) *spatial* – distinguishing between source and target geography; (ii) *semantic* – assigning the most relevant concepts from a controlled vocabulary; and (iii) *temporal* – adding timestamps for the reported event, the initial publication and subsequent revisions. Providing intuitive mechanisms for users to control these dimensions is a challenge that can be addressed by means of tightly coupled visual user interfaces.

The *Media Watch on Climate Change* (www.ecoresearch.net/climate), a Web portal to increase environmental awareness and the availability of environmental information, provides such an interface. It gives a comprehensive and continuously updated account of media coverage on climate change and related issues. The portal aggregates, filters and visualizes environmental Web content from 150 Anglo-American news media sites.

Figure 1 shows a screenshot of the user interface. The *Active Document* view on the left displays the currently selected document, including its mirror date and source/target geography. Below, just-in-time information retrieval agents list documents referring to similar topics and nearby locations. Clicking on the related references extends the quoted text, clicking on the circular marker activates that particular document. The semantic and geographic maps facilitate access to the underlying knowledge base. The information landscape in the upper right window shows semantic associations between documents. Peaks indicate clusters of documents on a popular topic, whereas valleys represent sparsely populated parts of the information space. Additional views such as a visual representation of automatically generated domain ontologies can be added to the display using toggle buttons above the maps. The *Geographic Map* shows the locations referred to in the listed articles; the tag cloud (not shown in Figure 1) summarizes

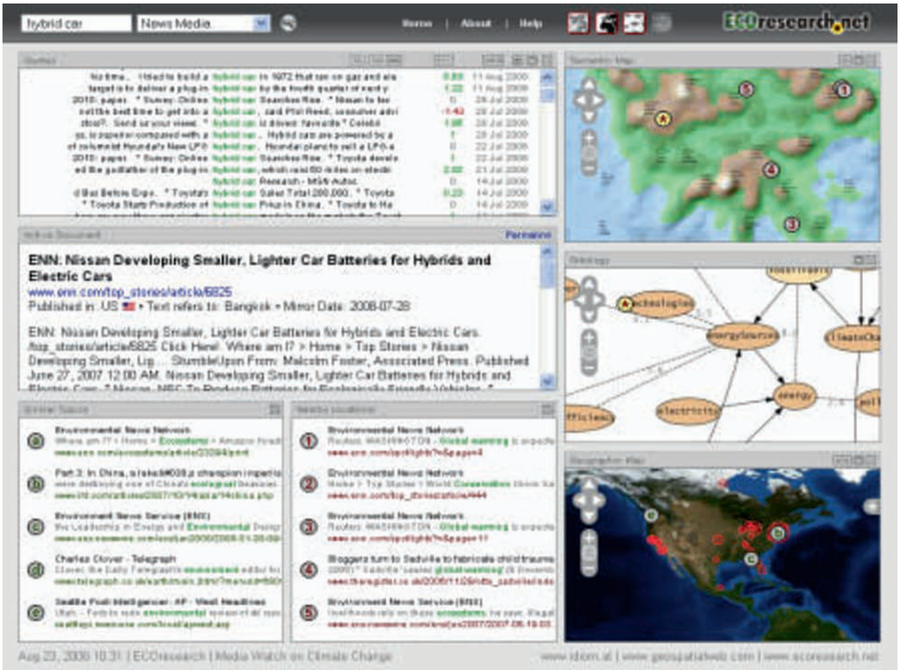

Figure 1. Media watch on climate change (www.ecoresearch.net/climate).

the repository's keywords indicating relative importance by font size. Clicking on the maximize buttons increases the map size. The "3D" button of the *Semantic Map* opens a three-dimensional "Knowledge Planet", which will be described in the following section.

Once a user queries for specific terms via the search box, an additional window displays a set of quotes including the target term as "concordances" (centering the target term and showing its immediate context in the various documents). Besides entering query terms, users can click on any position in the maps (not only on the document markers) to retrieve articles related to that particular location, topic, or domain concept. The different views are therefore said to be "tightly coupled" – user actions in one window trigger an immediate update of all other displays. The continuous and synchronized display of several views on the contextualized information space allows rapid and reversible interaction.

4. Knowledge Planets

Geospatially referenced information enables geobrowsers to map environmental news from various sources, track human activities and visualize the structure and dynamics of virtual communities. But geobrowsers can also serve as a generic rendering engine to project other types of imagery. Diverting them from their traditional purpose, they can be used to visualize *semantically* referenced information as *knowledge planets* based on layered information landscapes – visual representations of semantic information spaces based on a landscape metaphor (Chalmers, 1993), as outlined in the previous section. The planet metaphor allows concurrently visualizing massive amounts of textual data.

The underlying mapping algorithm supports dynamic document clustering (Andrews et al., 2001; Sabol et al., 2002). Initially, the document set is pre-clustered using hierarchical agglomerative clustering (Jain et al., 1999), randomly distributing the cluster centroids in the viewing rectangle. The documents belonging to each cluster, as determined by the pre-clustering, are then placed in circles around each centroid. The arrangement is fine-tuned using a linear iteration force-directed placement algorithm adapted from Chalmers (1996). The result resembles a contour map of islands. Fortunately, algorithms based on force models easily generalize to the knowledge planets' spherical geometries.

IDIOM and RAVEN (www.idiom.at; www.modul.ac.at/nmt/raven), two research projects investigating semantic services, have extended and refined the thematic mapping component to improve throughput and scalability, generate layered thematic maps and provide a Web Map Service (WMS) that serves these maps as image tiles for various geobrowsing platforms

(Sabol and Scharl, 2008). Figure 2 shows a prototype based on the Java SDK of NASA World Wind (worldwind.arc.nasa.gov/java). The transition from two-dimensional thematic maps to three-dimensional knowledge planets poses a number of conceptual and technical challenges – the initial arrangement of major concepts, for example, which should be guided by domain ontologies. Users will also expect a consistent experience when rotating the planet. This requires a seamless flow of concepts across the polar caps or when crossing the planet's 0° meridian line.

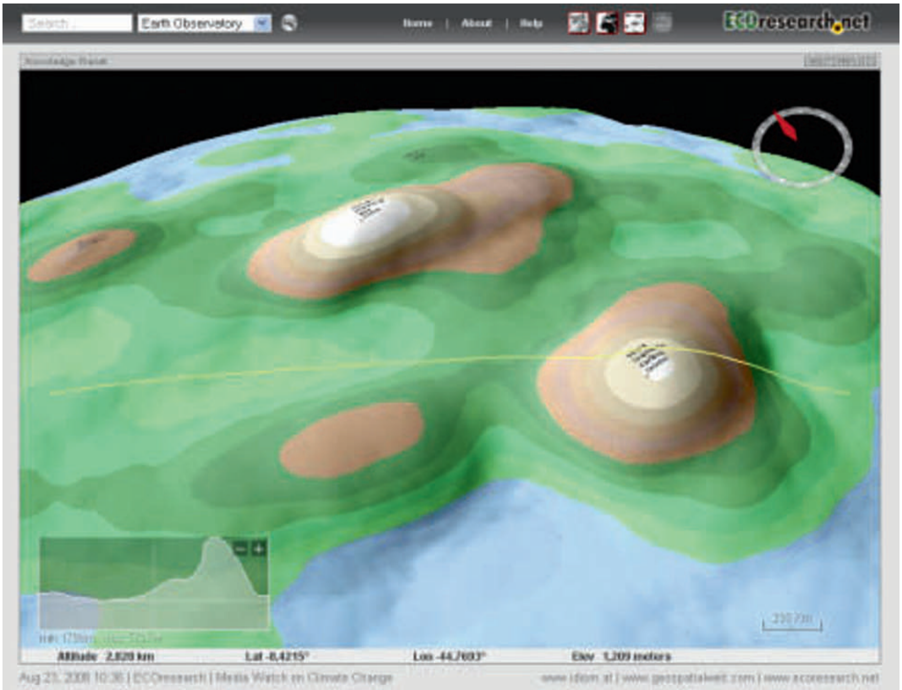

Figure 2. Knowledge planet based on the NASA World Wind Java SDK.

5. Summary and Conclusion

While many innovations that gain ground in the media industry are largely invisible to the end user, geobrowsers directly impact the consumption of news media, change mainstream storytelling conventions and provide new ways of selecting and filtering environmental news. Automatically annotating articles acquired from various sources creates knowledge repositories spanning multiple dimensions (space, time, semantics, etc.). Geospatial exploration systems can improve the accessibility and transparency of such repositories, setting the stage for the *Geospatial Web* as a new platform for content production and distribution, a catalyst of social change and enabler of a broad range of as yet unforeseen applications.

The introduction of geobrowsing platforms has popularized the process of "annotating the Planet" (Udell, 2005). This chapter outlined the underlying technology and discussed methods to "geo-enable" and visualize environmental news archives. The strategy of adding location metadata to existing news archives and accessing the vast amounts of information stored in these archives via geospatial services blends physical and virtual spaces, deepens our experiences of these spaces and incorporates them into our everyday lives (Roush, 2005). Coupling tagged knowledge repositories with satellite surveillance and other real-time data sources is particularly relevant to the environmental domain. Integrated information systems incorporating geobrowsing platforms are ideally suited for bringing together the various stakeholders, creating shared meaning, and building location-aware environmental communities on regional, national and global scales.

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SPATIO-TEMPORAL VISUALIZATION FOR ENVIRONMENTAL DECISION SUPPORT

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Abstract. Traditional visualization of Earth surface features has been addressed through visual exploration, analysis, synthesis, and presentation of observable geospatial data. However, characterizing the changes in their observable and unobservable properties of geospatial features is critical for planning and policy formulation. Recent approaches are addressing modelling and visualization of the temporal dynamics that describe observed and/or predicted physical and socioeconomic processes using vast volumes of Earth Observation (imagery and other geophysical) data from remote sensor networks. This chapter provides an overview of selected geospatial modelling and simulation, exploratory analysis of Earth Observation data, and high performance visualization research at Oak Ridge National Laboratory for developing novel data driven approaches for geospatial knowledge discovery and visualization relevant to environmental decision support.

Keywords: Spatio-Temporal Data, Visualization, GIS, Environment, Decision Support.

1. Introduction

The value of geospatial visualization of our environment has been well recognized and consequently spatial data have become critical to decision making processes, particularly for environmental issues, in planning, policy, and operational missions for government agencies from local to global scales. Traditional visualization of Earth surface features including terrain characteristics has been addressed through geospatial visualization which

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broadly refers to the visual exploration, analysis, synthesis, and presentation of geospatial data. However, geospatial visualization has implicitly included Earth Observation data or in other words, geospatial data that are visible (such as vegetation, urban structures, hydrography) or directly physically measurable (such as temperature, geophysical parameters). Environmental decision making is often very complex, requiring semi-structured and unstructured problems, large amounts of diverse and disparate multi-disciplinary databases. However, Earth Observation data still provides the fundamental reference framework for describing the issues and contexts in the decision making process for environmental problems such as sustainable development, watershed management, and air quality impacts (Bhaduri, 2006; Elvidge et al., 2007; Harbor et al., 2001).

1.1. EXPLOSION IN DATA COLLECTION AND DATA DIMENSIONALITY

Technological advancement resulting in both cost and time efficiency has prompted an explosion in the volume of spatial data that are being collected from remote sensors and developed from ground-based surveys. The amount of visual and image data are increasing at the rate of terabytes to petabytes of data a day with the progress in Earth observing satellite, airborne, and ground based remote sensing technologies (MacEachren and Kraak, 2001; Schowengerdt, 1993). In parallel, Earth simulated (such as output from climate, hydrology, and other environmental models) data are also being generated at an enormous rate (Bernholdt et al., 2005). This increase is both in terms of available databases as well as the size and content of the information resulting from the increasing spatial and temporal resolutions of the data. Clearly the success of scientific analysis for decision making will be strongly impacted by our capabilities in storing, analyzing, and creating meaningful information from the enormous databases, across the domains of natural sciences, social sciences, and engineering, within a potentially useful timeframe.

2. Visualization Challenges for Environmental Decision Support

Geographic Information Systems (GIS), developed since the 1960s, have traditionally addressed the cross-disciplinary data integration, analysis, and visualization issues within a geospatial framework. The maturity in GIS software in the 1990s as a common desktop tool provided an opportunity for the integration of environmental models within various GIS and the development of GIS-based Environmental Decision Support Systems (EDSS) (Bhaduri et al., 2002; Bhaduri, 2006). Though the concept and approach of GIS-based EDSS have been a major step towards informed decision making, its subsequent progress has been closely tied to the advances in GIS technologies (Lodha and Verma, 2000). For example, the very two dimensional nature of common GIS has allowed minimal ways to integrate data and information in the vertical dimension which is a critical component of our environment. The recent advent of Geographic Exploration Systems (GES), (such as Google Earth, Microsoft Virtual Earth, NASA World Wind), have allowed three dimensional visualization of Earth features (primarily buildings) that can be easily created (because of simpler geometric patterns) from available 3D spatial data (such as LIDAR) or computer graphics software (such as Google Sketch). There are two other issues related to geospatial visualization that are tied to the current state of GIS technology: (a) ability to analyze and visualize data in time (fourth dimension) and (b) ability to process large volumes of dynamic data sets; both of which are critical for environmental decision support.

2.1. VISUALIZING ENVIRONMENTAL PROCESSES

Current GIS adhere to a static spatial representation of the world, when in reality our environment is anything but static and majority of the ecological features display temporally dynamic behaviours. Understanding the environmental or landscape processes is critical for decision support, which requires visualizing changes in the state of environmental features. Our approach using traditional GIS has been to spatially and temporally compare one or more snapshots of the state of our environment that describes various environmental processes such as deforestation, urbanization, or expansion in road networks. However, such end point based analysis can primarily capture broad changes in observable Earth features and are inadequate for revealing any information about the temporal characteristics of the processes as defined by the onset, frequency, and rate of changes that occur in the features. The following are relevant examples of dynamic aspects of environmental processes:

- Geometrical changes of features over time (such as deforestation, desertification, and urban expansion).
- Positional changes of features over time (such as movement of people and other moving objects such as vehicles).
- Change of features properties over time (such as volume and velocity of electricity on electric grids; traffic on road networks; water on stream networks).

With the increasing temporal resolution of geospatial data in recent years through geo-observation satellites providing daily coverage at regional to national scales and through expanding in-situ sensor networks providing observation and measurement of our environment at local scales is turning the possibility of spatio-temporally visualize the changes that describe various environmental processes into reality (Ganguly et al., 2007).

2.2. VISUALIZING LARGE DYNAMIC DATA STREAMS

The challenge in processing and visualizing large volumes of high resolution Earth Observation and simulation data has been compounded by the drive towards real-time applications that require split-second response times to analysis on large and dynamic datasets (Xiong and Marble, 1996). Although, for desktop environments, the progress of individual processor speed, cache performance, and graphics capability has been impressive, it has not been adequate to match the growth of available spatio-temporal data. This provides an incentive for integration of high performance computation and visualization frameworks to generate large number of pixels for visualizing on large tiled displays that are common in tactical decision support environments. Consequently, there is an increasing trend in developing high-performance visualization architecture specifically for visualization of large spatio-temporal datasets (Sorokine, 2007).

3. Case Studies: Example Approaches for Dynamic Visualization

There is a compelling motivation to couple the powerful modelling and analytical capability of a GIS to perform spatial and temporal analysis on dynamic data streams with spatio-temporal visualization. Here we discuss a few of those approaches illustrated through some our research efforts at Oak Ridge National Laboratory (ORNL). These approaches do not constitute an exhaustive list of spatio-temporal visualization methods, but rather provide an insight into the potential power and possibilities of spatio-temporal visualization for planning and policy decision support across numerous disciplinary issues with a strong environmental aspect.

3.1. HIGH RESOLUTION POPULATION DISTRIBUTION AND DYNAMICS

Human population distribution data provides a fundamental component to the sustainable development framework. High resolution (sub-Census local level) population data is essential for successfully addressing key issues such as good governance, poverty reduction strategies, and prosperity in social, economic, and environmental health. Characteristics of human societies such as spatiotemporal distribution of population, their religious affinities, cultural trends and beliefs, socio-economic strengths, political affiliation among many others, have strong spatiotemporal nature but are not always captured in geospatial databases that can be easily visualized.

Geospatial data and models offer novel approaches to decompose aggregated Census data to finer spatial and temporal units. We have employed such an approach of multi-variable fusion of physical and social data that may or may not be in explicitly spatial formats to model and visualize relevant characteristics of human behaviour, natural process evolution, and landscape changes over space and time. This has resulted in the finest global population distribution model and database ever produced using worldwide imagery and other spatial data (Bhaduri et al., 2002; Dobson et al., 2003). LandScan population distribution model involves collection of the best available census counts (usually at sub-province level) for each country and four primary geospatial input datasets, namely land cover, land use, roads, slope, and other physiographic features that are key indicators of population distribution. We have further developed this approach where a large number of disparate and misaligned spatial data sets can be spatio-temporally correlated and integrated in an Activity Based Modelling (ABM) framework to understand, model, and visualize dynamics of population (Bhaduri, 2007; Bhaduri et al., 2007). LandScan USA represents a model and database for the US which describes population distribution at 90 m spatial resolution for night-time residential as well as daytime scenarios (Figure 1).

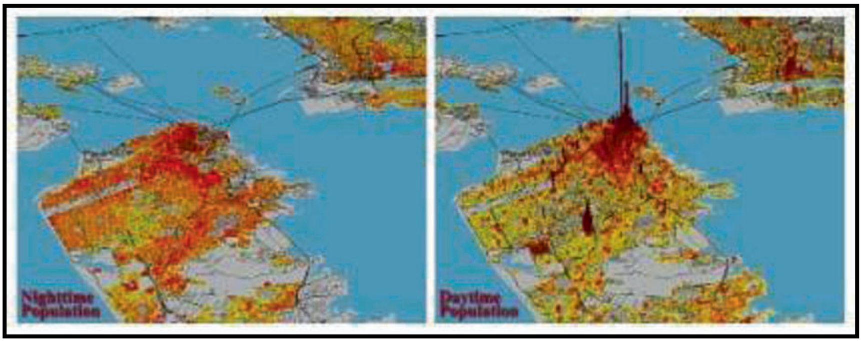

Figure 1. Diurnal dynamics of population distributions in San Francisco, USA are modelled with LandScan USA high resolution population data.

Locating daytime populations requires not only census data, but also other socio-economic data including places of work, journey to work, and other mobility factors such as daytime business and cultural attractions/ populated places datasets. Transportation modelling and simulation approaches can be used to describe and visualize movement of demographic groups (such as school children) in finer temporal resolutions to assess potential impact from atmospheric pollutions to commuting school children (Shankar et al., 2005; Xue et al., 2008).

3.2. CLIMATE CHANGE IMPACTS

Geospatial integration, analysis, and visualization of physical and model simulated data have been well recognized to impact scientific understanding of Earth system models as well as to enhance decision support systems (Khan et al., 2007; Kuhn et al., 2007). For example, General Circulation Models (GCM) and climate change simulations provide Earth simulation data can be integrated, observed, and examined with Earth Observation data. In order to gain insights into the mammoth and complex results from long-term climate predictions and impacts of climate change on geographic regions over decadal time scales, such integration of Earth Observation and Earth system data is critical. Moreover, this enhances our understanding of the GCM itself. Figure 2 illustrates projected difference in monthly temperatures averaged over the last decade of the 21st century and the current decade.

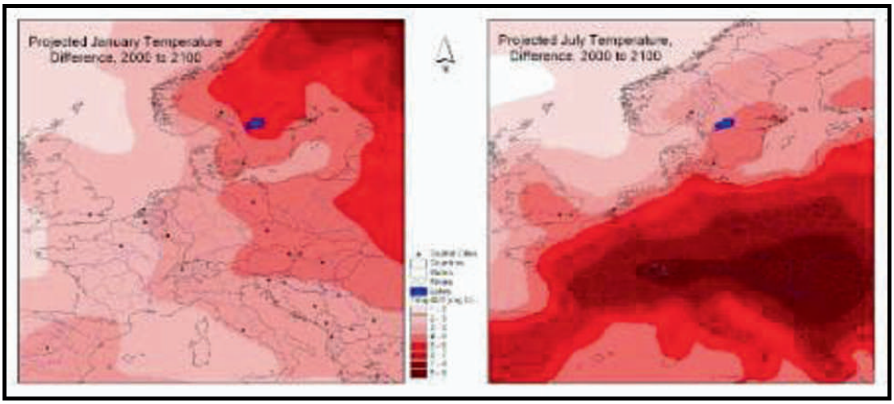

Figure 2. Projected difference in monthly temperatures averaged over the last decade of the 21st century and the current decade.

The projections correspond to the A1FI (fossil fuel intensive) scenario designed by the Intergovernmental Panel on Climate Change (IPCC), as implemented within the Community Climate System Model version 3 (CCSM3), which is one of the primary Earth system models used by the IPCC. The projected temperature differences in the eastern and northern portion of the European Union (EU) appear significant, especially considering these are monthly averages, in the winter and may have implications for snowmelt. However, parts of EU may actually enjoy a milder winter. The differences in summer temperature are pronounced in the southern regions, especially in the Baltic and the Alps mountain ranges. The political boundaries, rivers and lakes within the region are depicted to allow a visual feel for the possible impacts of the change. The Figure 3 illustrates how climate change may be visualized within a GIS interface to help understand the implications on impacts and adaptation, as well as potentially facilitate policy making at regional scales.

3.3. SITUATIONAL AWARENESS OF ELECTRIC GRID INFRASTRUCTURE

Among the many critical requirements for decision support, two important challenges arise in (i) effective spatiotemporal representation of dynamic data and (ii) efficient integration of such data from disparate and distributed sources. However, an optimal combination of data assets and modelling expertise are often beyond the resources available internally within a single organization but can be accessed and integrated through external sources and collaborations with other "community-of-practice" organizations. The recent advent of Geographic Exploration Systems (GES) coupled with that of the open standards-based data (web) services technology has provided a compelling foundation and opportunity to develop a solutions network for disaster preparedness and response. This concept is used in the current functions of the Office of Electricity Delivery and Energy Reliability (OEDER) of the US Department of Energy (DOE) to enhance the nation's ability to prepare and respond to natural disasters and other emergencies in a capability that enables Visualizing Energy Resources Dynamically on Earth (VERDE) (Shankar et al., 2008).

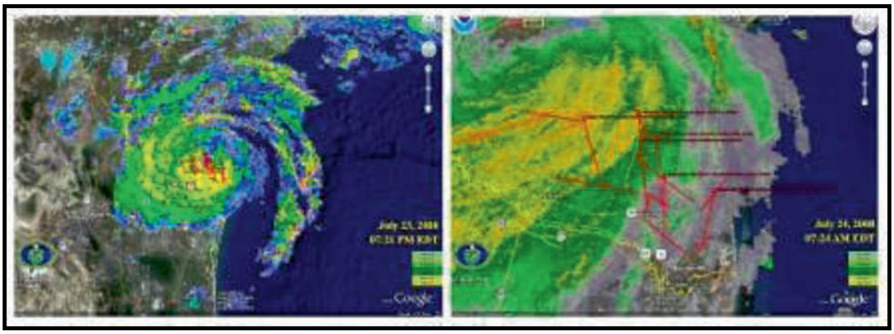

Figure 3. Infrared radar data shows the movement of Hurricane Dolly over 24 h and the impacted electric lines in VERDE.

This involves development of a computationally efficient geospatial modelling, analysis, and visualization framework that allows near real time processing and integration of remotely sensed data and derivation of more intelligent data derivatives. For a compelling visual display that humans can grasp intuitively, VERDE ingests and presents information creatively on the Google Earth platform displaying multi-layered information dynamically and in four-dimensions (including the temporal dimension). The electric lines are presented in a manner to capture an operator's attention and are displayed alongside (as well as over and under) critical data layers. VERDE provides users diverse information including accurate population counts within regions of interest, analysis and predictive results, energy infrastructure data streams, and real-time weather impacts and overlays. Additionally, VERDE's spatio-temporal animation of a blackout's progress or lines affected by a hurricane opens the mind's eye to the true implications of an event.

3.4. AUTOMATED CHARACTERIZATION OF LANDSCAPE PROCESSES

Vast volumes of Earth Observation (imagery and other geophysical) data from satellites and airborne platforms are currently used for image interpretation and geospatial feature extraction (Tobin et al., 2006; Cheriyadat et al., 2007; Vijayaraj et al., 2007). Figure 4 illustrates an example of time series analysis of remote sensing data can also be used for detecting temporal changes in geospatial features which may in turn identify and characterize natural or human induced processes (Fang et al., 2006; Potere et al., 2008).

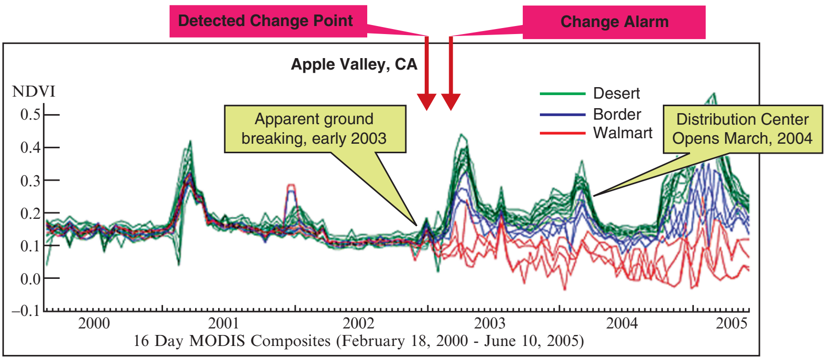

Figure 4. Automated temporal analysis of MODIS data reveals change in land cover marking the initiation of construction for a Walmart distribution center.

Automated feature extraction is a popular approach to cope with the high rate of data acquisition. However, these methods perform better quantitatively (numerical classification of pixels) rather than quantitatively that is to evaluate composition of features in broader geospatial context that are easily recognized by a human image interpreter. Understanding of the geospatial features and processes can plausibly be addressed by content and semantic based interactive information searching and retrieval from multiple sources of data with remote sensing imagery being the primary source.

4. Conclusions and Future Research

Complex relationships need to be better identified, modelled, and explained among the many landscape features and their environmental processes. For example, effective planning for future bio-energy supply demands thorough understanding of the ecological response of energy crops to weather/climate extremes. Dynamic analysis and visualization of spatio-temporal data, integrated with existing and evolving high performance GIS-based approaches, hold strong promise for enhanced environmental decision support. Future research should explore development of a conceptual model defined by domain-specific geospatial-temporal ontology with the goal to reduce the uncertainty in geospatial feature classification by using knowledge about the composition of classes. Moreover, through identification and definition of process specific theories geospatial knowledgebase can be created that can provide an effective framework for multi-level reasoning and query through visualization.

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VIRTUAL WORLDS AND SPINNING GLOBES

APPLICATION OF VIRTUAL WORLDS TO ENVIRONMENTAL SECURITY

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Abstract. Virtual worlds are online replicas of real-world environments, often geospatially accurate and globally complete. In many cases, they combine not only the physical environment, but also the human-oriented environment through virtual representations of people called avatars. Governments, businesses, and consumers are all users of this emerging technology, focused on applications such as social networking, engineering collaboration, education, enterprise management, and more. Virtual worlds hold tremendous promise for environmental security applications. They can be used to catalog, analyze, and visualize the environment as it exists today, as it once existed, or as it may exist in the future. They can also provide simulations of environmental security scenarios that are too dangerous, impractical, or unethical to either create or experience in the real world.

Keywords: Virtual Worlds, Environmental Security.

1. Introduction

Virtual worlds offer enormous potential for supporting both scientific and applied needs of the environmental security field. Building on the suggestion of a "GeoScope" by Buckminster Fuller over five decades ago, virtual worlds replicate the physical structure, appearance, and functionality of the real world in a virtual computer environment. Vice President Al Gore (Gore, 1998) popularized this concept in a 1998 speech that described his vision of an information system to archive, share, and apply knowledge about the Earth. The original NASA-led Interagency Digital Earth Working

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(IDEW) Group chartered in 1999 to implement this vision has since been disbanded. While there have been calls (Grossner et al., 2008) to reinstate the program, the vision's momentum has in large part transitioned to the private sector.

2. Three Paths to Virtual Worlds

Virtual worlds have evolved along three distinct technological paths over the last decade. The first of these is aligned with the Gore vision of virtual worlds as a library of Earth information and is focused on building *geo-replica virtual worlds* that mirror the physical world to the greatest extent possible (computational Earth simulations, such as those for climate research, are not considered virtual worlds for the sake of this discussion). Google Earth (Earth.google.com), Virtual Earth (maps.live.com), and NASA's World Wind (worldwind.arc.nasa.gov) are the most prominent examples (Figure 1). Most of the investment to date has focused on replicating the visual framework of the Earth, from the topography of the natural environment to the shape and appearance of urban structures.

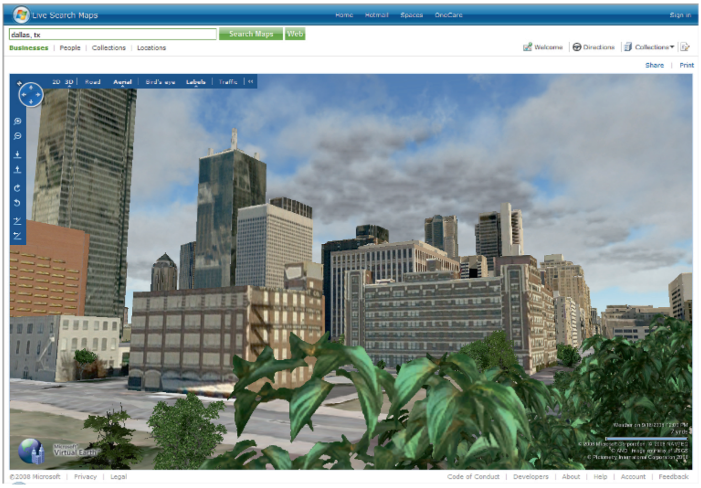

Figure 1. Example of a *geo-replica* virtual world. The Figure shows a highly detailed geometrically-accurate urban model from Microsoft's Virtual Earth.

The second class of virtual worlds takes the opposite perspective by focusing more on replicating the Earth's functionality rather than its precise physical form. These *geo-typical virtual worlds* have familiar environments of hills, fields, oceans, and buildings, though usually not with actual counterparts in the real world (Figure 2). Instead, these worlds attempt primarily to replicate the functionality associated with human social interactions. To do this, they include user-controlled models of people (known as avatars) as elements of the virtual world. The most prominent example of such a world is the online social world called Second Life (secondlife.com).

Figure 2. Examples of a *geo-typical* virtual world, from the NOAA island within Second Life. The left image shows an avatar viewing an evolving algal bloom in the ocean. The right image shows an avatar "experiencing" the environment within the crater of a volcano.

The third class of virtual worlds is those associated largely with gaming. In these *geo-fantasy virtual worlds,* both the physical form and the functionality of the virtual world often take on strong elements of fantasy (Figure 3). With online versions of these games, such as World of Warcraft (worldofwarcraft.com), thousands of users share the world and interact with each other. A number of online games have been introduced recently that allow the game-player to experience first-hand the importance of environmental issues, such as the educational game Spore (spore.com).

Figure 3. Examples of *geo-fantasy* virtual worlds. The example on the left is from the multiplayer online game called World of Warcraft. The example on the right is from the educational game Spore that allows players to experience first-hand the biological evolution of the creatures they design.

A primary goal of this chapter is to demonstrate that the environmental security community can benefit by embracing all three types of virtual worlds. Both the *physical context* and the *functionality* of the environment are essential to its security. Traditional approaches to environmental security tend to focus on the physical context of ecosystems, often neglecting critical interactions between the environment and society. Virtual worlds provide a new means to restore an appropriate balance.

3. Building Virtual Worlds

While the vision of virtual worlds may be compelling, the challenge of building them is daunting. At 1 m resolution, the Earth's surface has nearly a million billion pixels. The built environment requires modelling well over 1 billion structures, and replicating the natural environment even in a single urban area involves identifying and classifying hundreds of thousands of trees. The assortment of information layers that can be geospatially referenced and thus included in a virtual world is almost endless. Yet these challenges pale in comparison to the task of integrating human-scale social functionality – from the vagaries of social interactions to the morass of virtual ethics and governance.

3.1. CREATING PHYSICAL CONTENT

Content itself falls into two overlapping categories: the visual depiction of the world, and geospatially-indexed information that can be "layered" on or combined with the visual depiction. For geo-typical worlds, the visual depiction encompasses geometric and textual replication of both the natural and built environments. Accomplishing this involves work at three basic spatial scales: global, regional, and human.

At all of these scales, the foundation for visualization is digital terrain models corresponding to the bare-Earth surface. At global scales, the best data for creating such topographic models comes from radar satellites; higher-fidelity datasets are often available from other sources at national scales. Imagery from moderate-resolution imaging satellites such as Landsat or high-resolution commercial imaging satellites is combined with the topographic data to create textured 3D replicas of the land surface.

For urban areas, consistent modelling of buildings and structures requires both improved topographic data and higher-resolution textures. This can be accomplished at a somewhat course level with photogrammetric cameras (sometimes augmented by LIDARs) onboard aircraft. Scaling such processes to the thousands of cities and billions of structures in the world presents an enormous challenge. Microsoft has invested in automation of processes to do this. Google has instead elected to leverage community content, providing 3D modelling tools to individuals and local communities with the expectation that such distributed efforts can build the entire world. More detailed building models, such as what would be expected when navigating a city at street level, require the addition of imagery from vehicle-mounted or handheld cameras.

The obvious next step is to integrate exterior models of the world created in this fashion with interior models of buildings and other structures. This can be accomplished by adding textured geometric representations of the building interiors (similar to the exteriors), by integrating engineering models of buildings (typically created by the companies that designed and built them), or by creating quasi-accurate artistic representations of the building interiors. The complexity of building interiors, and the difficulty of accessing them to create 3D models, makes this a major challenge for the end goal of building globally-complete 3D virtual worlds.

With the vast amount of physical information needed to create globally-complete virtual worlds, acquisition of data on time-scales sufficient to keep the content current will become a significant problem as users begin to expect up-to-date information.

Finally, virtual worlds are incomplete without model representations of living objects, notably people. Considerable effort has been applied recently to the problem of realistically modelling human form and function. These models, known as avatars, can be remarkably lifelike in both their appearance and movement. A key aspect of avatar research today is enhancing the human-avatar interface, in particular the ability of avatars to replicate the subtle physical movements of their human counterparts.

This description largely reflects what is happening in geo-replica worlds. In geo-fantasy (gaming) worlds, physical content tends to be artistically created and can diverge dramatically from reality, depending on the theme of the game. Physical content in geo-typical (social network) worlds is typically created using artistic tools, a far less expensive approach for creating content on small scales. There is a significant trend, however, for use of realistic content in both gaming and social network worlds; much of the content being created for geo-typical worlds will eventually find its way into these applications.

3.2. ADDING ABSTRACT INFORMATION

This visual depiction of the world and the objects it contains is still an "empty" world unless complemented by the integration of abstract information about the world. Each building is associated with a wealth of such information, including its engineering design and building maintenance databases, its history and current ownership, the commercial or other activities it supports, emergency procedures for both inhabitants and responders, and far more. Rich spatially-related information is also associated with neighbourhood, city, regional, national, and global scales.

The inclusion of real-time information is almost certain to become a central feature of virtual worlds. Already we see the importance of real-time traffic information in personal navigation applications. “Sensor webs” will be installed for a wide variety of purposes to access information that can be incorporated into virtual worlds. Businesses and individuals will also be the sources for considerable real-time information, ranging from such things as movie times and ticket status to images and videos acquired with mobile phones.

3.3. INTEGRATING PHYSICS

Adding functionality to virtual worlds starts with simple physics. In a virtual world populated with objects, progressing beyond a static environment requires a specification for how objects change with time, as well as how they move and interact.

The geo-replica technology path suggests a desire to build physical functionality in a manner that closely follows that of the real world. In practice, rigorous adherence to this path is neither feasible nor desirable. While ensuring that objects obey the laws of gravity may seem desirable in a virtual world, do we want them to break when they fall? Should metal objects rust and should paint peel? And, if so, do we really want to allocate the computing power to accomplish it?

The challenge of adding functionality is particularly evident when considering environmental applications. Digital elevation models with draped imagery allow us to visualize the environment, but functional replication involves a complex description of the underlying physics, chemistry, and biology. Efforts are currently underway to do this in very limited cases. Drexel University neuroscientist Corey Hart and his associates, for example, have created an island called Terminus in Second Life on which an ecosystem of diverse creatures interacts and evolves according to a set of simple rules (among other things, he is comparing the actions of a virtual frog to its real-life counterpart in the laboratory).

Few problems exceed the challenge of adding the time dimension to virtual worlds. Simple time progression is straightforward for artistically-created objects. But real-world information has complex time-relationships: when it was created, what time period it refers to, and over what period it is relevant. Means for addressing this complexity are still being developed.

3.4. ENSURING UTILITY

If we do not become overwhelmed by the sheer fun of building virtual worlds, we will remember that we are building them to serve us. Yet, like the indexes available to access library information, virtual worlds need organization and navigation features to ensure their utility.

Prominent among these is the ability to easily search for and access the information archived in the digital world. Information's spatial context is inherently ambiguous. A reference to Al Gore, for example, implies geospatial information about where he is now, where he was born, the entire nation he served as Vice President, where he has travelled, and much more. Search tools that help us discover spatial information will require sophisticated disambiguation involving careful analysis of the context in which the query was made. Navigating through the information resulting from search queries is equally challenging: a simple request for the history of Paris would be overwhelming without some ability to further narrow information choices. Spatial equivalents of the internet's hyperlinks may become part of the solution.

As with today's internet, linking information is fundamental to virtual worlds' utility. Consider the relatively simple problem of managing a facility (such as an airport) through its lifecycle. Even the conceptual design must consider complex information about the urban context involving impacts on neighbourhoods, traffic flow, environmental consequences, and more. Tools such as Building Information Management (BIM) have arisen to integrate the many functions associated with information about a building starting with its design, continuing through its construction, and on through decades of use. Similar tools will be needed for engineering, decision-making, administration, and many other purposes.

3.5. SEEDING SOCIAL FUNCTIONALITY

Virtual worlds only become true replicas of the Earth when all physical and functional aspects of our world are included. While some may argue that environmental science needs only a replica of the "natural" world, we know that the largest uncertainties with regard to predicting climate's future come not from our limited knowledge of nature but rather from the challenges of predicting human influences (Intergovernmental Panel on Climate Change, 2008). Achieving climate solutions compels us to develop scientific forecasts of complex societal actions. We must be able to forecast social and economic information such as how people will change their energy usage patterns, governments' willingness to implement international climate treaties, business adoption rates for green technologies, and the likelihood that human ingenuity will surprise us with technological solutions.

Integrating the workings of a virtual society, from the intricacies of individual interactions to the complexities of societal structures, is an intimidating task. Experience with Second Life suggests that not everything needs to be designed into virtual worlds in advance; complex phenomena such as social structures, governance systems, and even economies "emerge" on their own given the right initial structure.

Emergent properties are, in part, a consequence of the large number of avatars in virtual worlds. The aggregate of thousands of avatar interactions creates content and situations that the virtual world inventors could never have included in advance. In social worlds such as Second Life, people tend to view their avatars as proxies for themselves. In games such as World of Warcraft, avatars are more typically perceived as abstract characters. The difference can have interesting consequences for the interactions.

Social functionality is largely about shared experiences, many of which are created in this emergent fashion. Most of our lives are spent in close proximity to other humans, yet the popular information technology today (email, text messaging) still keeps us remote from those we are interacting with. Virtual worlds replicate social proximity – through the inherent "multi-player" functionality and the rich visual replication of realistic environments – in ways that no other computer-based experience can. Stanford researcher Byron Reeves has even shown that avatars touching each other in virtual worlds can trigger an emotional response in the people controlling the avatars.

3.6. MERGING REAL WITH VIRTUAL

Today, virtual worlds exhibit the clear influence of their real world origins. But the real world is as yet largely unaltered by the presence of virtual worlds. As virtual worlds usage becomes commonplace, the socialization that occurs and the decisions made within those virtual worlds will ultimately influence how people act in the real world. It has even been suggested that virtual worlds are beginning to substitute for some real-world civic and social institutions (Williams, 2006). The inevitable coupling of real and virtual worlds is an ironic counterpart to the intertwining of society and the natural environment that characterizes climate change.

As with the real world, perhaps the most compelling feature of virtual worlds is contained in the simple word *context*. Our lives are embedded in context. We are surrounded by people, objects, sounds, and smells that may be largely unrelated to our current task but provide our lives both sensual richness along with unending opportunities for growth and discovery. The extent to which virtual worlds succeed in creating physical and functional context that is both realistic and compelling will be key to their adoption.

4. Using Virtual Worlds for Environmental Security

There are already many examples of virtual worlds being used for environmental purposes, and far more have been envisioned.

4.1. SCIENTIFIC KNOWLEDGE

Al Gore's vision of a digital Earth is founded on a means for archiving vast amounts of information about the Earth and enabling the visualization and understanding of that information. That alone would a profound benefit to the pursuit of scientific knowledge associated with environmental security. The ability to rapidly access information about the Earth as it is, as it was, and as it might become, would be powerful for society.

A number of researchers have begun to see even broader scientific potential from virtual worlds (Bainbridge, 2007). Google Earth and Virtual Earth provide tremendous context to assist with visualization and sharing of data. They are now commonly used for logistics of field campaigns and other location-based science. But the real promise of virtual worlds is novel research methodologies, such as in-world virtual laboratories for doing science, social and economic experiments performed in virtual worlds, and studies of how virtual worlds influence the real world.

Already, scientists have found ways to use virtual worlds as sophisticated what-if platforms. In 2005, a communicable infection was accidentally introduced into World of Warcraft, creating an impediment for players whose characters caught it. Two Rutgers epidemiologists thought this might be an interesting opportunity to study pathogen spread (Lofgren and Fefferman, 2007). What they found surprised them: players put themselves in risky situations more often than is accounted for in epidemiological models, in large part to help others but also out of simple curiosity. As the authors noted, such results can be used to identify deficiencies in the epidemiological models and fix them.

A controlled experiment similar to this would, of course, be unethical in the real world, but it is straightforward in virtual worlds. For environmental research, such capability is critical. Economics, human behaviour, and social dynamics are a major factor in how humans interact with the environment. Virtual worlds may provide one of the few means for performing controlled experiments on these topics. For example, as noted in Section 3.5, an understanding of emergent societal behaviours is critical to forecasting climate change. Statistical inferences from the large player populations, comparisons among different worlds or branching paths within worlds, and analysis of the early evolution within newly introduced worlds all provide tremendous opportunities for studying how social, economic, and organizational dynamics affect environmental issues.

4.2. ENGINEERING AND DESIGN

The engineering and design communities have long used 3D tools to create and visualize. Virtual worlds take this process a step further, by embedding the object or structure to be built within the context of its surrounding environment and enabling sophisticated collaborative design efforts. Even dynamic environments, such as crowd movement and air circulation, can be modelled. Suppliers of rooftop solar energy systems have discovered the value of virtual worlds, using them to rapidly size installations.

4.3. EDUCATION AND AWARENESS

The rich visual content and social interaction inherent to virtual worlds makes them an excellent tool for education and awareness. NOAA's Second Life islands (Figure 2) are designed so visitors can experience first-hand environmental hazards such as tsunamis, volcanic calderas, and algal blooms that are wise to avoid in real life. Spore (Figure 3) allows players to create worlds with ecologies and animals and then observe as the worlds develop under evolutionary pressures, leveraging the fun of gaming to perform ecosystem education. IBM's PowerUp (powerupthegame.org) is an online multiplayer game that uses a virtual world named Helios to educate teenagers about the engineering of energy solutions to avoid ecological disasters. Many smaller community websites have been developed using virtual worlds to advocate awareness of environmental issues to the public.

4.4. SIMULATION AND TRAINING

A considerable community has developed around use of virtual worlds for simulation and training. Simulations of the physical world, such as flight trainers, have existed for many years. Organizations such as the Serious Games Institute (seriousgames.org.uk) have built on this heritage to develop virtual worlds training applications for everything from development of basic business skills to understanding the challenges of being visually impaired to training nuclear power plant employees so as to reduce the risk of environment disasters associated with nuclear waste. The ability to evoke emotions and involve multiple individuals interacting as groups greatly improves fidelity for replicating real-world situations.

4.5. SITUATIONAL MANAGEMENT

Situational management and decision-making tools are critical for environmental natural disaster response, ecosystem preservation, environmental treaty monitoring, and many other environmental security applications. The visual context, shared decision-making capability, and clear communication provided by virtual worlds have made them a highly-desired element of such applications by government agencies as well as environmentally-sensitive industries. IBM uses virtual worlds as an interface to manage computer operations facilities, which is particularly effective when personnel are distributed around the world. The European Environment Agency's "Eye on Earth" website (eyeonEarth.edu, Figure 4) provides an excellent example for how the browser-based nature of online virtual worlds can be used to communicate with a large public constituency.

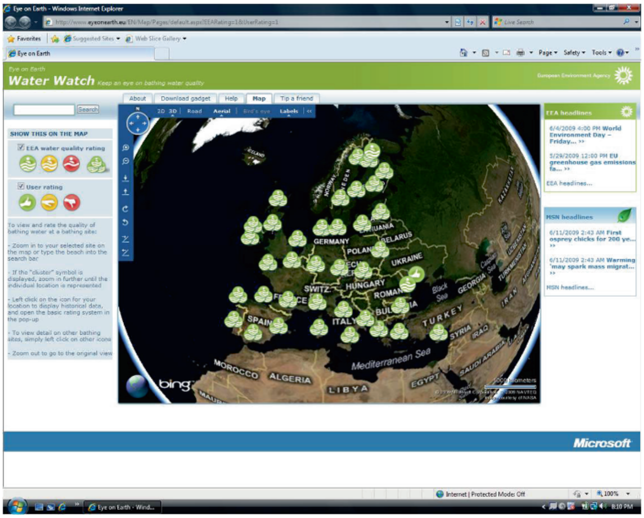

Figure 4. The European Environment Agency's Virtual Earth-based Eye on Earth website, showing water quality scores for more than 20,000 bathing sites across Europe.

4.6. REDUCING ENVIRONMENTAL IMPACT

Many have suggested that replacing real-world functions with their virtual-worlds counterparts can reduce environmental impact. An obvious example is online meetings to replace business travel or even vacation trips (though the energy used by servers for virtual worlds creates a significant carbon footprint itself). Virtual worlds are now integrated into applications for monitoring energy use in buildings, and companies selling carbon offsets employ them to visualize the exact source of offsets such as reforestation.

5. Toward the Future

Today's technology reveals the promise of virtual worlds. But technology advances so fast that our imaginations have trouble keeping up with the possible. A decade hence, computers are expected to be two orders of magnitude faster, networks will have much greater bandwidth with near-universal access, and the underlying client/server architectures will mature significantly. Virtual worlds will be visually richer, with greater information content and more intuitive user interfaces. Similar to today's internet, many new challenges will arise, from avatar viruses to physical object "spam". Demand for current content will motivate sensor systems aimed at monitoring every part of the world at all times.

For environmental security applications, virtual worlds will find many uses. Their ability to address both the physical and functional (behavioural, economic, and social) aspects of the world is central to their utility, as is their inclusion of both reality and fantasy. Rather than being an impediment to real-world applications, it is this very harnessing of fantasy – to perform tasks that may be ethically or practically impossible to accomplish in the real world – that will make virtual worlds so valuable to the environmental security community.

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GEOGRAPHIC INFORMATION PROCESSING: STANDARDS-BASED OPEN SOURCE VISUALIZATION TECHNOLOGY FOR ENVIRONMENTAL UNDERSTANDING

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Abstract. Environmental security is a global issue that will increasingly affect our ability to survive as a species. Collectively we must better appreciate the complex relationships that make life on Earth possible. Providing geographic information in its native context can accelerate our ability to process that information. To maximize this ability to process information, three basic elements are required: data delivery (server technology), data access (client technology), and data processing (information intelligence). NASA World Wind provides open source client and server technologies based on open standards. The possibilities for data processing and data sharing are enhanced by this inclusive infrastructure for geographic information. It is interesting that this open source and open standards approach, unfettered by proprietary constraints, simultaneously provides for entirely proprietary use of this same technology.

Keywords: Geographic, Visualization, Virtual Globe, Open Source, Open Standards, Geospatial, Open Geospatial Consortium, WMS, Server Technology, Java, JOGL, Java Applet, Web browser, Satellite Data Analysis, NASA.

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1. Geographic Visualization Technology

Virtual globes, or geographic visualization technologies, are well into their first generation, providing increasingly rich visualization of more types and quantities of information. However, they are still mostly single and proprietary programs, akin to a web browser whose content and functionality are controlled and constrained by the respective manufacturer. Today Google and Microsoft determine what we can and cannot see and do in these programs.

1.1. WHY WORLD WIND?

NASA World Wind began as a single program with specific functionality, to deliver NASA content. But as the possibilities for virtual globe technology became more apparent, we found that while enabling a new class of information technology, we were also getting in the way.

Researchers, developers and even users expressed their desire for World Wind functionality in ways that would service their specific needs. They want it in their web pages. They want to add their own features. They want to manage their own data. They told us that only with this kind of flexibility, could their objectives and the potential for this technology be truly realized.

World Wind client technology is a set of development tools, a software development kit (SDK) that allows a software engineer to create applications requiring geographic visualization technology.

1.2. MODULAR COMPONENTRY

Accelerated evolution of a technology requires that the essential elements of that technology be modular components such that each can advance independent of the other elements. World Wind therefore changed its mission from providing a single information browser to *enabling* a whole class of 3D geographic applications. Instead of creating a single program, World Wind is a suite of components that can be selectively used in any number of programs.

World Wind technology can be a part of any application, or it can be a window in a web page. Or it can be extended with additional functionalities by application and web developers. Figure 1 shows satellite tracking technology using multi-frames of World Wind for data visualization. World Wind makes it possible to include virtual globe visualization and server technology in support of any objective. The world community can continually benefit from advances made in the technology by NASA in concert with the world community.

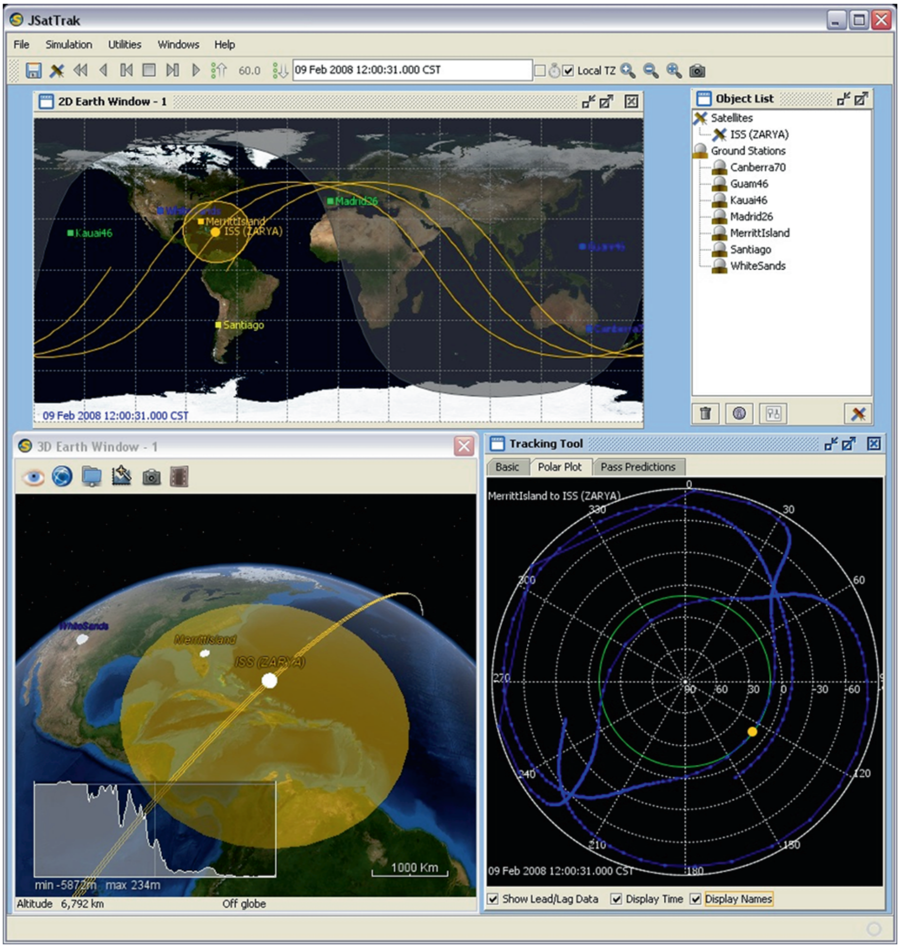

Figure 1. JSatTrak is a satellite tracking program written in Java. It allows you to predict the position of any satellite in real time, or in the past or future. It uses advanced SGP4/SDP4 algorithms developed by NASA/NORAD to propagate the satellite orbits.

2. Open Source and Open Standards

NASA World Wind is NASA Open Source software. This means that the source code is fully accessible for anyone to freely use, even in association with proprietary technology. Figure 2 shows open source satellite data analytical technology that will use World Wind for visualization.

Imagery and other data provided by the World Wind servers reside in the public domain, including the data server technology itself. This allows others to deliver their own geospatial data and to provide custom solutions based on their users' specific needs.

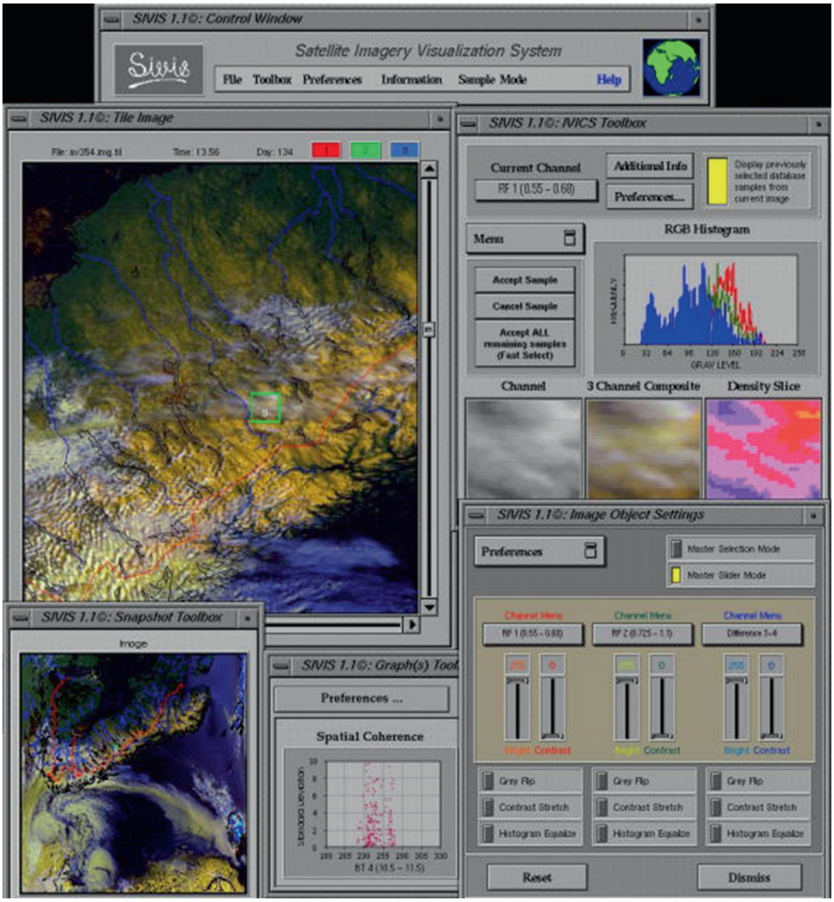

Figure 2. Satellite Imagery Visualization System (SIVIS) currently being enhanced with World Wind for improved access to multi-spectral data analysis, as funded by NASA and in conjunction with the Geoinformatics Group at the University of Alabama, Huntsville.

3. World Wind Vision

NASA World Wind has always had one overriding purpose, to enable rich use of NASA's and the world's geographic data. The premise for this vision is simply "Now it can be done!" A concept map for this can be seen in Figure 3. Some of the enabling issues are:

- Hardware now supports 3D visualization cheaply.
- Network access and bandwidth widely available.
- Increasingly savvy public, largely due to ubiquitous geographic data.
- The world's sense of global community increased.
- Explosion in geo-data availability, much in the public domain.

- Cheap software and distribution mechanism.
- Hordes of programmers with the imagination to innovate and the desire to contribute.
- Manipulation and understanding of geographic data no longer a luxury, but a necessity.

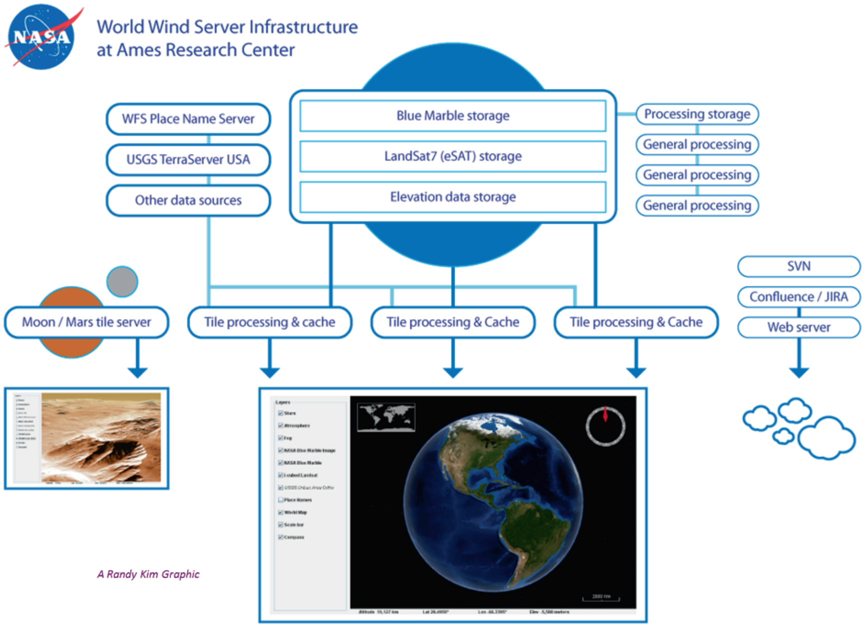

Figure 3. Data processing and infrastructure.

4. World Wind Java (WWJ): What It Is, and Is Not

4.1. WWJ SOLVES THE GEO-BROWSER PROBLEM

- Makes the application master instead of servant.

4.2. WWJ IS A COMPONENT

- WWJ is a plug-in providing an Earth context for applications.
- WWJ does the hard stuff (see Figure 4).
- Terrain generation from real, remote data at high frequency.
- Image display and selection from terabytes of remote imagery.
- Rapid management of data retrieval from distributed sources.

- Getting it all to show up when and where it's supposed to in one easily incorporated component.
- WWJ is cross-platform open source technology.

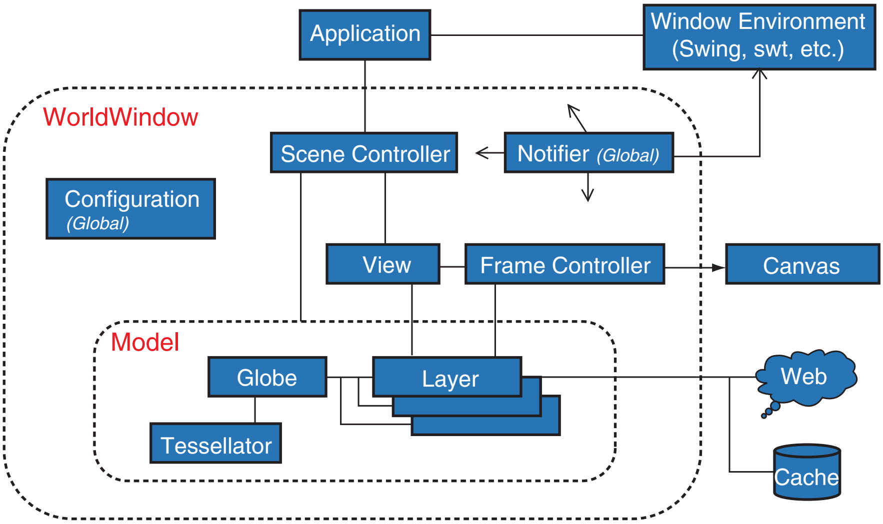

Figure 4. WWJ architecture and operation.

4.3. WWJ IS NOT AN APPLICATION, IT IS ENABLING TECHNOLOGY

World Wind has established relationships with both private industry and other national governments. We are regularly contacted by entities who are already using World Wind technology and wish to learn more for how it can support their enterprise.

5. World Wind Future

Support for World Wind is provided by multiple U.S. federal agencies which have needs for open standards and open source visualization and server technology. World Wind provides the utmost in security and adaptability while also insuring for continual optimization of these core technologies. Collaboration with other governments and U.S. business enterprises via Space Act Agreements offers the opportunity for others to participate closely with the World Wind development team and assure integration of those interests with successive releases of these core technologies.

SKYLINEGLOBE: 3D WEB GIS SOLUTIONS FOR ENVIRONMENTAL SECURITY AND CRISIS MANAGEMENT

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Abstract. SkylineGlobe (www.skylineglobe.com) is nowadays a state-of-the-art complete solution for 3D WEB GIS globe visualization and analysis offering worldwide services, software and solutions. SkylineGlobe software platform based on open OGC® standards enables users to harmonize, process, visualize, integrate, analyze, stream and disseminate 3D geographic information for environmental security, wide-scale mission planning and collaborative crisis management.

Keywords: 3D WEB GIS, Real-Time, On-Demand, On-the-Fly, Distributed Data Processing, Streaming, Harmonization, GPS, Integration, Collaboration.

1. Skyline Software Systems: A Long History in 3D Environments

Since 1997, Skyline Software Systems has been developing 3D real-time visualization based on geographical datasets.

Started in Israel, from developing military & defence applications based on the interactive visualization of little regions with voxel 3D flat engines, this software house has been continuously working at new improvements, evolving to a polygonal 3D globe engine able to enhance all the possible integrations between data formats, devices, services and standards.

Now based in Chantilly VA – USA, Skyline Software Systems, Inc. is member of OGC® (Open Geospatial Consortium – www. opengeospatial.org) and USGIF (United States Geospatial Intelligence Foundation – www. usgif.org), and strategic partner of Intergraph, Oracle, Intel, Microsoft and Object-Raku.

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2. SkylineGlobe Technology Overview

SkylineGlobe Enterprise implementation is a bundled software offering containing all of the necessary Skyline software to set-up a customized, privately-hosted 3D visualization solution, including the following modules:

- TerraBuilder with Multi-Processor extension
- TerraGate with Direct Connect, Collaboration Server and Streaming Feature Server
- TerraExplorer Pro with TerraDeveloper extension and TerraExplorer Plus for end users
- SkylineGlobe Enterprise Web Package (EWP)
- SkylineGlobe Manager
- As optional it may include SkylineGlobe Pro or SkylineGlobe Pro C2MP (Command & Control/Mission Planning)

The SkylineGlobe Enterprise solution is fully scalable, with licenses to support from ten to tens of thousands of concurrent users.

2.1. TERRABUILDER: CREATING 3D TERRAINS

3D terrains are the result of elevation and imagine data fusion in a single file. Skyline 3D terrains are created in the TerraBuilder environment and come out in the optimized MPT proprietary format.

TerraBuilder allows users to quickly create, edit and maintain Skyline 3D terrain databases, supporting most standard data formats for imagery and elevation source data and efficiently handling massive databases.

Although MPT format can contain different resolution data, with no dependency between elevation and imagine, for different areas having different level of interest, the 3D terrains created may easily reach dimension of tens and hundreds GB, always in relation of to the resolution quality of the elevation and imagine sources and to the UnityPerPixel (UPP) resolution assigned to each source for output and finally in the compression factor for elevation and image chosen by user.

2.1.1. TerraBuilder multi-processor: sharing the processing workload

TerraBuilder Multi-Processor extension allows the user to share the work-load of processing among several computers within the same network, reducing the time of 3D terrain creation in reason of the number and quality of CPUs working together.

This could really be considered an asset when time is a limited resource, as happens in crisis management.

2.2. TERRAGATE: STREAMING 3D TERRAINS

3D terrains, due to their size, cannot be directly and fully delivered to end users through the Internet, but this is possible thanks to TerraGate powerful network data server streaming technology, capable to handle and deliver seamlessly TB of datasets over the web to thousands of concurrent users.

When a TerraExplorer/SkylineGlobe client application start asking for a Skyline 3D terrain over the web, TerraGate understands the area of interest and delivers to the client only that area, increasing progressively the detail level by level until all the data available (or required by the visualization highness) is passed.

TerraGate is the main server application of the SkylineGlobe Enterprise bundle but this also includes three different important additional modules.

2.2.1. DirectConnect: on-demand & on-the-fly 3D terrain creation and delivering

The handling of 3D WEB GIS massive projects lead Skyline development unit to an impressive enhancement of this technology's possibilities.

DirectConnect is an extension of TerraGate streaming server for its direct connection to TerraBuilder environment: instead of serving a pre-processed MPT files the TerraGate server is in connection to the related TerraBuilder Project having a proprietary TBP file format, allowing the end user to have the most-updated 3D terrain is possible to have in the lower time is possible to spent.

In fact, the TerraBuilder Project just specifies the path to the sources: using the same path for source files, even from different servers using different connectors (Oracle Spatial Database, Web Map Server, ECW Image Web Server), when replacing old elevation and/or image datasets with updated ones, leads to the creation of up to date 3D terrains, eliminating the need for data pre-processing.

Note that the above 3D terrain creation process will consider just the areas of interest asked by TerraExplorer/SkylineGlobe clients. Moreover, the DirectConnect gives users the ability to easily update parts of the Project.

Using TerraGate DirectConnect extension in conjunction with Terra Builder Multi-Processor extension allows the fusion and the streaming of imagery and elevation data on-demand and on-the-fly in their native formats directly to TerraExplorer/SkylineGlobe clients and in a reasonable time during emergency.

2.2.2. Streaming feature server: optimizing the feature data delivering

The ability to pre-cache data enhances applications that use very large static feature layers where performance is crucial.

SkylineGlobe Enterprise includes a solution called Streaming Feature Server (SFS): a web server that can store feature data as vectors, polygons, points, from various data sources and/or connect directly to spatial databases (Oracle Spatial, ArcSDE, Shape files, etc.) and stream them efficiently to TerraExplorer/SkylineGlobe clients via a standards-based Web Feature Service (WFS). It can output data as standard Tiled WFS or scrambled and compressed.

SFS is a scalable solution to support additional formats and to serve out data to a large number of users (SFS Cluster), offering optimized performance for interactive 3D visualization acting as an advanced cache database. It includes a web based management tool for the control of sources, layers, users, settings, and so on.

2.2.3. Collaboration server: sharing the scene in real-time

Through the TerraGate Collaboration Server users have the ability to open real-time interactive collaboration sessions and share data to provide a true Common Operating Picture.

The manager of the session, the one who created a new session on the server, running the communication service and becoming the leader of the same session, is the only participant that has permission to give the leadership of the session to another user. The manager may invite other users to the session by e-mail.

The leader of the session is the user that sets the location of the camera by navigating freely in the 3D world and all other users can attach to his point of view.

Joining a collaboration session, TerraExplorer/SkylineGlobe clients can:

- Send the camera position to all other participants in the session.
- Attach their own main 3D view (camera) to the session leader view; clearing this option the user may come back to navigate freely on the terrain, and selecting it again to get re-attached to the session view.
- Type and send messages to all the participants.
- Add text labels and draw lines.
- Use a virtual cursor, available in different colours, visible to all participants.

2.3. TERRAEXPLORER: VISUALIZING AND INTEGRATING 3D TERRAINS

The Skyline 3D terrains are created to be seen, together with integrated information, in any 3D GIS client from the TerraExplorer Family:

- TerraExplorer Pro: it is an easy-to-use tool for advanced editing, analyzing, annotating and publishing photo-realistic interactive 3D environments using Skyline's 3D Terrains: the application-based projects comes out in the proprietary FLY format containing all the settings and the references to related outer content. Its powerful API allows the user to perform all the most important practices they would need, as importing and querying elevation, image and feature layers and its attributes (even underground) from local disks and/or from remote servers, visualizing GPS devices real-time movement, projecting videos on terrain even from real-time dynamic devices, managing/ joining collaborative sessions, using advanced 3D measurement and analysis tools.
- TerraDeveloper: it allows the creation and the distribution of full customized application or HTML pages using the powerful Terra Explorer Pro API and a set of Active X controls.
- TerraExplorer Runtime Pro: it is required for the distribution and use of any application, developed using TerraDeveloper, that uses the TerraExplorer Pro API and capabilities, such as authoring and editing tools, terrain analyzing, layer export, etc.
- TerraExplorer Plus: it allows the user to run, through internet and web applications, a set of tools and extensions that use the comprehensive TerraExplorer Pro API, also adding the ability to add and modify all the objects and layers of a project.
- TerraExplorer Viewer: it is a freely downloadable/distributable client application that anyone can use to navigate through high resolution Skyline's 3D world environments, accessing 3D terrains over Internet, over a Network or via CD Rom/DVD media distribution.

2.4. SKYLINEGLOBE ENTERPRISE WEB PACKAGE (EWP): CUSTOMIZING WEB MAPPING SERVICES

This is a complete package based on ASP.NET for the customizations of mapping portals over the web. It includes the main SkylineGlobe 3D web pages and all the associated tools:

- Layers manager tool
- Drawing tool
- Measurement tool
- Communities section
- Worldwide gazetteer tool and database

- SkylineGlobe Pro advanced tools (available for SkylineGlobe Pro users)

EWP also includes a developer section to expand application with additional tools developed by customers.

Powered by an Oracle/MS SQL database and provided with Oracle Express database, EWP gives opportunity to customize the portal using JavaScript and SGAPI (SkylineGlobe APIs) to change the layout, to select and add tools, to develop and publish new tools.

2.5. SKYLINEGLOBE MANAGER: MANAGING & CONTROLING THE 3D GLOBE EXPERIENCE

It is a web based application for the control of the exposed tools and layers and for the monitoring of the users' accesses and traffic statistics.

3. Managing Global Datasets in a Global Application

This SkylineGlobe platform, based on open OGC® standards such as WFS and WMS, can operate as a seamless 3D interface with other existing legacy systems already available in crisis management organizations, and finally represents an enterprise solution for the easy development of photo-realistic and interactive customized applications: the optimal choice for integrate intelligence knowledge coming from military & defence best practices with civil protection and crisis management needs.

3.1. HARMONIZATING THE COORDINATE SYSTEMS

The harmonization of geographical datasets, often available only in one of the many national/regional coordinate reference systems, is been one of the many challenges of the global mapping systems. And this is even truer for 3D globes, as geographical datum is also in tight relation with elevation.

The SkylineGlobe enables the integration in a single geodetic coordinate system, using WGS84 Datum and degrees unit for latitude and longitude parameters for identifying univocally one point in the planet. This is possible at various points of the workflow: when importing sources for 3D terrain creation or when importing layers over a 3D terrain, in a Skyline Globe/TerraExplorer project. A special plug-in is used in both cases, allowing the management of the datasets re-projection from hundreds of different coordinate systems.

So, in case of need of updated image to be seen, we can both update the contents used by TerraBuilder (or by TerraGate with TerraBuilder using DirectConnect) for the creation of a new 3D terrain, or we can just import new datasets (features, elevation and images) using a SkylineGlobe/Terra Explorer client to see those datasets in real-time. In both cases the datasets may lay in a local or a remote server.

Moreover, annotations and feature layers edited in SkylineGlobe/Terra Explorer clients are exportable to ESRI Shape file in hundreds of different coordinate systems.

3.2. HARMONIZATING THE DATA FORMATS

As acknowledged within GI (Geographical Information) community, there are also a wide number of data formats for both vector data and raster data type; so another challenge for GI people is still concerning data format translation for use them inside applications.

There are a lot of efforts in establishing standards for both vector and raster data type. It is worth specially citing OGC® and USGIF, organizations which has collected Skyline Software Systems, Inc.'s membership.

SkylineGlobe includes a number of plug-ins, embedding both open source library and third parties SDK, for the integration of both vector and raster data types.

Also in this case this harmonization can be done during 3D terrain creation and/or in 3D terrain visualization & integration, giving the users the freedom to choose the solution that best fits their needs.

3.3. INTEGRATING THE SERVICES

Is absolutely a truth the fact that GI is increasing in quality, with a consequent increase of file numbers due to bigger list of data availability for the same territory (different type of parameters monitored and different time of acquisition); file dimension is also increasing due to the higher resolution available, specially for raster data type.

For these reasons, the use of web based application is becoming necessary, as is always more useful to use datasets laying in other parts of the world than users are, and is not possible at all to have all this information in a single local network.

As GI and its strategic knowledge are finally raising to a wider great consideration at each planning level, from regional to national and from international to global, there are a lot of efforts for the development of SDIs (Spatial Data Infrastructures): large web portals where is possible to research datasets of interest through a catalogue, often using metadata, and visualize or download them making a selection from the query result or just browsing from a structured collection.

There are many ways of planning an SDI, depending on who is supplying the datasets and who is going to use them, and how all this have to deal with the terms of use. As consequence the number of SDI at regional and national level is growing, but often these infrastructures use different standards to deliver datasets to users.

An answer to the harmonization challenge in the exposition of geographical datasets over web services comes from the already cited OGC, which actually includes all the major GI related software houses. OGC® has validated some relevant standards like WFS (Web Feature Services), WMS (Web Map Services) that are already commonly used by the most important SDIs in the world.

SkylineGlobe is a solution that integrates, in various points of its workflow, customized connectors to the above mentioned OGC® standarddized services and to the major commercial server-based solutions as ESRI ArcSDE, Oracle, SQL and ODBC. These enable users to visualize datasets delivered from all the globe and, if they are just acquired and coming from an environmental emergency, to analyse them in near real-time so to help decision makers better understand the phenomena.

Furthermore, annotations and feature layers edited in SkylineGlobe/TerraExplorer clients are exportable to Oracle Spatial Database.

SkylineGlobe has many implementations worldwide. One of the most significant is actually the French National Geoportal (www.geoportail.fr), managed by IGN (Institut Géographique National – www.ign.fr) demonstrating how, with 20 K concurrent connection available, 2.6 Gbits/sec bandwidth, 180 dedicated servers, 150 TB storage capacity and 300 M pre-calculated images (re-projection, colour balancing, compression, …), this is a scalable enterprise solution, now available for Microsoft, Mac and Linux users.

3.4. MONITORING GPS DEVICES IN REAL-TIME

SkylineGlobe/TerraExplorer clients are including the GPS tracking tool: an NMEA-0183 v2.1 format compliant interface to integrate several dynamic, ground and/or aerial, GPS tracked units into the interactive 3D scene environment reading the real-time location directly from a COM port and/or from a stream file.

The GPS tool supports multiple entities in a single device and allows fast forwarding capabilities when reading the information from files. The GPS-moving objects may be represented in a variety of 2D or 3D graphic symbols, and trace-lines trailing the object routes may also be represented into the 3D scene for a better understanding of the dynamic unities' movements.

3.5. MONITORING AREAS PROJECTING VIDEOS ON TERRAIN

Another useful real-time feature available in SkylineGlobe/TerraExplorer clients is the Video on Terrain tool: this allows the users to project on the 3D terrain a video coming from a device acquiring in real-time.

If the device is capable of movement, the application may read a telemetry file to move the projector in synchrony, always projecting the video in the right position over the 3D terrain, where it has been acquired.

To optimise performance both on server than on client side, it is possible to use streaming video applications and formats, like Microsoft Media Server (MMS) streaming.

3.5.1. UAV video interfaces

SkylineGlobe/TerraExplorer clients using C2MP (Command & Control/ Mission Planning) Extension includes the video interfaces for UAV such as the Predator, allowing real-time video on terrain presentation to put video feeds into proper geographic context.

3.6. COLLABORATING FROM DIFFERENT SITES

Collaboration Server module allows users to open/join and manage interactive collaborative sessions for information sharing and crisis management.

This is an important feature making possible to share the same 3D scene with many people each standing in different control station and/or acting in different region of interest.

Using 3D geo-datasets in an interactive and collaborative environment produces a more efficient understanding of the phenomena evolution saving time usable for rapid dispositions and actions. Moreover, there is no more need of moving general decision quarters inside the crisis area, avoiding the risks there might be in the region for technicians and administrators.

3.7. MEASURING 3D TERRAIN WITH ADVANCED TOOLS

SkylineGlobe/TerraExplorer clients with Pro API have 3D advanced measurement and analysis tools facilitating decision taking. Some of them in particular, like Best Path and Threat Dome tools, are useful when the creation of new roads/path and/or new communications' network is urgent, on the basis of max/min slope and distance between antennas installation.

Other measurement and analysis tools include distance calculator (horizontal, vertical and aerial), area measure, contour map, terrain profile, view shed analysis, line of sight.

3.8. USING ALL THE FEATURES TOGETHER: THE REAL-TIME 3D DIGITAL EARTH

Imagine to integrate all the features available in the SkylineGlobe Enterprise solution. We could manage an environmental crisis setting up a coordination between different stations and mobile units: a first station far from where the event took place, a second one (or many) closer and many mobile units inside the region of interest with connected PC, video and GPS devices.

From the remote station we can control and coordinate the units activities, as we can update projects so to visualize and analyze new datasets coming from satellites or from UAV video feeds or from mobile units.

Updating projects from a remote control station allows all the organization, including the mobile units, to have an up to date 3D interactive visualization of the region as new datasets come to be available even from servers outside the organization's network. This could be done in different ways, starting from clients projects and arriving to TerraBuilder 3D terrain creation project, depending on the urgency.

Collaborative sessions might be open to all the operators so each mobile units can communicate problems to the control stations and these can propose solutions. Emergency information can be delivered broadcast to each participant.

New interesting annotation layers might be uploaded to SFS so to be available to each operator in the field. SFS might be used for to upload and serve new updated datasets as they are ready to de delivered, including those acquired by mobile stations.

WFS and WMS standard services might be used to get datasets from outside and/or to let datasets inside the organization be available even to exterior collaborating organizations.

3.9. USE CASES

3.9.1. Earthquake struck in Sichuan province – China

The Chinese government launched massive rescue efforts promptly after the devastating Earthquake struck in the Sichuan province on the afternoon of 12th May 2008. Skyline immediately participated in the rescue efforts from May 14th by working closely with Cglobe, its local strategic partner and sole distributor in China.

Cglobe is being customizing the Skyline 3D software for the specific missions of numerous government departments so to use them in conjunction with the latest aerial and satellite imagery, radar, terrain elevation and other spatial information to visualize and analyze the impacted areas for rescue efforts.

Several rescue systems based on the Skyline 3D software and developed by CGlobe's engineers are deployed at multiple central, disaster management and rescue-related government departments including:

- State Bureau of Surveying and Mapping (SBSM)
- National Geomatics Center of China (NGCC)
- National Development and Reform Commission
- National Workplace Emergency Management Center
- The Ministry of Environmental Protection
- The Ministry of Health
- The Ministry of Public Security

3.9.2. ASEAN+3 Project: sharing datasets for environment protection

The *ASEAN +3 Satellite Image Archive for Environmental Study* project, expected to be completed by September 2008, is designed to make it easier the sharing of satellite image archives between the ASEAN+3 member countries: Brunei, Burma, Cambodia, China, Indonesia, Japan, Laos, Malaysia, Philippines, Singapore, South Korea, Thailand and Vietnam.

An internet-based distribution network for the dissemination of 3D information will integrate three SkylineGlobe components:

- TerraBuilder, for the fusion of imagery and elevation data
- TerraExplorer Pro, for the customization of the 3D base file with GIS and other data such as live sensor feeds
- TerraGate, Skyline's internet streaming component

In the ASEAN+3 community, satellite imagery is usually acquired, archived and maintained separately by space agencies in countries with ground receiving stations. Incorporating existing information into a region-wide database will enable researchers and governments to better understand and manage of environmental phenomena such as deforestation, pollution, poor water quality, flooding, prolonged dry seasons and declining public health.

CONTINENTAL, NATIONAL REGIONAL, LOCAL EXPERIENCES – CASE STUDIES

THE CHALLENGE OF A SPATIAL DATA INFRASTRUCTURE FOR THE MEDITERRANEAN ISLANDS

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Abstract. The realization of a Spatial Data Infrastructure for the Med-islands can contribute to the sustainable development of such territories, which are considered as “special areas” in the European Union, since it not only supports the implementation of the environmental policies but also strengthens the social and economical development of their citizens. Two fundamental pillars to pursue these objectives are the harmonization of the spatial datasets of the Med-Islands, achieved by the detailed data model developed, and the use of 3D WebGIS technologies, which allow enhanced viewing and processing functionalities. Two prototype SDI applications for the Med-Islands have been developed, one using open source and the other proprietary WebGIS technologies, both showing the viability of the approach based on the agreement and sharing of common standards and procedures.

Keywords: Island, SDI, INSPIRE, Webgis, 3D, Data Model.

1. Introduction

The article 158 of the Treaty of Amsterdam (European Union, 1997) states that “effective consideration of the handicaps faced by EU Island Regions

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must today be transformed into specific political actions and clear legal provisions, fully integrated in the system of European decisions". Among the actions to be taken for the EU islands is the promotion and strengthening of their Information Society technologies, part of which is their Spatial Data Infrastructure (SDI).

A contribution to achieve such objectives has been given by the two on-going European Union supported projects, both of them aiming at the implementation of an SDI for 100+ Med-Islands:

- "Med-Isolae 3D – Mediterranean Islands 3D Aerial Navigation", a Targeted Project co-funded by the Directorate General Information Society and Media of the European Commission, under the eContentplus Programme (www.medisole-3d.eu).
- "Medisolae – Mediterranean Islands Sustainability ISO-based Action Plan 2006-2015", funded under the European Unity Community Initiative Programme Interreg III B Archimed – Archipelago Mediterraneo (www.medisolae.eu).

2. Why a Spatial Data Infrastructure for the Mediterranean Islands?

According to the European Directive INSPIRE (establishing an Infrastructure for Spatial Information in the European Community) (European Parliament and the Council, 2007), the term Spatial Data Infrastructure (SDI) denotes the collection of technologies, policies and institutional arrangements that facilitate the availability of and access to spatial data, and, from the architectural point of view, the six component elements of an SDI are: metadata (i), spatial data sets (ii), spatial data services (iii), network services and technologies (iv), agreements on sharing, access and use (v), coordination and monitoring mechanisms, processes and procedures (vi).

In the "island-context" the role of an SDI is not only to support the implementation of the environmental policies, since the SDI of the Med-Islands serves multiple purposes as use in tourism, planning and, in general, policy making for the straight benefit of the Med-Islands, which are considered as "special areas" in the European Union.

In fact, there is an emerging need to address the use of Geographic Information, involving local authorities and stakeholders, to enable the use of standardized data-sets and to provide interoperable access to them to the outside world, as pillars for the sustainable development of the islands themselves.

To this end the SDI of the Med-islands consists of:

- A spatial data infrastructure which harmonizes the spatial data of the numerous Med-islands and improves the usability and accessibility of standardized spatial information based on INSPIRE guidelines/specifications, ISO/TC-211 and OGC® (Open Geospatial Consortium) standards.

- A 3D-aerial WebGIS flying-over application, linked to the Google Earth™, Virtual Earth™ and ESRI-ArcGlobe™ platforms, for island navigation as a virtual-visiting, allowing the users to easily approach island features such as points of interest (POI), road networks, mountains and hacking trails, beaches, archaeological sites and monuments, city facilities, visitor information centers and many others.
- A dissemination, exploitation and sustainability plan for the commercial use of the geo-portal, offering information about the islands and sales of services related to the spatial datasets.

In addition, the SDI contributes to the economic and social strengthening of the Med-Islands since it:

- Encourages the creation of island SDI networks and knowledge cross-fertilization.
- Promotes the Internet geospatial technology for tourism and other sectors.
- Links island data providers, users, technology providers, management, and promotion organizations.
- Supports the Local Authorities and the implementation of investments policies.

3. The Data Model

The design and realization of the SDI of the Med-islands started from the harmonization of its spatial datasets. To this end the following steps have been made:

- The identification of a feature list that is in line with the INSPIRE themes and contains additional feature classes which are “non-INSPIRE-themes”, but at the same time useful/needed for the geo-portal functionalities.
- The definition of a structure of the feature classes that is compliant with the applicable standards (ISO TC211 + Inspire Implementing Rules) and is simple and complete for the non-Inspire Feature Classes.
- The development of the GDB (Geodatabase).
- Full assistance provided to Med-islands data-providers in the GDB compilation.

Figure 1 schematically shows the Feature List, with a differentiation between the Feature Classes belonging/not belonging to the Inspire Themes. The Feature Classes belonging to the Inspire Themes are included in the Annex I and II of the Directive.

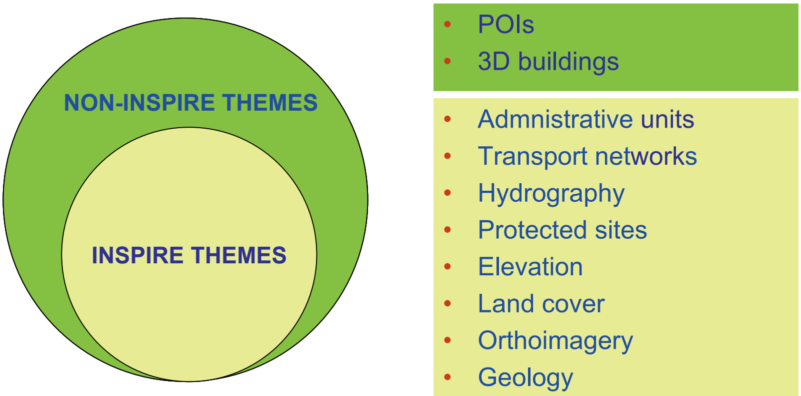

Figure 1. Feature list.

The structure of the feature classes is shown in the Table 1.

TABLE 1. Structure of the feature classes.

Theme code	Description (INSPIRE)	Feature class name	Feature class code	Feature class type
au	National territory divided into units of administration for local, regional and national governance. The administrative units are separated by administrative boundaries. Also includes the boundaries of national territory and the coastline.	Coastlines	au_co	Vector (area)
		Regions	au_re	Vector (area)
		Prefectures	au_pr	Vector (area)
		Municipalities	au_mu	Vector (area)
		Communities	au_cm	Vector (area)
tn	Road, rail, air and water transport networks and related infrastructure. Includes links between different networks. Also includes the trans-European transport network as defined in Decision 1692/96/EC25 and the future revisions of this decision.	Roads	tn_ro	Vector (line)
		Water_network	tn_wn	Vector (line)
		Ports	tn_po	Vector (point)
		Airports	tn_ai	Vector (point)

		Links_networks	tn_ln	Vector (point)
hy	Hydrographic elements, both natural and artificial including rivers, lakes, transitional waters, reservoirs, aquifers, channels or other water bodies, where appropriate in the form of networks and linked with other networks. Includes river basins and sub-basins as defined in Directive 2000/60/EC.	Rivers	hy_ri	Vector (line)
		Lakes	hy_la	Vector (area)
		Transitional_waters	hy_tw	Vector (area)
		Reservoirs	hy_re	Vector (area)
		Aquifers	hy_aq	Vector (area)
		Channels	hy_ch	Vector (line)
		River_basins	hy_rb	Vector (area)
		River_sub_basins	hy_rs	Vector (area)
ps	Area designated or regulated and managed to achieve specific conservation objectives.	Protected_sites	ps	Vector (area)
el	Digital elevation models for land, ice and ocean surface. Includes terrestrial elevation, bathymetry and shoreline.	Contour-lines	el_cl	Vector (line)
		DTM/DEM/DSM	el_dm	Vector (grid)
lc	Physical and biological cover of the Earth's surface including artificial surfaces, agricultural areas, forests, (semi-)natural areas, wetlands, water bodies.	Land_cover	lc	Vector (area)
or	Geo-referenced image data of the Earth's surface, from either satellite or airborne sensors.	Orthoimagery	or	Raster
ge	Geology characterised according to composition and structure. Includes bedrock and geomorphology.	Geology	ge	Raster
Theme code	**Description**	**Feature class name**	**Feature class code**	**Feature class type**
po	Points of interest	Pois	po	Vector (point)
3b	3D buildings	3D_buildings	3b	TBD

In addition, for each Feature Class a proper set of attributes has been identified and name, typology, format and range have been accordingly defined for each attribute.

Separate and detailed instructions have also been given to the Med-Islands regarding other important items, such as the CRS (Coordinate Reference System) and the metadata standards, the latter being managed following the ISO-19115 applicable standards (ISO, 2003).

The Feature Class "POIs" (Points of Interest) contains spatial datasets of particular importance and most of the portal functionalities (spatial data services) are based upon it. The POIs are structured in nine main categories and 60 sub-categories and their data model has been structured in order to be fully compatible with a navigable geodatabase to be used in the Personal Navigation Devices.

Regarding the Feature Class “3D buildings”, the data model, its specifications and the processing workflow are still on-going, due to the complexity to standardise the 3D city model production chain (aerial oblique images, satellite orthoimages, street level pictures, texturing, etc.).

For the convenience of the Med-islands, two versions of the geodatabase have been produced, using ESRI ArcGIS 9.2:

- Personal geodatabase (mdb extension – MS Access file)
- File geodatabase (gdb extension – ESRI geodatabase)

The data provider has to choose the preferred version and compile it with ESRI ArcGIS 9.2.

4. The WebGIS Technologies

A basic architecture to set up interoperable spatial services (Nature-GIS, 2005) is depicted in Figure 2.

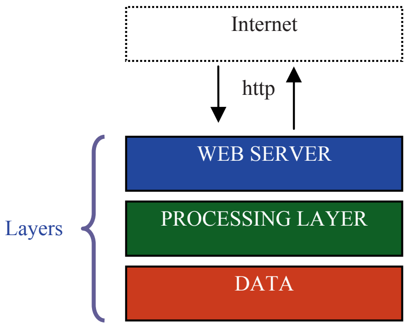

Figure 2. Basic architecture.

In this architecture, the “web server” layer consists of a Web Server, i.e., a software application using http that may host or provide access to content and respond to requests received from web browsers.

Typical software components of the web server layer are Apache (for Linux, Mac, Solaris and Windows), Microsoft IIS (only for Windows) and Java Servlet Engines.

The “processing layer” consists of a software application that allows content management and publishing of geographic data in an interoperable way, often using server-side technologies. The semantics defined in the Web Services of the OGC® specifications are implemented in this layer. Typical software components of the processing server layer are Mapserver (from UMN), Degree (from University of Bonn and the lat/lon German company), ArcIMS or ArcGIS Server (from ESRI), GeoMedia (from Intergraph). If the web services run into Java Environments and are implemented as Java Servlets, additional software components are required, such as a Java Virtual Machine (J2SE) and a Servlet Engine or Application Server (Jakarta Tomcat).

Regarding the "data layer", geographic data can be stored in different ways:

- In files (raster data can be stored in raster file formats such as JPEG, TIFF, GeoTIFF, ECW, etc. Vector data can be stored into various formats such as ESRI ShapeFile, DXF, DGN, etc.).
- In databases, managed by spatial data base management systems such as Oracle Spatial, ESRI ArcSDE, Postgres, etc. Spatial Databases are preferred for higher data volumes, for multi-user data access and updating, for stringent security reasons, for complex spatial and non-spatial operations on the data).

The web server and processing layers are generally on the same computer. The data layer, when managed by spatial data base engines, is generally hosted on other computer(s) accessible through a LAN.

In the two following sub-sections two prototype SDI applications for the Med-Islands are described, developed with open source and proprietary software technologies, respectively.

4.1. OPEN SOURCE WEBGIS TECHNOLOGIES

The first prototype has been developed for the Cyclades islands and for the Kriti island in Greece, with open source WebGIS technologies.

With reference to Figure 2, the web server is Apache 2.2.8 and the software components of the mapserver (processing layer) are UMN Mapserver 4.10.0, Pmapper 2.1.2 and PHP 4.4.4.

From the client side only a web browser is needed to access the application.

In the Figures 3 and 4 two snapshots of the island of Syros (Cyclades) are shown. In the first one are shown some of the vector physical layers (rivers and road network), superimposed to a raster digital terrain model created by the vector elevation contour line. In the second one are show, at a scale 1:5,000, the road network and the Points of Interest classified in their main categories, superimposed to an Ikonos pan-sharpened satellite image. In Figure 3 the main components of the web page are also visible: the search-for box (1), the fine-zoom/slide-bar tool (2), the dynamic scale-bar (3), the overview map (4), the legend (5), the toolbar with the navigation tools (zoom-in, zoom-out, pan, identify, select, auto-identify, measure, add a point of interest, refresh map) (6), additional tools (print map, download map, help) (7).

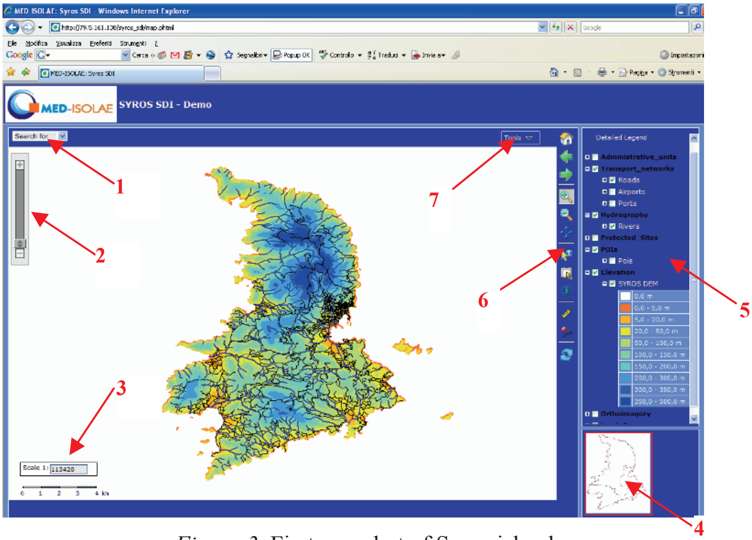

Figure 3. First snapshot of Syros island.

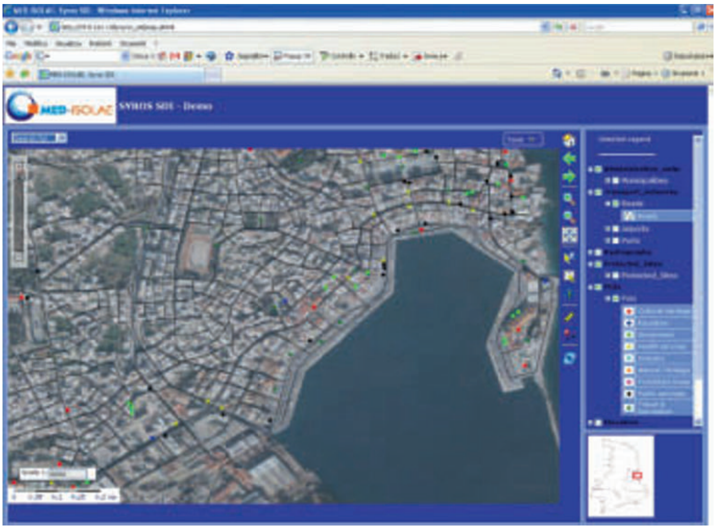

Figure 4. Second snapshot of Syros island.

4.2. 3D WEBGIS TECHNOLOGIES

A second prototype has been developed for the island of Santorini in Greece, based on ESRI ArcGIS Server technologies, focusing on 3D data and related services.

3D documents are created starting ArcGlobe and/or ArcScene, and data are added into them, as surface data, image data, 2D or 3D feature classes, layer (.lyr) files, or just copying and pasting layers between ArcGIS applications. Once data is added to a 3D view, changes on layers are rendered by modifying layer properties. Thus, complete coverages are produced with elevation and base heights tabs, symbology, 3D features, 2D symbols and other properties that affect the 3D view, including background colour options, illumination, and vertical exaggeration.

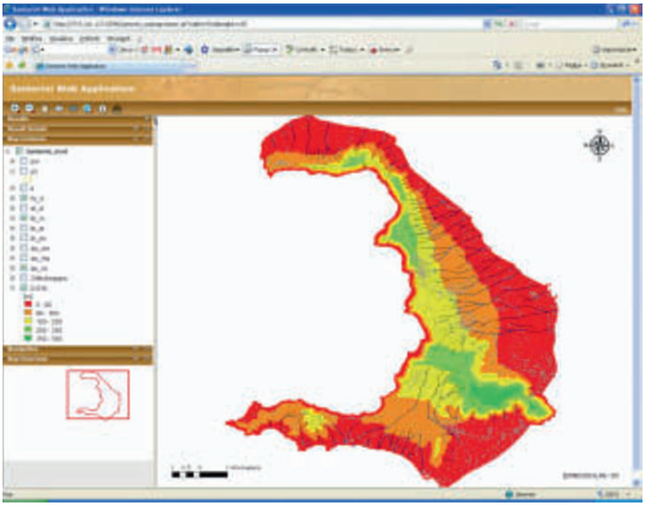

Figure 5. First snapshot of Santorini island.

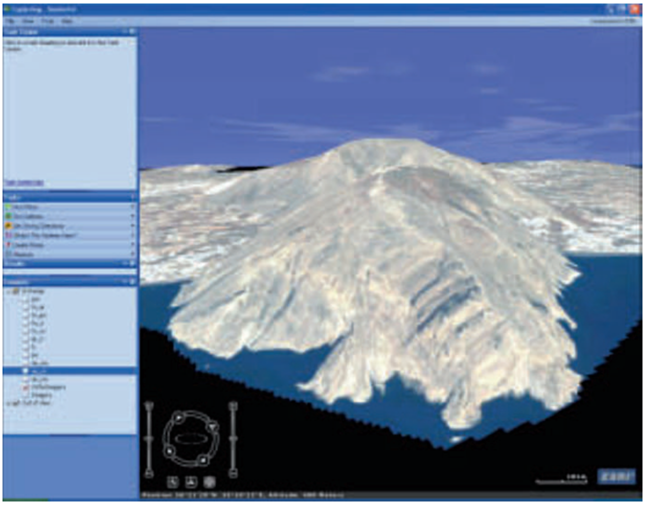

Figure 6. Second snapshot of Santorini island.

In order to access the application the client needs the free viewer ArcGIS Explorer. An enhanced application based on ArcGIS Server 9.3 allowing to mashup ArcGIS Server maps, data, tasks, and geoprocessing services with Google Maps and Microsoft Virtual Earth to take advantage of these popular web map interfaces, is under development.

In Figures 5 and 6 two snapshots of the island of Santorini are shown. The first one is a web application showing in a web browser environment vector data (rivers and road network), superimposed to a raster digital terrain model created by the vector elevation contour line. In the second one it is shown a highly mountainous area of the island, with an Ikonos pan-sharpened satellite image draped on a detailed digital terrain model, all in the ArcGIS Explorer environment which allows full 3D flying over functionalities.

5. Conclusions

The realization of a Spatial Data Infrastructure for the Med-islands can contribute to the sustainable development of such territories, which are considered as "special areas" in the European Union, since it not only supports the implementation of the environmental policies but also strengthens the social and economical development of their citizens.

Two fundamental pillars to pursue these objectives are the harmonization of the spatial datasets of the Med-Islands, achieved by the detailed data model developed, and the use of 3D WebGIS technologies, which allow enhanced viewing and processing functionalities.

Two prototype SDI applications for the Med-Islands have been developed, one using open source and the other proprietary WebGIS technologies, both showing the viability of the approach based on the agreement and sharing of common standards and procedures.

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A DISTRIBUTED REAL-TIME MONITORING SYSTEM FOR LANDSLIDE HAZARD AND RISK ASSESSMENT

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Abstract. The Italian territory, as shown by the recent landslide inventory carried out after 267/98 National law, is affected by diffuse and high hydrogeological risks all over the mountainous areas. In most situations, in presence of high and extensive hydrogeological hazard, traditional "structural" engineering actions can't be done due their expensive costs. In such conditions the only viable way to reduce hazard may be pursued by real time territory monitoring. AMAMiR (Advanced Monitoring Action for Mitigation of Hydrogeological Risk) is a distributed real-time monitoring system created to control landslide activities in the city of San Martino di Finita, in Calabria (South of Italy). It can also be easily used for monitoring a wide range of natural phenomena. AMAMiR is capable of collecting data from heterogeneous sensors as GPS, inclinometers, ground raingauges, piezometers, extensometers, etc. All the data are collected and processed in real time and immediately made available on the web through a special user-friendly portal that permits also navigation through geocoded maps. AMAMiR system represents a very cost-effective powerful tool that can be used to support decision making for public administrations and risk management for civil protection purposes.

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Keywords: GPS, Real Time Monitoring, Remote Sensing, Landslide, GIS.

1. Introduction

The complex geological history of Calabria, in the south of Italy, makes its territory fragile and particularly prone to hydrogeological disasters. The presence of several active faults makes this region at high seismic risk. In particular, the city of San Martino di Finita (Cosenza) is crossed by the so-called "San Fili-San Marco Argentano" fault (Tortorici et al., 1995), which marks the contact between the metamorphic rocks of the Calabrian Coastal Chain and sedimentary rocks of the Crati River Valley (Cosenza). The fault develops over 10 km in depth and extends along the foothills band for about 30 km, affecting several towns. The fault is associated with a cataclastic band, thick up to 500 m, along which the rocks are highly fractured and permeable to water. The large presence of underground water and the particular geotechnical characteristics of the materials of the cataclastic band, lead to widespread landslides all over the entire area of the fault, with wide superficial and deep instability. Landslides can achieve remarkable dimensions inducing high risks to many towns.

In this geological framework, the city of San Martino di Finita, all over its territory, is affected by a high hydrogeological risk. In presence of intense and continuous rainfalls period, the rise of underground water level may trigger large landslides.

Due to the dimension and deepness of landslide bodies, known in the area, traditional engineering "structural" actions are too expensive to mitigate landslide risk. In such conditions the only viable way to reduce risk is the real time monitoring and assessment of Civil Protection Plans.

To mitigate hydrogeological hazard in San Martino di Finita, a real time monitoring project AMAMiR (Advanced Action Monitoring for the Mitigation of the Hydrogeological Risk) has been carried out.

AMAMiR was the result of an agreement between the National Research Council – Research Institute for Hydrogeological Protection (CNR – IRPI) and the city of San Martino di Finita. The main goal of the project is the analysis of the hydrogeological hazard in San Martino di Finita and the implementation of a real-time monitoring system to assess parameters which can affect landslide activity. The technological infrastructure has entirely been designed and realized by e-Guide S.r.l., an Infomobility.it S.p.A. company.

2. The AMAMiR Project

AMAMiR is a real-time monitoring system capable of managing data from heterogeneous remote sensors. Currently, available sensors measure different data type such as: atmospheric parameters (pressure, temperature, humidity, wind, etc.), ground parameters (rainfall, deformations and rotation of buildings, landslide movement, water springs characteristics (turbidity, flow, Ph, conductivity, etc.), underground data (piezometric level, water soil content, etc.). Figure 1 shows all sensors currently deployed all over San Martino di Finita area.

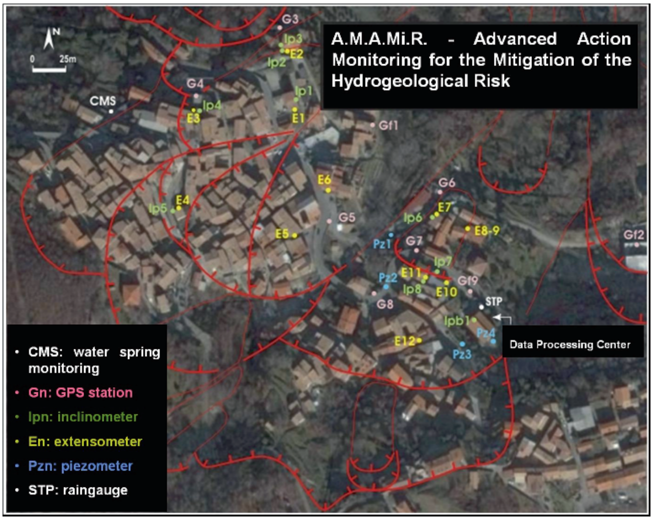

Figure 1. Map of the sensors currently deployed all over “San Martino di Finita” area (Cosenza, South of Italy).

Sensors are assembled through “smart nodes”, geographically distributed, able to handle the local acquisition, temporary storage and transmission of recorded data. A middle-tie software system, automatically interacts with both the “smart nodes” and the central DBMS. The transmission of signals is achieved using different media and standards: cable (TCP/IP, rs232, rs422), Wi-Fi, GPRS, ADSL.

Each “smart node” is independent and acquires data in a self-contained way from one or more sensors or GPS. Furthermore, it is capable to store data locally and it transmits them to the data-processing centre, as soon as possible, when the communication channel is free. Absence of connectivity or communication network problems do not affect the entire system and do not cause data loss.

Through a special WebGIS portal (www.amamir.cnr.it) it is possible to query the AMAMiR DBMS and control in real time the sensors distributed all over the territory, in a simple and immediate way (Figure 2).

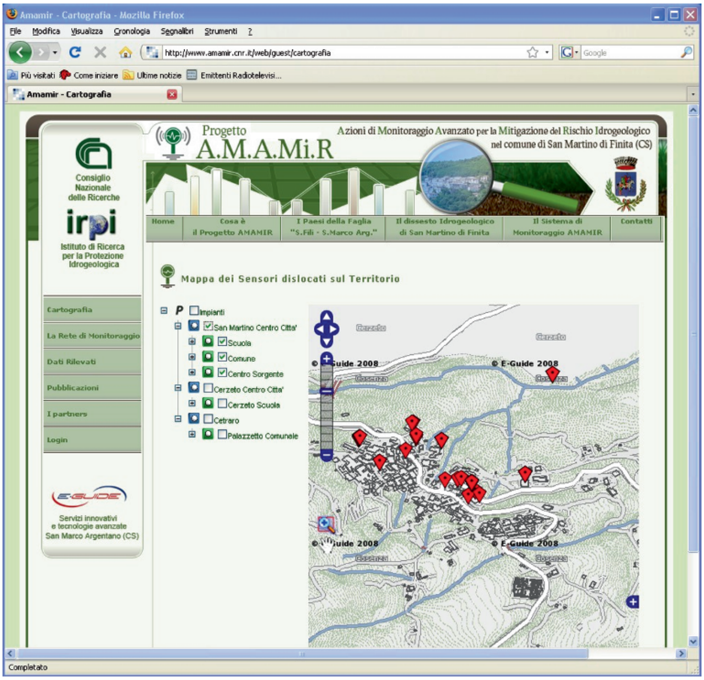

Figure 2. WebGIS portal for reading remote sensors data in real time (www.amamir.cnr.it).

To monitor San Martino landslides, the measure of surface movements is done using two types of complementary sensors: GPS to register absolute displacements, extensometers and tiltmeters for monitoring buildings deformations (Figure 3). GPS data are processed using the GAMIT software (Herring et al., 2006), a high level tool developed at MIT Institute (USA). In order to obtain real time results and high precision and accuracy, GAMIT is used with two processing cycles of calculation: in real time, with "ultra-rapid" ephemerides, and delayed of a week, using "final" ephemerides. This strategy allows an immediate solution, although less accurate, and in a second step, when final ephemerides are available, results are replaced with a fine precise solution. The reference GPS station (Figure 3), used to evaluate baselines, is located in the city of Cerzeto (CS), 2 km far from San Martino di Finita. The stability of the reference GPS station is controlled using IGS (International GNSS Service) referenced frame sites (e.g., Matera). Fixed and mobile GPS stations are spread over the whole territory of San Martino (Figure 1).

AMAMiR system is designed to be easily upgraded and engineered to accommodate different typologies of sensors and a large numbers of “smart nodes”. The system is able to monitor a wide range of spatially distributed phenomena and it is arranged for the use of auto-locating data loggers that allow an immediate and simple setup of new remote sensors. These auto-locating data loggers are automatically recognized by AMAMiR structure and, as soon as they are powered on, start a procedure for localization, transmission, reading and updating of the central database.

In general, all data collected by sensors distributed all over the territory reach the Data Processing Centre through the “smart nodes”, where they are analyzed and processed for an immediate dissemination through the WebGIS Portal (Figure 4).

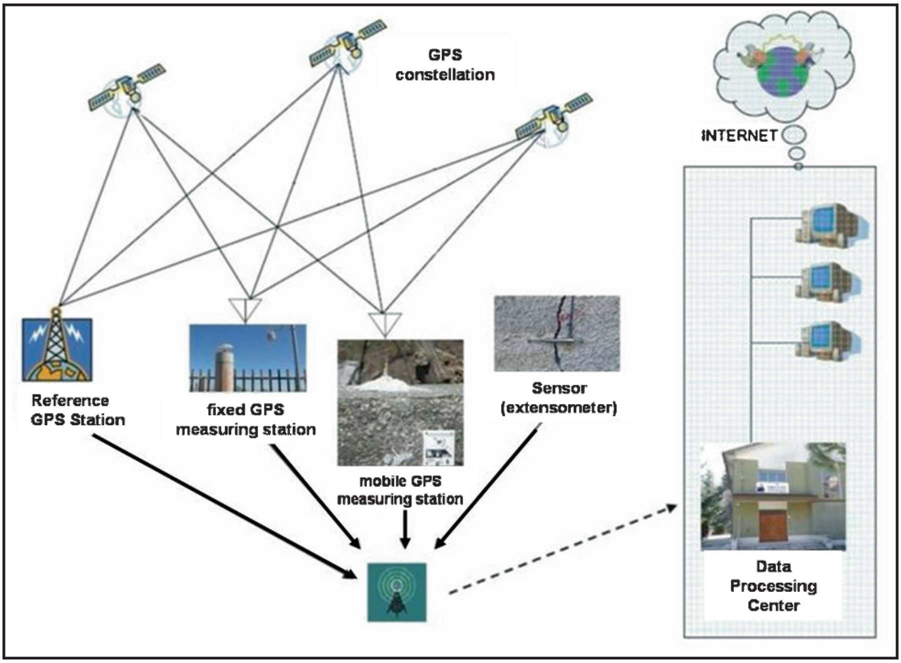

Figure 3. Sensors to monitoring San Martino landslides; the measure of surface movements is done using GPS and extensometers.

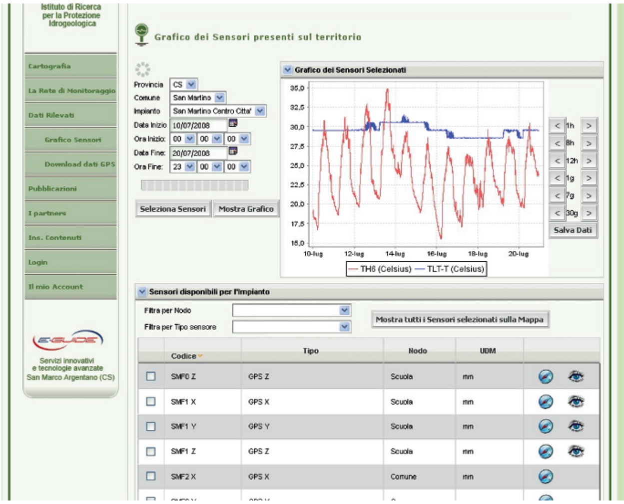

Figure 4. Example of real time reading data from the WebGIS portal (www.amamir.cnr.it).

3. Preliminary Results

AMAMiR system was started on January 2008 and, after a period of calibration and validation, sensors data have been stored from March 2008. The ability of simultaneously monitoring heterogeneous data, allow users to recognize the evolution of the landslide activity in San Martino di Finita. Figure 5 shows the effects of a sequence of ordinary rainfalls occurred on March. After these rainfalls, sensors have detected a tiny displacement of the landslide body. In particular, extensometers have shown an increase of about 0.4 mm in buildings fractures and piezometers a rise of water levels. Although quite ordinary, this first event has provided some preliminary information on the behaviour of the site under observation. Compared with precipitations, the more superficial groundwater (the only monitored, at the moment) have had a lag time of about 48 h while the effects on extensometers have been detected after 14 days (Figure 5). This delay probably is related to the time necessary to recharge deepest groundwater, according to the landslide dept, estimated at about 70 mt.

Figure 6 shows an example of data processing for the GPS station SMF2. GPS data are analyzed with GAMIT software using as reference the GPS station of Cerzeto. Figure 6 shows the trend of $Y(t)-Y(t_0)$, where $Y(t)$ is the Y-component of the vector position Cerzeto-SMF2. ($Y(t_0)$ is the initial reference value).

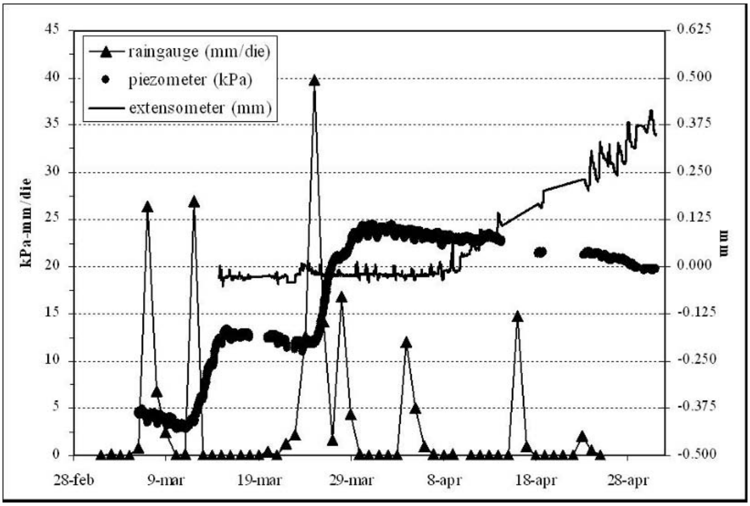

Figure 5. Comparison between raingauge data (filled triangles), piezometric data (filled circle) and extensometer data (solid line) for rainfalls above San Martino di Finita occurred in March/April.

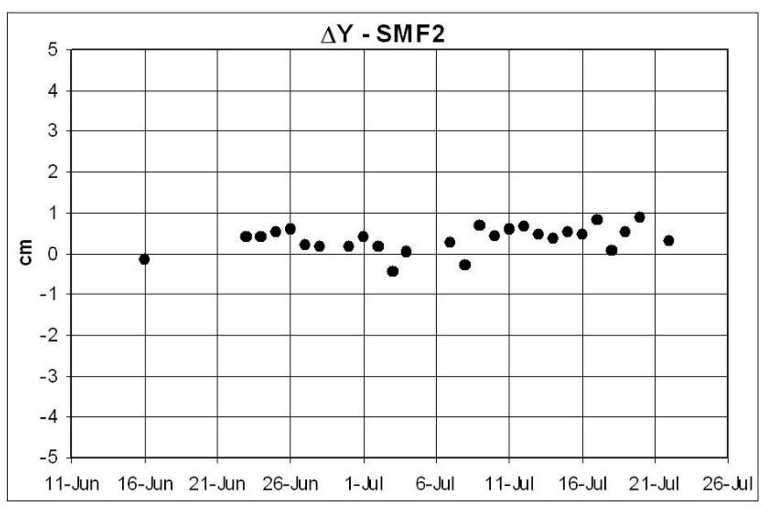

Figure 6. Trend of Y(t) – Y(t0) for the GPS fixed station SMF2. Y(t) is the Y-component of the vector position Cerzeto-SMF2 in time, and Y(t0) is its initial value.

4. Conclusions

AMAMiR is a real-time monitoring system able to handle spatially distributed sensors of different types. The different sensors are locally managed by "smart nodes" which collect, store and transmit data. The managing software process automatically the information collected by the "smart nodes" and sends them to the Processing Centre. The results are available in real time on a WebGIS portal (www.amamir.cnr.it).

The communication between different parts of the AMAMiR system is done through various methods of data transmission: cable (TCP/IP, rs232, rs422), Wi-Fi, GPRS, ADSL. In case of absence of connectivity, to prevent data loss, each node is independent and able to read and locally store data which will be transmitted to the data-processing centre as soon as possible.

Until now, AMAMiR has shown good stability and robustness in managing remote data. The flexibility of the whole system makes it easy to increase the number of remote sensors and an immediate start up when auto-locating data loggers are used. The system is able to monitor, in real time, a wide range of natural phenomena like landslides, floods, etc. The AMAMiR system is a powerful tool, very cost-effective, that can be easily installed everywhere and used to support decision making and protection from hazards for civil protection purposes.

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VALIDITY OF DRASTIC AND SI VULNERABILITY METHODS

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Abstract. The phreatic aquifer of Oued Guéniche (prefecture of Bizerta, northeast of Tunisia) which occupies an area of 83 km^2 has a great economical importance because it is used for irrigation and domestic consumption. The area of the aquifer is essentially occupied by agricultural zones, characterised by an increasing use of chemical fertilizers. Those chemical fertilizers threaten the quality of the ground waters. The study of the vulnerability to pollution of this aquifer was made by applying two vulnerability methods: the generic DRASTIC which is an intrinsic vulnerability method, and the Susceptibility Index (SI) which is a specific vulnerability to agricultural pollution method. This study employed the Geographical Information System (GIS) technology as a system for the acquisition, storage, analysis and display of geographic data. The validity of the two methods to agricultural pollution by nitrates was verified by comparing the distribution of nitrates in the groundwater with the distribution of the different vulnerability classes. That comparison demonstrated that the SI method is the more valid method in the studied system.

Keywords: Vulnerability to Pollution, Aquifer, Nitrates, GIS, DRASTIC, SI.

1. Introduction

The underground waters represent an important resource exploited for human consumption and for the agricultural and industrial use. Those waters

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are usually contaminated by pollutants of different natures: biological, chemical or physical. The prevention against the aquifer pollution constitutes an important stage to which scientists are providing an increasing effort specially in studying the aquifer vulnerability. The studied aquifer is the phreatic aquifer of Oued Guéniche (prefecture of Bizerta, northeast of Tunisia). It is located in a plain essentially used for agriculture with an increasing consumption of chemical fertilizers. Thus, this study aimed at verifying the validity of the following parametric vulnerability methods: the generic DRASTIC (Aller et al., 1987) and SI (Ribeiro, 2000) methods. The first method is an intrinsic vulnerability one while the last one is a specific vulnerability to pollution by agricultural pollution. Those methods consist in systems of numerical quotation based on the consideration of different factors affecting the hydrogeological system. The use of GIS technology in the evaluation of aquifer vulnerability is necessary because GIS is a system for the acquisition, storage, analysis and display of geographic data.

2. The Used Vulnerability Methods

2.1. DRASTIC METHOD

DRASTIC (Aller et al., 1987) is a parametric method that was developed by the US Environmental Protection Agency (US EPA) for evaluating the intrinsic vertical vulnerability of groundwater systems on a regional scale. Intrinsic vulnerability is the term used to define the vulnerability of groundwater to contaminants generated by human activities. It takes account of the inherent geological, hydrological and hydrogeological characteristics of an area, but is independent of the nature of human activities. The acronym DRASTIC stands for the parameters included in the method: Depth to water, net Recharge, Aquifer media, Soil media, Topography, Impact of vadose zone, and hydraulic Conductivity of the aquifer. DRASTIC indexes calculated are roughly analogous to the likelihood that contaminants released in a region will reach ground water, higher scores implying higher likelihood of contamination.

The DRASTIC method includes two versions: the generic (or normal) DRASTIC version applied in the case of inorganic pollutants (e.g., in the case of nitrates), and the pesticides DRASTIC version applied in the case of pesticides. The method yields a numerical index that is derived from ratings and weights assigned to the seven model parameters. The significant media types or classes of each parameter represent the ranges which are rated from 1 to 10 based on their relative effect on the aquifer vulnerability.

TABLE 1. Generic DRASTIC parameter weights (Aller et al., 1987).

Parameter	Weight
D : depth to water	5
R : efficient or net recharge	4
A : aquifer media	3
S : soil media	2
T : topography	1
I : impact of the vadose zone	5
C : hydraulic conductivity of the aquifer	3

TABLE 2. Criteria for the evaluation of vulnerability in the DRASTIC method (Aller et al., 1987).

Vulnerability degree	Vulnerability index
Low	1–120
Moderate	121–160
High	161–200
Very high	200

The seven parameters are then assigned weights ranging from 1 to 5 reflecting their relative importance (Table 1). The DRASTIC Index is then computed applying a linear combination of all factors according to the following equation:

DRASTIC Index = Dr*Dw + Rr*Rw + Ar*Aw + Sr*Sw + Tr*Tw + Ir*Iw + Cr*Cw

where D, R, A, S, T, I, and C are the seven parameters and the subscripts r and w are the corresponding rating and weights, respectively. The DRASTIC index values vary from 23 to 226 in the case of the generic version and fall into four classes corresponding to four vulnerability degrees (Table 2).

2.2. SI METHOD

SI (susceptibility index) method (Ribeiro, 2000) is a vulnerability method for evaluating the specific vertical vulnerability to pollution originated by agricultural activities mainly by nitrates. Specific vulnerability is the term used to define the vulnerability of groundwater to a particular contaminant or group of contaminants. It takes into account the properties of the contaminants and their relationship with the various components of intrinsic vulnerability.

The DRASTIC method has been used as a base, on which four original parameters have been maintained: depth to water, annual efficient recharge, aquifer media and topography, and a new one has been introduced: the land cover type. The principal types of land use and their assigned ratings provided by a team of Portuguese scientists (Ribeiro, 2000) are shown in Table 3.

TABLE 3. Main soil occupation classes and correspondant LU values (Ribeiro, 2000).

Land use class	**LU rating**
Industrial discharge, landfill, mines	100
Irrigated perimeters, paddy fields, Irrigated perimeters, paddy fields, Irrigated and non irrigated annual culture	90
Quarry, shipyard	80
Artificial covered zones, green zones, continuous urban zones	75
Permanent cultures (vines, orchards, olive trees, etc.)	70
Discontinuous urban zones	70
Pastures and agro-forest zones	50
Aquatic milieu (swamps, saline, etc.)	50
Forest and semi-natural zones	0

The weight string (Table 4) has been modified in relation to the DRASTIC method. The SI index values measuring the aquifer vulnerability fall into four classes corresponding to four vulnerability degrees (Table 5).

TABLE 4. Weights attributed to SI parameters (varying from 0 to 1, from the less to the most important) (Ribeiro, 2000).

Parameter	D	R	A	T	LU
Weight	0.186	0.212	0.259	0.121	0.222

TABLE 5. Criteria for the evaluation of vulnerability in the SI method (Ribeiro, 2000).

Vulnerability degree	**Vulnerability index**
Low	<45
Moderate	45–64
High	65–84
Very high	85–100

The different modifications have been effected taking into consideration the characteristics of common agricultural contaminants, such as the nitrate ion. The following factors were not taken into consideration: vadose zone media, soil type and permeability of the aquifer media. This last parameter is very difficult to evaluate spatially and it has already taken into consideration in the A parameter (Aquifer media) by the fracturation and granulometry factors. The type of soil is indirectly represented by the land use type: "For the purpose of groundwater pollution risk assessment, the soil zone can, in practice, either be allowed for, indirectly when estimating the subsurface pollution load from diffuse sources, or directly in combination with aquifer vulnerability, the resulting categories applying only to diffuse source pollution" (Foster, 1987). Attenuation processes in the soil and vadose zones relative to persistent contaminants are considered by Vrba and Zoporezec (1994) to be of less importance. Foster (1987) also minimizes the vadose zone role: "In the case of persistent mobile pollutants, the unsaturated zone merely introduces a large time-lag before arrival at the water-table, without any beneficial attenuation. In many other cases, the degree of attenuation will be highly dependent upon the flow regime and residence time". In actual fact, besides the cleansing processes, which implicate the degradation of the contaminants, dilution processes are primordial in the vulnerability assessment. They determine the restoration capability of the aquifer, which can also be expressed in terms of residence time (volume of water contained in the aquifer divided by the rate of recharge).

3. Study Area

The phreatic aquifer of Oued Gueniche is located in the prefecture of Bizerta (northeast of Tunisia) (Figure 1). Its total surface is 83 km^2 and is situated in a plain between latitudes North 500.5676 and 513.208 km and longitude East 425.5766 and 437.778 km (Lambert North Tunisia coordinates). That aquifer is limited to the first 40 m.

The main towns and villages in the study area are El Alia, Menzel Jemil, El Khetmine, El Azib, Ejjouaouda, and Daouar Maghraoua. The main rivers crossing the study area are Oued Guéniche, Oued El Azib, Oued El Galaâ, Oued El Hella, Oued Jeddara, Oued El Meleh, and Oued Nechrine. The annual average rainfall varies between 485 and 599 mm (DGRE, 1990–2005) and the annual average temperature is about 18°C (INM, 1990–2005). The water resources of this aquifer have a great economical importance for this agricultural region. In fact, about 1,400 wells are currently exploited in the study area and an annual volume of 10.5 million m3 from these wells (the equivalent 126.3 mm) is used for irrigation. The aquifer's area is essentially occupied by agricultural zones characterised by an increasing use of chemical fertilizers which threatens the groundwater's quality.

Figure 1. The phreatic aquifer of Oued Guéniche.

The identification of the hydrogeological units and subunits as well as the assessment of the DRASTIC and SI parameters requires a good knowledge of the geology, the hydrogeology, the soil media, the topography, the meteorology and land use in the study area. The data used in this study are taken from different studies: geological (Burollet, 1951, 1952; El Ghali and Ben Ayed, 2000), hydrogeological (DGRE, 1990–2005; Ennabli, 1966; Haj Ltaief, 1995), geophysical (Ennabli, 1966; Haj Ltaief, 1995), climatic (DGRE, 1990–2005; INM, 1985–2005), pedologic (Gilson, 1995; Le Floc'h, 1959), topographic (OTC, 1981) and land-use studies (CRDA de Bizerte, 2000).

4. Application of the DRASTIC and SI Methods

4.1. GIS, AN EFFICIENT TOOL FOR THE STUDY OF VULNERABILITY

GIS technology allows a correct and continuous evaluation of the aquifers' potential concerning the exploitation capacity and vulnerability towards the danger of contamination with different pollutants, creating an objective overview. GIS means: Maps (document that contains data and describes hydrogeological events), information that is structured into a Database (information that can be used in the surveillance of the correct exploitation of groundwater) and Correlations between the two types of information: graphical and non-graphical (they are at the base of interpretations, studies, designing water supply systems, evaluation and impact on the environment).

The GIS software IDRISI 32 V2 and CartaLinx 1.2 were used to establish the different thematic maps and to generate the vulnerability to pollution maps in the present study. IDRISI 32 is a comprehensive geographic analysis and image processing system, while CartaLinx 1.2 is a spatial data Builder, a digital map development tool that serves as a companion to a variety of popular Geographic Information System (GIS) and Desktop Mapping software products. CartaLinx uses a full topological editor/digitizing system with capabilities for automatically building vector topology; automated generation of polygons and assignment of ID's by means of polygon locators (label points); insertion, deletion, or movement of nodes, arcs or arc vertices; real-time projection/datum transformation of digitizer and GPS input data to meet mapping reference system specifications; feature filtering and extraction to new spatial databases based on feature attributes (filter) or location (clip).

4.2. APPLICATION OF THE GENERIC DRASTIC METHOD

The depth to water map was obtained by interpolating 122 depth to water values recorded in 2005 by the DGRE, homogenously distributed in the study area. The aquifer net recharge was calculated according to the Williams and Kissel method (1991), the most suitable method to the studied area (Hamza et al., 2006). The aquifer media was determined using lithostratigraphic correlations based on the data of electric prospection, of boring logs and of geological maps of the study area (Haj Ltaief, 1995). Six geoelectric sections passing by 13 boring logs distributed in the study area have been established.

In addition to these data, values of hydraulic conductivity of the aquifer (Ennabli, 1966) measured in nine well distributed localities, were used to estimate the aquifer lithology in these localities based on tables giving values of hydraulic conductivity for different lithologic types of the aquifer (Rodrìguez et al., 2001). All these data, as well as the 2005 data of depth to water, permitted to determine the thickness as well as the lithology of the aquifer. The pedologic data was extracted from two sources: the pedologic map at the 1:50,000 scale of the southern border of the lake of Bizerta (Le Floc'h, 1959) and the hydropedologic map of the area of Menzel Jemil – El

Alia at the 1:12,500 scale (Gilson, 1995). The surface slope map was established using the two topographic maps (1:25,000 scale) covering the study area (OTC, 1981). The data of lithology of the vadose zone was extracted as the same way as the aquifer lithology data. Finally, the hydraulic conductivity of the aquifer has been determined referring to the nine values of hydraulic conductivity already mentioned.

Moreover, we used the map of aquifer lithology already established as a base to estimate the values of hydraulic conductivity using a bibliographic table giving the hydraulic conductivity values for different types of aquifer lithology (Rodrìguez et al., 2001). When all thematic maps had been registered and geo-referenced, they were on-screen digitized to create point, segment, and polygon maps of the different geographical entities. The different obtained maps are first classified according to the DRASTIC classification using the IDRISI 32 Reclass function. Second, by using the Image Calculator function of IDRISI 32, each mapped parameter is multiplied by the value of its weight. Third, the seven numerical maps are gathered, hence we obtain a vulnerability index map. The latter is itself classified according to the DRASTIC classes (Table 2) to establish the final vulnerability map.

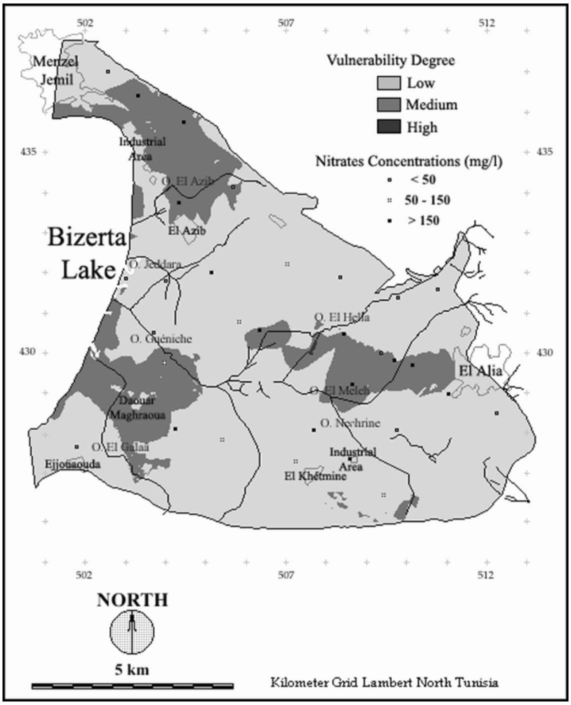

Figure 2. Generic DRASTIC vulnerability map.

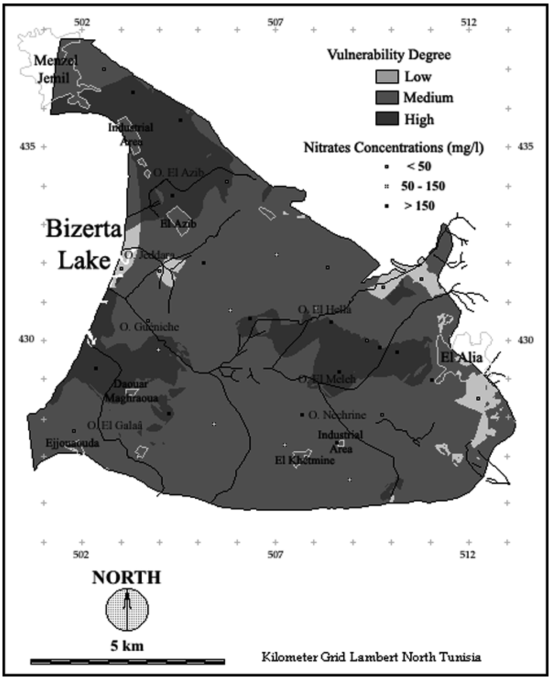

Figure 3. SI vulnerability map.

The established generic DRASTIC map (scale 1:50,000) shows three vulnerability classes: low, moderate and high (Figure 2). The low vulnerable zones occupy 78%, the medium vulnerable zones occupy 21% and the high vulnerable ones occupy less than 1% of the total area.

4.3. APPLICATION OF THE SI METHOD

The four maps related to the parameters depth to water, annual efficient recharge, aquifer media and topography, were already prepared in the frame of the elaboration of the DRASTIC map. The preparation of the land use map was based on that of the prefecture of Bizerta (CRDA de Bizerte, 2000). The five thematic maps are classified using the IDRISI 32 Reclass function. Then, each mapped parameter is multiplied by the value of its weight. Later on, the five numerical maps are gathered to establish a vulnerability index map which is itself classified according to the SI classes (Table 5) ending by obtaining the final vulnerability map. The obtained SI vulnerability map (scale 1:50,000) shows three vulnerability classes: low, medium and high (Figure 3). The low vulnerability zones occupy 4%, the moderate vulnerability zones occupy 75% and the high vulnerability ones occupy 21% of the total area.

5. Vulnerability to Pollution by Nitrates, Validity of the Used Methods

The validity of the application of the generic DRASTIC (Aller et al., 1987) and SI (Ribeiro, 2000) methods to the study of pollution by nitrates was verified in the studied aquifer by comparing the distribution of nitrates in the groundwater and the distribution of the vulnerability classes. Stigter et al. (2006) defined the low nitrate concentrations as the concentrations lower than 50 mg l^{-1}, the moderate ones as the ones between 50 mg l^{-1} and 150 mg l^{-1}, and the high ones as those larger than 150 mg l^{-1}.

TABLE 6. Coincidence between nitrate concentrations and the different vulnerability classes of the Generic DRASTIC vulnerability map and SI methods.

		Number of high values of $[NO_3^-]$ (>150 mg l^{-1})	Number of moderate values of $[NO_3^-]$ (stated between 50 and 150 mg l^{-1})	Number of low values of $[NO_3^-]$ (<50 mg l^{-1})
Generic DRASTIC vulnerability map	High vulnerability	0	8	4
	Moderate vulnerability	0	1	5
	Low vulnerability	0	2	10
SI vulnerability map	High vulnerability	10	2	0
	Moderate vulnerability	0	5	1
	Low vulnerability	0	6	6

There are 30 available nitrate measures registered in 2005 in the study area. Based on Table 6, we deduce that the nitrate concentrations are distributed as follows:

- For the generic DRASTIC map, among the 12 values exceeding 150 mg l^{-1}, eight values coincide with the moderate-vulnerability zone, four with the low-vulnerability zone and no one with the high-vulnerability zone. Among the six values situated between 50 and 150 mg l^{-1}, only one coincides with the moderate-vulnerability zone and five with the low vulnerability one. Finally, among the 12 values below 50 mg l^{-1}, 10 coincide with the low-vulnerability zone and only 2 with the moderate-vulnerability zone.

- For the SI map, among the 12 values exceeding 150 mg l^{-1}, 10 (83% of the values) coincide with the high-vulnerability zone, and only two (17% of the values) with the moderate vulnerability one. Among the six values situated between 50 and 150 mg l^{-1}, five (83% of the values) coincide with the moderate vulnerability zone, and only one with the low-vulnerability zone. Finally, among the 12 values below 50 mg l^{-1}, six (50% of the values) coincide with the low-vulnerability zone, and six others with the moderate-vulnerability one.

6. Conclusions

The use of GIS techniques for the elaboration of such studies is indicated, not only for the automatization of certain operations that suppose very complicated mathematical algorithms but also for the ease of the interpretation of the results.

The comparative study of the two vulnerability maps to the available nitrate measures shows that the most valid map for the assessment of the vulnerability to pollution by nitrates is the SI map, with a coincidence percentage of 70% between the nitrate concentrations and the different vulnerability degrees (21 values per 30). The generic DRASTIC map demonstrates a coincidence percentage of 37% between the nitrate concentrations and the different vulnerability degrees (11 values per 30). The DRASTIC method is an intrinsic vulnerability method which does not takes into consideration neither the nature of pollutants nor the factors managing the specific vulnerability as the land use factor. The conservative behaviour of nitrates does not permit a correct vulnerability assessment by intrinsic methods such as DRASTIC, which ascribe a great significance to the attenuation capacity of the involved hydrogeological parameters.

This study case show the advantage of using the SI method that has been conceived taking into consideration the chemical properties of nitrates together with the existing relations between this pollutant and the various components considered in the intrinsic vulnerability. In that specific vulnerability method, the land use parameter allows the integration of specific factors for each type of land use, such as the recycling effect in irrigation zones, and allows a better sensibility to the real local conditions.

The SI method was verified in many study areas in Portugal (Francés et al., 2002; Ribeiro et al., 2003; Stigter et al., 2006) and in Tunisia (Hamza et al., 2007). However, since the susceptibility index is an empirical method, a better evaluation of the weight of each parameter and a more specific rating of land, taking into account factors as duration, quantity and intensity of fertilizer application in a specific area, will allow obtaining a more accurate result.

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ENVIRONMENTAL SECURITY AND PASTORALISM

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Abstract. Pastoral areas are home for more than 200 million people and provide essential environmental, economic and social services at global level. Despite the key role of grasslands for many emerging economies, these areas are historically affected by intensifying challenges, like droughts, desertification, burgeoning populations and extreme poverty. As a result of these conditions many countries in Africa, Middle East and Asia are host to a disproportionate number of the world's violent conflicts, where vulnerable pastoralist communities play a key role. The main aim of this paper is to provide an overview of the importance of pastoral areas for the security and an analysis of the role of Geomatic tools to support environmental security analysis in pastoral areas, with special consideration for the activities carried out by ILRI as part of its global mandate to eradicate poverty and insecurity through sustainable livestock production.

Keywords: Environmental Security, Pastoralism, Geomatic, ILRI.

1. Environmental Security and Pastoralism

1.1. INTRODUCTION

In Genesis: "Cain said to his brother Abel; And when they were in the field, Cain rose up against his brother Able and killed him (…)." The reader will notice that what Cain actually said to Abel is omitted in the passage. One

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religious commentary gives a plausible explanation. Cain and Abel had divided the world between them. Cain owned all the land and "became a tiller of soil," while Abel took possession of the livestock and "became the keeper of sheep." According to this interpretation, Cain told Abel to get his livestock off his brother's land and this triggered the first violent conflict over territory. Pastoral conflict is as old as civilization itself but is it merely a coincidence that "many of today's major conflicts are fought in pastoral regions – places such as Somalia, Afghanistan, Sudan and Palestine?" (Nori and Crawford, 2005). Even in more recent times many authors have underlined the need to put the relationship between Environmental Security and Pastoralism at the centre of the political agenda. The vast region of deserts, grasslands and sparse woodlands that stretches across the Sahel, the Horn of Africa, the Middle East and Central Asia is by far the most crisis-ridden part of the planet. With the exception of a few highly affluent states in the Persian Gulf, these dryland countries face severe and intensifying challenges, including frequent and deadly droughts, encroaching deserts, burgeoning populations and extreme poverty. All these regions score at the very bottom of the United Nations' Index of Human Development, which ranks countries according to their incomes, life expectancy and educational attainments. As a result of these desperate conditions, the dryland countries are host to a disproportionate number of the world's violent conflicts. Look closely at the violence in Afghanistan, Chad, Ethiopia, Iraq, Pakistan, Somalia and Sudan – one finds tribal and often pastoralist communities struggling to survive deepening ecological crises. Water scarcity, in particular, has been a source of territorial conflict when traditional systems of land management fail in the face of rising populations and temperatures and declining rainfall. Where commentators often see political and religious ideologies at the core of these conflicts, it is more often extreme poverty and environmental stress that lie at their root (Sachs, 2008).

1.2. GLOBAL CHANGE AND PASTORAL AREAS

From a quantitative point of view grasslands areas are distributed over 52.5 million of km sq. and are the first biome in the World in terms of extension and the second, after the tropical forests, in terms of biomass (Lieth, 1975). The World population that directly depends on the pasture areas in tropical and subtropical regions for its own alimentation safety its estimated on 200 million people which have over 35 millions of cattle TLU (Tropical Livestock Units), 4.5 millions of sheep and about 5 millions of goats (Sere' et al., 2008) distributed on an surface a quarter of the surface of the earth (Koocheki and Gliessman, 2005; Thornton et al., 2003). Currently the African continent alone has approximately 22 millions of cattle TLU (Sere' et al., 2008).

The different livestock species are found in very variable livestock production systems that range from pastoralist communities to mixed-crop livestock systems and intensive livestock systems. Livestock production has been practiced in Africa for millennia. For people in pastoral systems livestock are key assets, providing multiple economic, social, and risk management functions. They are furthermore a crucial coping mechanism in variable environments, and as variability increases they will become more important. There is a growing body of literature on the role of livestock in providing pathways out of poverty for poor households (Freeman et al., 2008).

In recent years the changes in livestock production and marketing have been accelerating, as seen in Asia and other developing regions of the world. The different livestock systems are changing rapidly due to changing demographics, general economic development, and environment changes including land use and climate change, new technologies and knowledge, as well as other factors. These rapid changes in turn have direct effects on the growth of the livestock sector.

Since the last decades pastoral systems are facing deep environmental, economic and social changes. From an environmental point of view the increase in the quantitative and qualitative degradation of renewable natural resources due to climate change and antropic factors create competition for scarce resources.

From an economic point of view pastoral systems adapt to global changes resulting in what different authors called the "Livestock revolution" (Delgado et al., 1999). This is due to an increase of consumption of meat food and derivates from the population living in the cities and in the suburbs of the Developing Countries. The growth of incomes plus a higher and easier access to goods have brought about a big change in the life style of the population resulting in a "food revolution" in terms of demand for livestock products. Between the 70s and the 90s the meat consumption in the developing nations has risen by 70 million of metric tons on average (MMT), while milk and dairy products demand has been increased with 105 MMT of liquid milk equivalent (LME). These values are respectively three and two times higher than the rise in demand in the Industrial Countries in the same period (Hall et al., 2004).

From a social point of view old strategies of pastoralists to deal with changing environs are not always suitable anymore to cope with new and fast environmental and economic changes, requiring new adaptation strategies. As pastoralist societies worldwide have undergone drastic changes over the last few decades Leneman and Reid (2001) argue that pastoralists need to take part and find a role in the new forms of globalization. The use of violence, as the creation of political alliances with organizations involved in illicit activities (i.e. poaching in Kenya, Uganda and Tanzania, drugs in Somalia and firearms in Sudan), is part of the new "extreme" coping strategies.

International organizations and non State actors traditionally involved in security studies are actually interested to develop a better knowledge on the driving forces of the pastoral conflicts and on the impact of the pastoral groups on the security at local, country and regional level.

2. Evidence from a Geomatic Based Approach to Environment Security Analysis in African Pastoral Areas

2.1. PERSPECTIVES IN THE THOUGHT ON ENVIRONMENTAL SECURITY: FROM QUALITATIVE TO QUANTITATIVE ANALYSIS

Studies into the relationship between environmental factors and human-induced scarcity as cause of violence are rooted in the Malthusian analysis (Malthus, 1798). However, the modern debate on environmental security began only in the late 1980s. It has always been quite intense, especially since 1994 (Dabelko, 2004; Kaplan, 1994), and received an increasing political interest. The need for scientific assessments of the links between environment and conflict to promote conflict prevention, cooperation, and peace-building is, today, identified as a priority by many governments (Toepfer, 2004). Several research groups and individual researchers worked on these issues, and their findings constitute a source of still ongoing discussion. Within the first, pionieristic studies realized by multi-disciplinary teams we remember the Environmental Change and Acute Conflict Project (ECACP, known also as Toronto Group) led by the Trudeau Centre, formerly the Centre for Peace and Conflict Studies, University of Toronto, the Environment and Conflicts Project (ENCOP) of the Swiss Peace Federation, the Peace Research Institute of Oslo (PRIO), and the Environmental Change and Security Project (ECSP) of the Woodrow Wilson International Center for Scholars (Washington, DC). The research has been conducted mainly by international policy researchers and focused on the role of the scarcity of renewable resources such as cropland, forests, water, and fish stocks. Attention has been devoted to the theoretical analysis of the possible pathways, beginning with scarcity and leading to outbreaks of violence.

Within the first pionieristic quantitative studies the researchers of the PRIO in Oslo have applied statistical quantitative methods to verify the connection between environmental scarcity and the actual presence of violence. The results show that environmental factors can play a role in creating favorable conditions for the development of conflicts and acute violence (Hauge and Ellingsen, 1998). A distinction has been made on the consequences of abundance rather than scarcity, and on the role of non-renewable resources. According to the statistical tests performed by Soysa (2002), it is the abundance of non-renewable natural resources (i.e. gold, diamonds, oil) rather than the scarcity that is more strictly correlated to violence, according to the fact that ''armed conflict is often driven by greed-motivated factors rather than grievance.'' The opposite situation is characteristic of the conflicts related to the competition for renewable resources (i.e. water, soil, biodiversity), where the scarcity is the driving factor of the conflicts.

Most recently studies benefits from the application of Geomatic technologies like GIS, Remote Sensing and Simulation Models. By using these technologies is possible work simultaneously on the qualitative (i.e. through the use of tools for conceptual modelling) and quantitative aspects of the Environmental Security (i.e. studying the spatial and temporal variability in the driving factors of the conflicts).

2.2. GEOMATIC AND ENVIRONMENTAL SECURITY FOR PASTORAL AREAS

While the civil war and resource scarcity literature has produced a plethora of conflict models that seek to explain the onset and duration of wars (Collier and Hoeffler, 2001; Fearon and Laitin, 2003; Sambanis 2004), the models presented in the pastoral conflict literature are generally less robust (Baxter, 1993; Bollig, 1993; Hendrikson et al., 1996; Ocan, 1994).

The actual state of art of the research on the Environmental Security in pastoral areas is mainly based on the two following main approaches:

- *GIS and simulation models* to modelling the framework based on theoretical models. Statistical and GIS datasets are collected to create a system of thematic layers referring to the different parameters of the model. In the recent literature are documented case of application of this methodology to development of analysis at country level, like, i.e. the creation of a GIS for the Homer-Dixon model in Kenya (Bocchi et al., 2006), or with a focus on ethnic conflicts (Lim et al., 2007) and political causes of conflicts (Anonymous, 2001).
- *Remote Sensing* technologies and data for the identification of the climatic driving forces of the crises and conflicts in pastoral areas. For many areas of Africa and Asia has been identified an empirical relationship between climate variables, especially temperature, changes in the growth cycle of key species for animal nutrition and conflicts.

A similar pattern has been identified in Middle East and Mediterranean areas for the in relationship to the incoming desertification of pastoral lands (Kefi et al., 2007).

The actual state of art of the applied Geomatic research to Environmental Security in pastoral areas involves the integration of geodatabase managed through GIS, simulation models and remote sensing for the creation of early warning system on pastoral conflicts. A pilot experiment on the potentiality has been carried out by the CEWARN (Conflict Early Warning and Response Mechanism) programme for the Horn of Africa. The CEWARN is an initiative of the seven-member Intergovernmental Authority on Development (IGAD), playing a key role in executing one of its core mandate of promoting peace and security in the Horn of Africa region. CEWARN's Mandate is to "receive and share information concerning potentially violent conflicts as well as their outbreak and escalation in the IGAD region".

There is a high potential for the creation of efficient early warning system for the support of the decision-making process in countries traditionally threatened by some of the most violent conflicts of the modern time. Key however is the interest of international organizations in the improvement of information knowledge systems and data-sharing as a cardinal tool for the creation of Instruments for Stability (EC, 2008). The same consideration is valid for the role that livestock have been shown to play in coping with risk and providing livelihood options (Kristjanson et al., 2004). There is much more information available on cropping systems' responses than on livestock systems' responses and this is reflected throughout the adaptation literature. Moreover, there is only very limited knowledge about the interactions of climate with other drivers of change in livestock-based systems and on broader development trends.

A wide range of possible adaptation options exists, from technological changes to increase or maintain productivity, through to learning, policies and investment in specific sectors and risk reduction options, which may increase the adaptive capacity of poor livestock keepers. Farmers already have a wealth of indigenous knowledge on how to deal with climate variability and risk. Recent studies (Beyene et al., 2006; Heilß, 2003; Kaufmann, 2005) have shown that agro-pastoralists make use of spatial heterogeneity to cope with temporal heterogeneity and their ability to buffer climatic variation depends on the diversity in the production system.

However there is still a need to assess these adaptation options in relation to reducing vulnerability of humans and ecosystems, particularly options associated with livestock, with the object of maintaining or increasing (food) security, incomes and resilience while maintaining key ecosystem functions. Such assessment needs to be done in conjunction with well-targeted capacity building efforts to help farmers deal with changes in their systems that go beyond what they have experienced in the past. Furthermore, improving the learning process and learning cycles of agro-pastoralists is a critical element in increasing the adaptive capacity of agricultural systems (Leeuwis and Ban, 2004; Morriss et al., 2006; Woodhill and Röling, 1998).

3. The Experience of ILRI

3.1. INTRODUCING THE ILRI EXPERIENCE

ILRI (International Livestock Research Institute, www.cgiar.ilri.org) is a non-profit and non-governmental research centre of the CGIAR (Consultative Group for International Agricultural Research, www.cgiar.org), a network of 15 research centers distributed all around the World. ILRI works at the crossroads of livestock and poverty, bringing high-quality science and capacity-building to bear on poverty reduction and sustainable development. ILRI works in Africa, Asia and Latin America, with offices in East and West Africa, South and Southeast Asia, China and Central America with over 700 staff from about 40 countries. About 80 staff are recruited through international competitions and represent some 30 disciplines. Around 600 staff are nationally recruited, largely from Kenya and Ethiopia. For the research activities ILRI is funded by more than 60 private, public and government organizations of the North and South. The institute's expenditure for 2006 was USD 35.4 million.

All ILRI work is conducted in extensive and strategic partnerships that facilitate and add value to the contribution of many other players in livestock research for development work. ILRI employs an innovation systems approach to enhance the effectiveness of its research. Fundamental change in culture and process must complement changes in technologies to support innovations at all levels, from individual livestock keepers to national and international decision-makers (ILRI, 2008). The strategic intention of all the research projects is to use livestock as a development tool, one that widens and sustains three major pathways out of poverty: (1) securing the assets of the poor, (2) improving smallholder and pastoral productivity and (3) increasing market participation by the poor (Perry et al., 2003).

ILRI conducts research in five themes: targeting research and development opportunities; enabling innovation; improving market opportunities; using biotechnology to secure livestock assets; people, livestock and the environment, and ILRI is also responsible for the coordination the System-wide Livestock Programme of the Consultative Group on International Agricultural Research (CGIAR).

3.2. ILRI AND ENVIRONMENTAL SECURITY FOR PASTORAL AREAS

ILRI is involved already in several of the different specific horizontal issues of interest for the theme of environmental security discussed throughought this volume. Over the last 20 years, researchers at the International Livestock Research Institute (ILRI) have collected and generated an extensive range of spatial and non-spatial data. A number of these layers are directly related to livestock, such as distribution, health and production. Other layers, however, cover more general topics such as human population density, climate and infrastructure. Some of the datasets cover only specific project, while others are county-wide, regional, continental or even global. ILRI started cataloguing data available at the institute in an easy to access format and availing it over the internet/intranet. This effort has so far resulted in some of the layers being directly downloadable from ILRI's website as well through the GEOportal (www.ilri.org/gis and www.ilri.org/portal). Efforts to organize, standardize, clean and document all available data and the exciting world of interactive online mapping is currently underway.

ILRI has experience of broad-brush mapping to assist in the targeting of livestock-related research aimed at poverty alleviation. Examples are livestock poverty mapping, which produced sets of maps that located significant populations of poor livestock keepers, and to assess in very broad terms how poor livestock keeping populations were likely to change by 2050. The work was reported in Thornton et al. (2002, 2003). The information generated was subsequently used in an animal health priority setting study for Asia and Africa (Perry et al., 2003). The most recent example is the mapping of climate vulnerability and poverty in Africa. As the world's climate continues to change at an unprecedented rate, the impacts of climate change are likely to be considerable in Africa as well as other tropical developing regions. Many countries in sub-Saharan Africa currently have limited capacity to adapt to changing climate and increased probabilities of extreme events such as drought or flood (Thornton et al., 2006). The role of land fragmentation due to environmental, economic and social factors (i.e. different pastoral tribal strategies to control more natural resources) have been analyzed in depth through a wide project based on the application of geospatial technologies for the quantification of the effects of the land fragmentation on the security (http://www.reto-o-reto.org).

As follow up on the above mentioned activities, ILRI just finished a study on the vulnerability to climate change and climate variability in the greater Horn of Africa. This project is being implemented with financial support from the International Development Research Centre under the Climate Change and Adaptation in Africa Program (IDRC-CCAA).

Beside mapping ILRI is looking for new and innovative ways to help local communities to cope with changing conditions. For example, through ASARECA, ILRI is involved in helping improve the lives of disadvantaged pastoralists by providing access to timely and accurate early warning messages using a digital satellite radio broadcast to mitigate the adverse effects of climatically induced shocks.

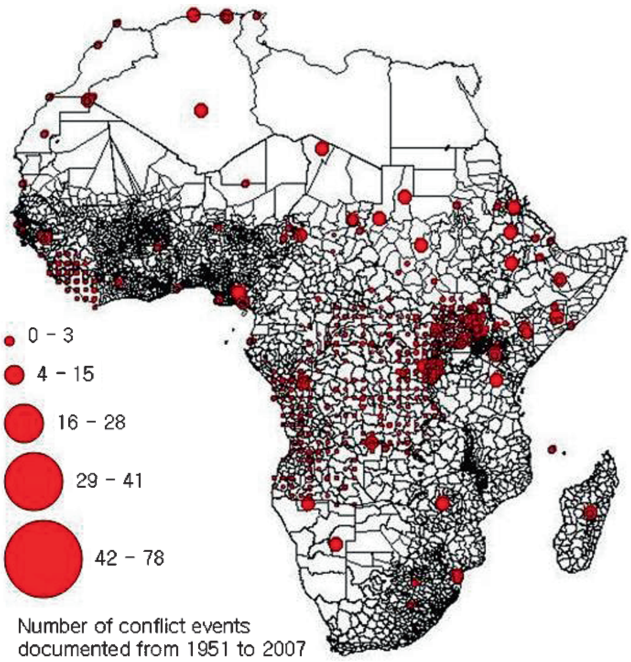

Figure 1. Data collection and standardization at continental level on conflicts in Africa.

Examples of the concrete products developed by the research activities carried out by ILRI at different scales (continental, regional and country) are shown in Figures 1, 2, 3 and 4. Different dimension of the environmental security are underlined: from the continental mapping of armed conflicts at high spatial and temporal resolution (Figure 1) to the use of different scenarios of climate change at continental level (Figure 2), and from the impact of water resources on pastoral sector in a regional perspective like the Nile River Basin (Figure 3) to more specific analysis of poverty classification at sub-district level (Figure 4).

ILRI is actually involved in the creation of a Continental dataset of the armed conflicts in Africa. Characterized by high temporal (daily) and spatial (village) resolution the database provides a list of about 6,000 cases

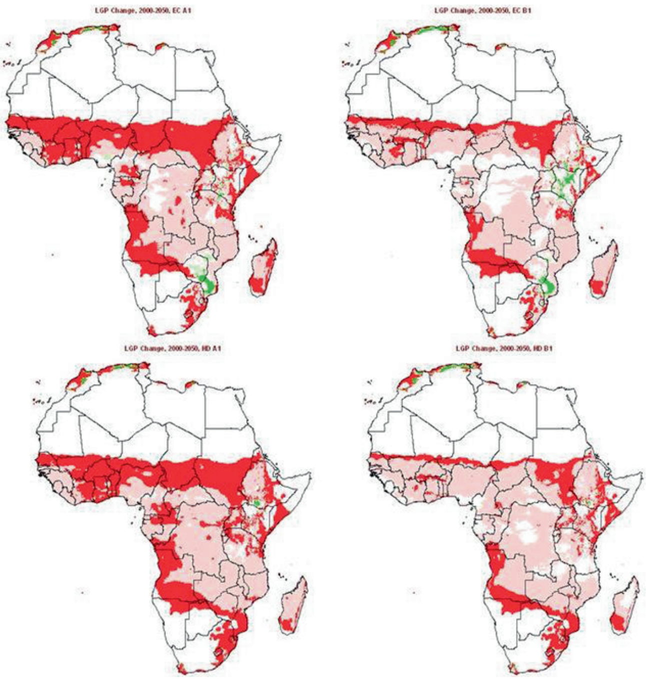

Figure 2. Scenario at continental level on climate change.

(number of incidents, opponents, human casualties, livestock casualties) detected by using public information systems (CEWARN, ITDG, PRIO, US Dept. of State, ACLED), bibliographic sources and local newspapers. Due to their relationship with the security, especially for areas ecologically fragile also refugees and IDPs camps managed by the UNHCR have been mapped. (Weidmann et al., 2007).

Figure 2 shows maps of projected changes in LGP (Length of the Growing Period of the vegetation) from 2000 to 2050 for the African continent, from downscaled outputs of different simulation models (ECHam4 GCM and HadCM3 GCM). Following IPCC (www.ipcc.ch) map legends, these changes were classified into five classes: losses in LGP of >20% ("large" losses); of 5–20% ("moderate" losses); no change (±5% change); gains of 5–20% ("moderate" gains); and gains of >20% ("large" gains). Various points can be made about these maps. First, it should be noted that some of the large losses and large gains are located in areas with a LGP less than 60 days, i.e., in highly marginal areas for cropping. Second, there is considerable variability in results arising from the different scenarios, and there is also variability in results arising from the different GCMs used. Third, if anything could be generalized about these different maps, it is that under the range of these SRES scenarios and the GCMs used, many parts of sub-Saharan Africa are likely to experience a decrease in the length of growing period, and in some areas, the decreases may be severe. In other words, projected increases in temperature and projected changes in rainfall patterns and amount (increases in rainfall amounts are projected in many areas) combine to suggest that growing periods will decrease in many places. There are also a few areas where the combination of increased temperatures and rainfall changes may lead to an extension of the growing season, and these appear to occur in some of the highland areas.

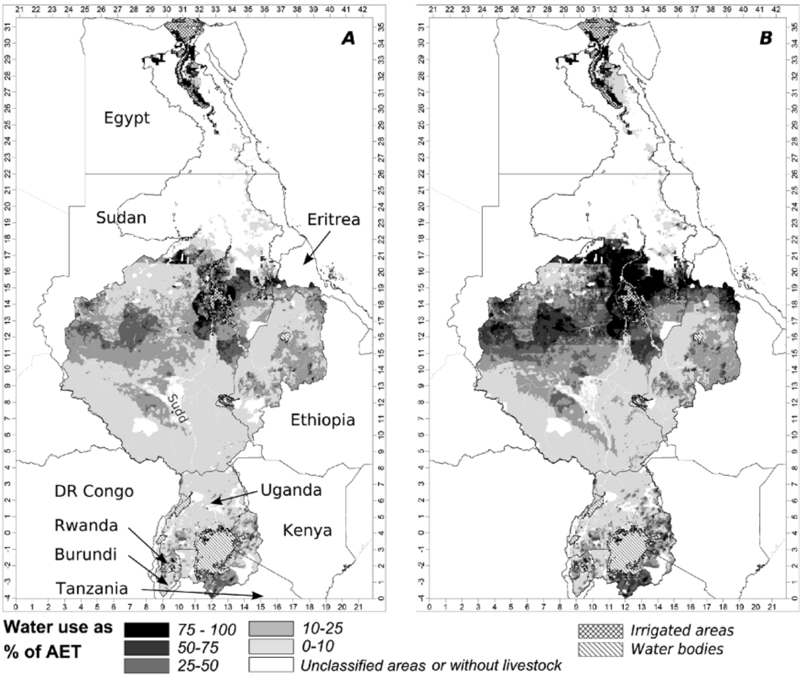

Figure 3. Analysis at regional level (Nile river basin) on natural resources management.

Livestock are major consumers of water but also sustain millions of pastoralist and farming families. In regions where water is a scarce commodity, such as the Nile basin, there is a need for strategies to improve livestock water productivity (LWP). This requires a better understanding of the spatial distribution of livestock water and feed demand, and their linkage to water availability. As part of a project to livestock water productivity in the Nile basin, an inventory of available data at regional and national levels needed to calculate feed demand and water for feed production was made. Next, a spatial framework was developed in which dynamic models of digestion in ruminants and crop water requirements, and estimates of animal drinking water requirements, were combined to estimate total livestock water requirements. The latter were subsequently compared to water availability within the basin.

Results were used in the identification of hotspots and recommendation domains for strategies for increasing LWP were identified, including areas where livestock production might best be encouraged or discouraged within the context of increasing water productivity and reducing land degradation.

In the figure the total annual livestock water use expressed as percentage of the total estimated annual evapotranspiration (AET) is given in average rainfall years (A) and in historical lowest rainfall years (B), thus showing areas were constrains in water and feed are more likely to play a role in drier years.

Sharing such information between upstream and downstream stakeholders and among stakeholders across sub-basins can contribute to strategies for

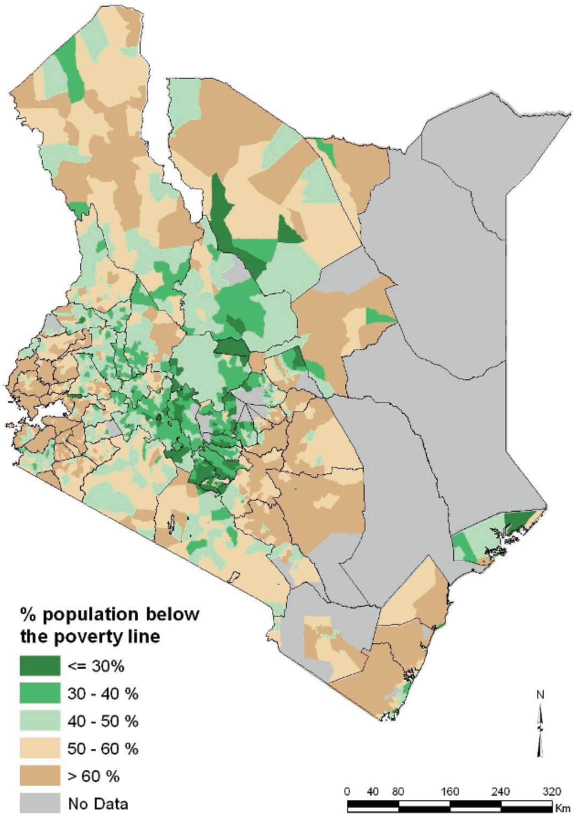

Figure 4. Data collection at country level on poverty.

increasing water productivity basin wide. Note on software use: All analyses were carried out using the open source softwares R (statistical software), SQLite (database) and SAGA GIS (geospatial analyses), including statistical and overlay analyses in R, raster operations in SAGA through the RSAGA interface and data calculations and management in SQLite / Spatialite through the RSQLite interface.

As the link between poverty, environment, climate change and security has been deeply analyzed in literature (Thornton et al., 2008) ILRI is involved in several activities of poverty mapping. The new poverty maps (like the one shown in Figure 4 with the population that fall below the poverty line, calculated separately for urban and rural population) provides a tool for better understanding the distribution of poverty in East Africa, and for helping to monitor progress towards meeting the Millennium Development Goals. Recent poverty reduction strategies have improved the pro-poor focus of national development strategies, but there is generally a weak analytical basis for considering policy options and trade-offs, and weak sector-specific policies regarding reaching the poor.

4. Conclusion

Scenarios provided by many authors for the near future of pastoral areas of the world show many emerging countries face deep changes in terms of environmental, economic and social capitals (Figure 5). Local governments of countries located in pastoral areas, non state actors and international organizations needs scientific support to the decision-making process to prevent conflicts and violence and to facilitate the eradication of poverty. The use of Geomatic-based tools could play a key role for the knowledge

Figure 5. A Maasai herder with the son and an AK-47.

improvement on the complexity of ecological and economic driving forces of pastoral systems and for the creation of operative instruments for stability characterized by multi-country decision-process, that will be facilitate by the use of modern technologies for data standardization and sharing.

Pastoral communities are able to adapt to changes in environmental, economic and social livelihood capitals. The use of violence to copy with environmental scarcity and competition for natural resources is facing a deep change due to the diffusion of firearms and the turnover to new generations.

Despite the need for continental and global projects coordinated between emerging countries and Western countries is still a clear and present priority, the work of organizations with global mandate for scientific research on pastoral areas. The research experience of ILRI show how many pilot projects for the harmonization of environmental data access and processing, the creation of tools (i.e. Geodatabase and Geoportal) for information sharing with local governments, the mapping of adaptive capacities and the development of tools for Environmental Security analysis in pastoral areas could be used as guidelines for the implementation of regional or continental projects.

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INVESTIGATION PROCESSES AT THE KATO SOULI BASIN

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Abstract. This work presents the results of gravity, TEM and geological surveys conducted in the area of Kato Souli (Greece), as study of its hydrogeological characteristics and mapping through GIS. The gravity survey offered a rather detailed image of the alpine basement and together with surface geological observations, insight into the post-alpine tectonic processes that have controlled the development of the area. The TEM survey produced detailed three-dimensional images of the aquifer systems and salination conditions. The results have shown that (a) the alpine basement is located much deeper than previously thought and, (b) that the sea water intrusion takes place both near sea level and at depth. The depth and morphology of the alpine basement are believed to have been fashioned by faults that either have not been active during the Quaternary, or are buried under thick terrestrial and alluvial deposits. Sea water intrusion forms at least two distinct salination horizons, presumably as a result of intersecting faulting structures that facilitate horizontal and vertical transportation of sea water between permeable formations. The vertical alternation of permeable-impermeable rock formations may be attributed to (alpine) folding, which results in vertical repetition of the same lithological units, in this case karstified marbles.

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1. Introduction

This chapter presents the results of gravity, TEM and geological surveys conducted in the area of Kato Souli, (Greece), as study of its hydrogeological characteristics and mapping through GIS: given that the aquifers (karstic and unconfined) experience intense salination effects (e.g., Koumantakis et al., 1994), one principal objective of the surveys was to evaluate the depth and morphology of the basement (hence the macroscopic characteristics of the structures hosting the aquifer systems) and to map the geoelectric (salination horizons) and neotectonic structures in an attempt to understand the origin and development of such phenomena. Notably, this would also provide information about reverse pollution effects, i.e., data on the paths through which pollutants due to intense agricultural activity may be transported to the sea and to the nearby natural reserves of Schinias wetland and pine forest. Finally, the results of the surveys may contribute to the understanding of the geology and tectonic evolution of the study area and, to a lesser extent, the regional geology and tectonics.

The area total basin has an area of approximately 40 km^2 and is shaped like a parallelogram with dimensions 9 × 4.6 km and NE-SW oriented long axis. The relief is very smooth, almost flat as can be seen in Figures 1 and 4. The plains are bounded to the north by mounts Kotroni, Strati and Terokoryfi, to the west by the Penteliko mountain complex, to the south by Marathon bay and to the east by the Drakonera and Mytika uplands. The transition to the highlands coincides with abrupt topographic changes.

2. Geology

The area is almost completely covered by alluvial deposits and post-alpine sediments. Until recently, it was generally thought that the maximum thickness of post-alpine sediments was 100 m (Kounis, 1985), while a thickness of 50 m is mentioned by Tzouka (2003) at the vicinity of Mt. Drakonera, based on interpretations of VES data. Nevertheless, and on the basis of the gravity survey reported herein, the thickness of the post-alpine deposits is considerably larger, approaching 500 m at the southernmost margin of the study area (see Section 3). The alluvial deposits are fairly typical and indicate progressive withdrawal of the sea during the last ~6,000 years, at a mean rate of 0.4–0.5 cm/a (Maroukian et al., 1993; Pavlopoulos et al., 2006). The flanks of the highland areas to the north (Patima area) and east (Sfakona area) stretches of the Plain are covered by undivided screen and talus cones of low-intermediate cohesiveness.

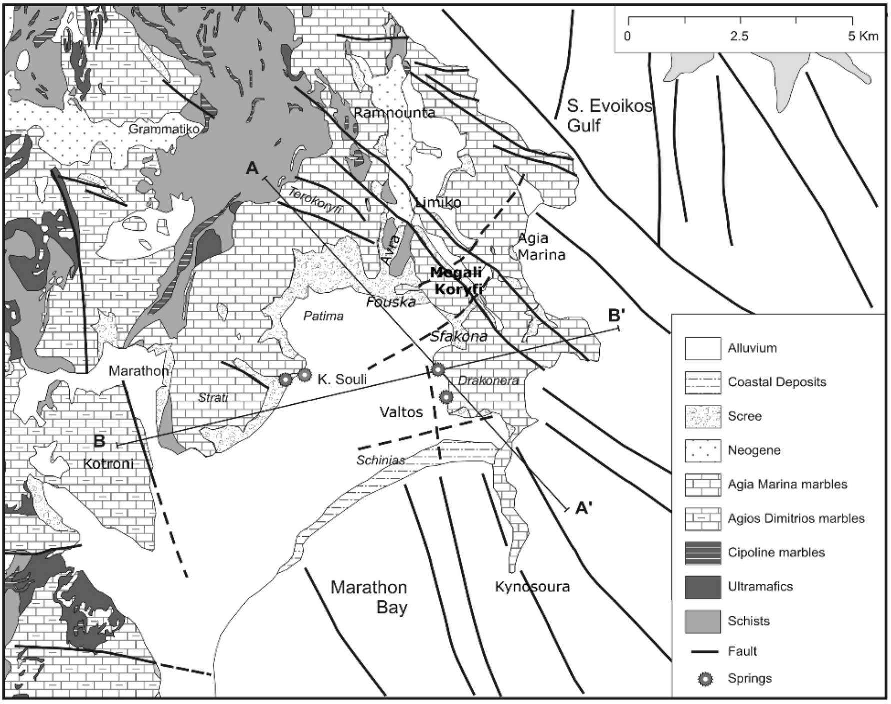

Figure 1. Map of the area (modified from HCMR, 1989; Lozios, 1993). Toponyms referred to in the text and the traces of the interpretive geological cross sections of Figure 7 are also marked.

The nearest – in terms of geography – outcrop of post-alpine sediments can be observed at the Limikon area, north of the Plain. They are sandy marls and sandstones intercalated with conglomerates, possibly of Pleicone age (Katsikatsos, 1990) and thickness possibly in excess of 50 m. Neogene – PleioQuaternary deposits are not observed at the surface, but they may well be buried under the Quaternary sediments of the Plain, especially in areas where the geophysical studies have determined large depths to the alpine basement (see Section 3).

The alpine basement comprises the formations of the autochthonous Attica Unit. Lozios (1993) reports that the base of the stratigraphic column comprises the Ramnounta Schists (highly altered chloritic – feldspathic schists), the thickness of which is estimated by Katsikatsos (1990) to be ~400 m. According to Lozios (1993), this formation is homologous to the “Ano Souli – Hagioi Theodoroi schists”, or “Marathon schists” reported by Katsikatsos (1990). The schists are overlain by the “Hagia Marina marbles” and the “Hagios Dimitrios – Terokoryfi marbles”, which Lozios (1993) considers homologous to the upper Cretaceous formations. Katsikatos (1990) refers to these formations as the “Hagia Marina marbles” and “Marathon marbles" respectively. Their thickness is considerable and may even exceed 800 m.

3. Gravity Survey

The main target of the gravity survey was to image the alpine basement, to determine the thickness of the post-Alpine sediments and to reveal the covered structure of the Marathon Plain. One hundred and twenty gravity stations were established in the area, distributed in such a way that the mean distance between any two neighbouring stations is approximately 500 m. As shown in Figure 2, they are spread throughout the post-alpine formations covering the Marathon and Kato Souli plains, while several stations are located on the metamorphic basement (uplands) to control the inversion and interpretation processes. This distribution is expected to resolve with adequate precision, of the basin margins as well as the depth and morphology of the basement under the post-alpine formations. Details about the measurements, data reduction and interpretation procedures are given in Chailas et al. (2007), so that only a brief introduction will be attempted herein.

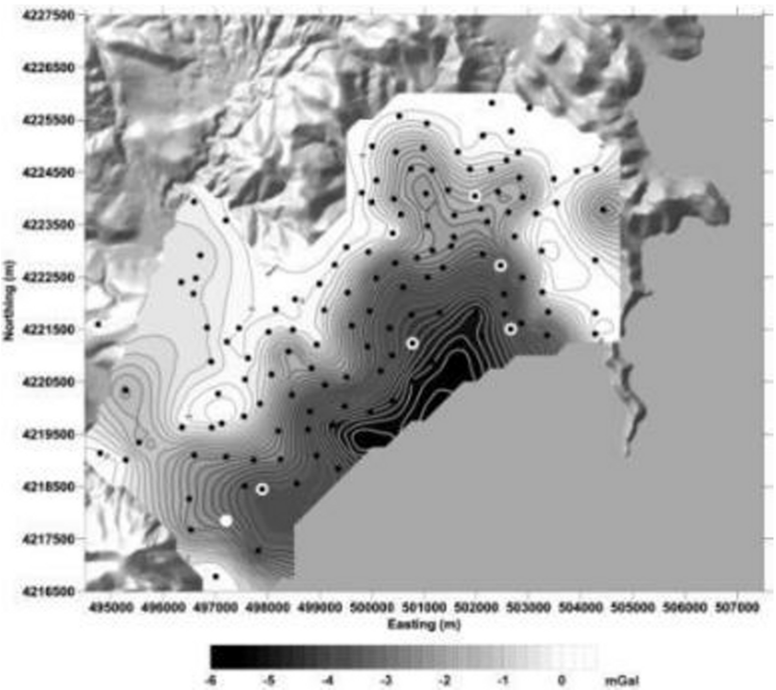

Figure 2. Residual Gravity Anomaly Map of the area overlaid on a shaded relief of the DEM prepared for the analysis. Overlaid is the distribution map of the gravity stations. Coordinate axes in metres, EGSA projection system.

The coordinates of gravity stations were obtained with differential GPS positioning, which affords an accuracy of a few millimetres in both the horizontal and the vertical coordinates. Gravity measurements were taken with a LaCoste and Romberg Model G gravity meter. Standard observation and reduction/adjustment procedures were followed for both gravity and GPS data. The terrain correction was computed for a radius up to 21 km around each station. The standard Bouguer anomaly (not shown herein) was calculated using a density 2.67 g/cm^3; with values ranging between 49.5 and 61 mGal, it exhibits a strong westward downhill trend (regional field). To remove the trend, use was made of the gravity data bank available from Lagios et al. (1996): the Marathon gravity data set was spatially extended with data extracted from the data bank and the regional field was calculated by fitting a quadratic surface to the spatially extended data set. The resulting *residual* anomaly map is presented in Figure 2. Values range between 0 and 6 mGal and exhibit a general NW-SE trend with significant fine structure at the area of Kato Souli. The residual anomaly is generally plunging to SE and showing a step-like change in the areas of Kato Souli and Oinois River. It is also apparent that the boundaries of the Basin are quite well defined by the abrupt change of the gradient of the anomalous field along the Alpine – Post Alpine boundary.

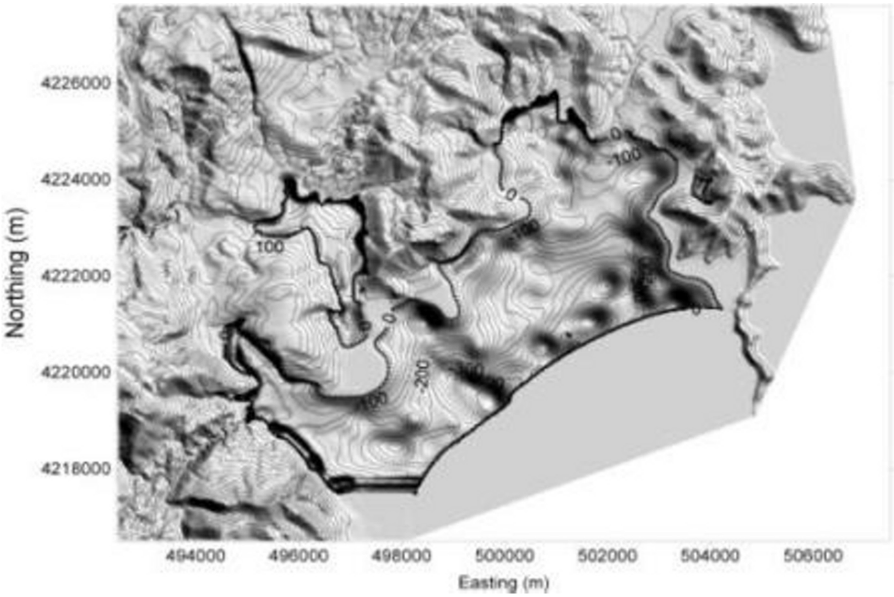

Figure 3. 3D Model of the Marathon Basin basement relief combined with the detailed shaded relief of the surrounding area topography. EGSA projection system.

The residual anomaly was inverted using an unpublished 3-D algorithm developed by S. Chailas and based on the theory of Radhakrishna Murthy et al. (1990). In this approach, any three-dimensional geological object can be modelled with some configuration of adjacent vertical polygonal laminae. Density contrasts between object and host structures are kept constant and the inversion procedure iteratively adjusts the vertical extent of the model until it homes-in to a solution. In this implementation, the post-Alpine formations of the Marathon Basin were considered to be a single object with a density contrast of –0.5 g/cm^3 against the basement rocks. The upper surface of the model (surface topography) was kept constant and the lower surface (Alpine basement) was allowed to vary. The results (topography of the basement) are shown in Figure 3, combined with a digital elevation model of the surrounding area.

The structure of the basin is well resolved and affords a first and very important observation: it has hitherto been accepted that the basement of the Marathon basin comprises marbles located at a depth of 40–55 m below surface near the margins of the basin and up to 60 m at the central parts (Melissaris and Savropoulos, 1999; Tzouka, 2003; Margonis, 2006). This understanding was mainly founded on interpretations of geoelectric (Schlumberger) data, particularly those by Melissaris and Savropoulos (1999). The existence of marbles at such depths has not been verified by drilling; the deepest boreholes in the area do not exceed 20 m (e.g., Margonis, 2006). Our work has conclusively shown that the basement is located at definitely greater depths and that its morphology is intricate and tectonically controlled (see below). There's no karstic aquifer at depths of 50–60 m below the Marathon Basin and scrutiny will show that the 'shallow' basement assumption was based on misinterpretation of the Schlumberger data. Instead we probably have to deal with a system of sedimentary aquifers possibly communicating through the intricate tectonic fabric (see Section 5).

4. Transient Electromagnetic (TEM) Survey

The geoelectric structure of the Kato Souli area was investigated with the Transient Electromagnetic (TEM) method, which is very sensitive to conductive formations such as those resulting from sea water intrusion. Information about the TEM method, especially with respect to its application in groundwater research, can be obtained from standard literature, e.g., Fitterman and Stewart (1986), Nabighian and McNae (1991), Christiansen et al. (2006), etc. A total of 36 soundings were conducted at Kato Souli, distributed so that the mean distance between them would be approx. 200 m (Figure 4). This affords adequate imaging of laterally extended structures, such as for instance are salination horizons and intermediate depth sedimentary aquifers.

Figure 4. TEM measurement sites at the area of Kato Souli. T1, T2 and T3 indicate the sections presented in Figure 5 and discussed in the text. EGSA projection system.

Measurements were carried out with the TEM-FAST 48 HPC system (Barsukov et al., 2007). In all cases the single-loop configuration was implemented, with 50 × 50, 50 × 70, 70 × 70 and 100 × 100 m loops, depending on the available space. Typical examples of TEM data are shown in Figures 5a,b (left). The study area is basically suburban with light industrial activity and analogous noise environment, mainly produced by the emissions of the power distribution grid. This type of noise affects the late times of the transient process. A handful of stations also suffer from galvanic distortions due to nearby grounded metallic conductors (mainly fences), which also affect the late times (e.g., Figure 5b, left). In both cases the healthy (distortion-free) data are shown with black triangles and the distorted data with gray triangles. In general, the noise is significant at times $t > 4$–5 ms, but, depending on the location of the sounding, it may affect anything in the band 1–15 ms. As it turned out, this was somewhat fortunate because the depth, depth-extent and layout of the target formations were already resolved by the time that noise began to dominate (see Figure 5). The best quality data were measured at the Valtos area (wetlands) and the worst at the NW areas, where it was emitted by failing groundings of pumping installations.

The interpretation was carried out with approximate inverse imaging after Svetov and Barsukov (1984) and Barsukov et al. (2007) and, mainly, linearized 1-D inversion with Levenberg-Marquardt stabilization to layered Earth models. Distorted data were not used in the inversions. Typical examples are also shown in Figures 5a,b (right). Given the geology of the study area, (aquifers in layered sediments), the models would normally satisfy the observations with a relatively small number of layers, 3–5 as a rule. The resulting simple layered models were subsequently collated (see Figure 4) and interpolated to produce the resistivity pseudosections presented in Figure 6. They were also interpolated in three dimensions to produce the isosurface of 10 Ωm, which delimits the zone(s) of intense salination – volume(s) with resistivity lower than 10 Ωm – which is shown in Figure 7 together with the gravimetrically determined topography of the alpine basement.

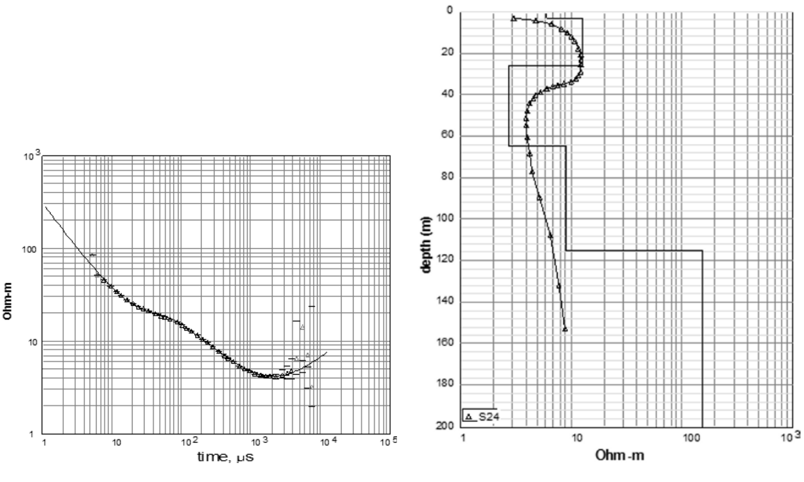

Figure 5a. Examples of measured data and their interpretation: Sounding S24. **Left:** The discrete curve (up triangles) represents the late-time apparent resistivity (in Ωm), as a function of time (in μs). The continuous black curve represents the late-time response of the layered 1-D model which interprets the measurements and is depicted in right-hand side graph. **Right:** The discrete curve (triangles) represents the approximate inverse image of the measurements towards a resistivity vs. depth profile. The continuous line represents the 1-D layered model that optimally interprets the measurement and produces the late-time apparent resistivity response shown in the left-hand side graph.

Study of the resistivity cross sections T1-T3 (Figure 6) and the combined resistivity – basement topography images (Figure 7) shows that sea water intrusion is both prominent and extensive. In general terms, the salination horizon is thicker at the south and east parts of the surveyed area, with particular reference to the zone defined by the localities of Kato Souli, Patima Fouska, Sfakona and Valtos where it extends from –30 m to –80 m and at places up to –100 m. The saline – brackish water table is thinner to the N-NE, extending between –30 m and –70 m, albeit clearly present and detectable up to the northern edge of the studied area.

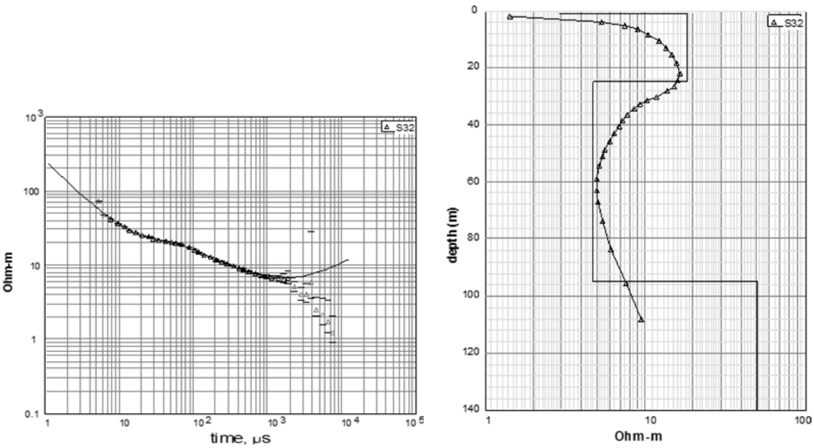

Figure 5b. Examples of measured data and their interpretation: Sounding S32.

The relatively high resistivity formations (>100 Ωm) observable at elevations lower than –80 m to –100 m in section T1 between sites S8 and S10, section T2 between S21 and S1 and section T3 between S29 and S9 *do not* correspond to the alpine basement, as is also evident from Figures 3 and 7: the basement there is to be found at depths greater than 200 m.

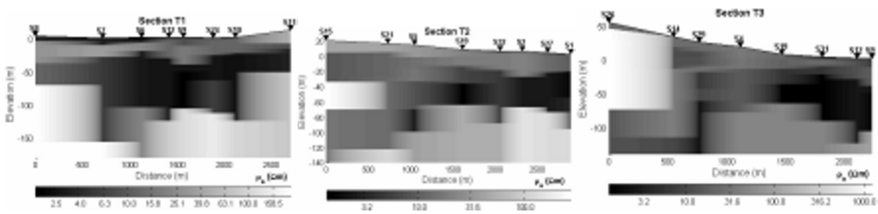

Figure 6. Resistivity pseudosections constructed by collating 1-D layered interpretations of TEM soundings (also see Figure 4).

Given the low density of these resistive domains, it appears possible that they comprise relatively impermeable post-alpine deposits such as marls. Conversely, the alpine basement is detected in section T1 beneath sites S8 and S11, in section T2 at site S15 and in section T3 beneath S26 and S14. In all these cases it is characterized by *very* high resistivity (>300 Ωm and up to 2 kΩm) indicating the presence of compact impermeable rock, possibly schists. The remarkable coincidence in basement depth determinations between the TEM and gravimetric methods is also noteworthy.

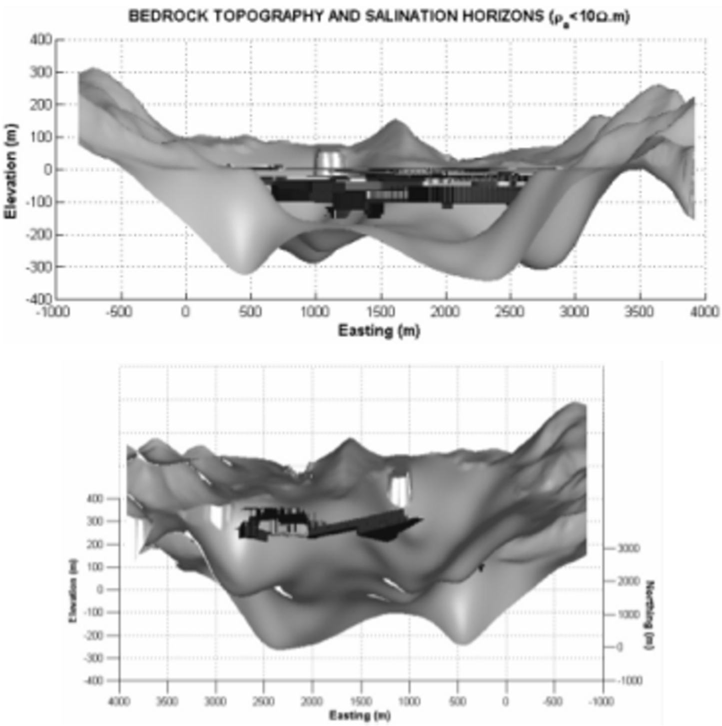

Figure 7. Three dimensional representation of the 10 Ωm isosurface which delimits the zone of intense salination, together with the gravimetrically determined topography of the alpine basement. Top panel is a head-on view, bottom panel is from N and below.

The data of Figures 6 and 7 clearly show that the salination horizon (and all aquiferous formations indeed), are located almost exclusively within the sediments and at depths considerably shallower than those of the alpine bedrock. However, it is important to point out that at the north and north-east of the surveyed area, the salination horizon intrudes into the basement and apparently is to be found farther along, possibly unto the coast. Inasmuch as it is presumed that the permeable rock in the alpine basement comprises karstified marbles, this indicates a transition from sedimentary to karstic aquifer conditions and provides an additional hint about the process transporting sea water into the sediments of the Marathon – Kato Souli Plain.

Finally, as evident in sections T2 and T3 (Figure 6) and in Figure 7, a *second* saline – brackish water layer has been detected at the N and NW parts of the surveyed area, also within the alpine basement and at elevations lower than –120 m. This is attributed to a second (deeper) karstic aquifer, again presuming that the permeable rock formations comprise karstified marbles.

5. Tectonics

The alpine basement comprises exclusively metamorphic rocks, which have undergone two phases of plastic (folding) and one phase of brittle deformation (Lozios, 1993). At large scales one observes isoclinal, as well as open folds with NE-SW and NW-SE axes respectively. As a result, in the immediate area of interest and specifically northward of the Fouska area of Kato Souli, the Ramnounta schist formations appear on top of the Hagia Marina marbles, at the core of an anticline with a general NNE-SSW orientation at the Avra crest, between Mts Agrilia and Megali Koryfi. This is the only outcrop of Ramnounta schists within the surveyed area.

The younger brittle deformation phase is expressed with WNW-ESE to NW-SE faults. Onshore, structures of such orientations are located to the NE of the Plain (Megali Koryfi and Misovardia faults). These are traceable for at least 8 km consecutive and quite probably extend into the sea, where the NW-SE fault system dominates. Scrutiny has also shown the existence of neotectonic faults with NE-SW and NNW-SSE to N-S orientations respectively, which are no longer considered to be active.

The older fault generation may exert a very significant influence on the hydrogeological conditions of the study area, because the network of discontinuities it is associated with still comprises a preferential water transportation pathway. This hypothesis is based on the examination of the morphology of the alpine basement, which exhibits local rises and depressions that can hardly be attributed to exclusively exogenous factors like erosion. It appears that the post-alpine sediments have covered a palaeo-terrain that had been tectonically controlled. In consequence, it is suggested that there exist buried tectonic structures (faults and fault zones), whose geometry and kinematics is difficult to determine even at the outcropping alpine formations due to the conspicuous absence of characteristic stratigraphic markers (horizons).

Locations with strong indication for the existence of inactive faults are the Fouska and Sfakona areas at Kato Souli. There, the alpine basement exhibits increased slopes and approaches the elevation of –300 m, with morphology characterized by an elongate depression of approximately ENE-WSW orientation just northward of Kato Souli. The S-SE boundary of the depression is flanked by a rise of the same orientation, while further southwards (Valtos area) the basement drops to elevations as low as –500 m. Such anomalies can hardly be attributed to non-tectonic causes, hence the suggested existence of inactive faults with approximate ENE-WSW orientation, passing just south of Megali Koryfi and continuing a westward course under the post-alpine sediments of the Plain.

The gravimetric determination of alpine basement morphology also shows that at the eastern margin of the Plain (Mt. Drakonera), the basement exhibits steep slope (35–40°) and plunges to the elevation of –300 m. There is no surface indication for the existence of a fault zone at the area. However, examination of the neotectonic map of the S. Evoikos gulf (Hellenic Centre of Marine Research, 1989), reveals the existence of NNW-SSE oriented faults at Marathon bay; the northward continuation of one of these faults *identifies* with the eastern boundary of the Plain and the flank of Mt. Drakonera.

In concluding, it appears that tectonic activity may exercise a twofold influence on the hydrogeological conditions of the study area. First, the alpine folding deformation phases have created inversions of the original stratigraphic column and/or repetition of formations, thus producing alternation of permeable and impermeable rocks. Second, the brittle neotectonic deformation (both older and younger faulting phases) have configured the morphology of the alpine basement and have created preferential water transportation pathways that facilitate the vertical communication between permeable alpine formations.

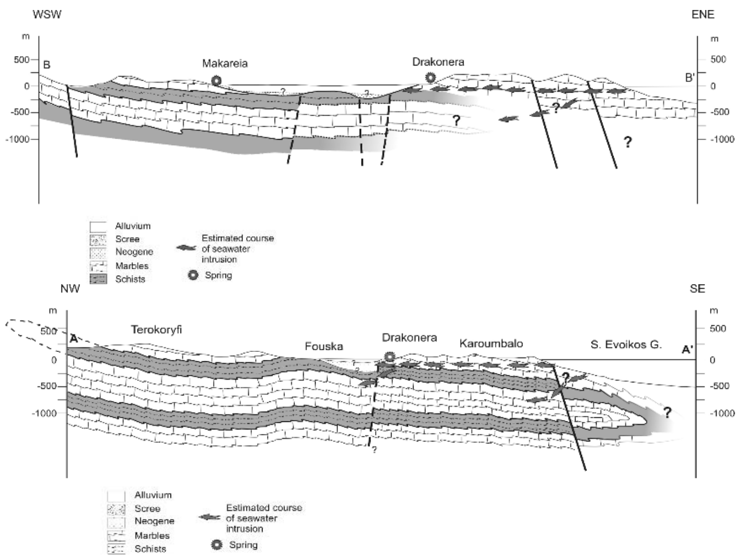

Figure 8. Interpretive geological cross sections (see Figure 1).

6. Conclusions

The hydrogeological conditions of the area heavily depended on the litho-stratigraphic configuration and tectonic deformation, as well as on the proximity of the sea, groundwater use and natural or anthropogenic pollution of the groundwater tables. The geophysical investigations have shown that (a) the alpine basement is located much deeper than had previously been estimated and, (b) that the sea water intrusion takes place both at near sea level and at depth. The geological appraisal of these results, in terms of the litho-stratigraphy and the tectonics of the area, facilitates an interpretation of the geophysical observations.

The gravimetrically determined depth and morphology of the alpine basement are believed to have been fashioned by fault tectonics and, specifically, by faults that either have not been active during the Quaternary, or are buried under thick terrestrial and alluvial deposits. At least two distinct groundwater horizons have been detected at different elevations, both of which appear to suffer from sea water intrusion. This may be attributed to the network of discontinuities formed by older and younger faults and fault zones, which facilitates the horizontal and vertical transportation of sea water between permeable geological formations (marbles) at different levels. The vertical alternation of permeable-impermeable rock formations may be attributed to (alpine age) folding, which results in the repetition of the same permeable lithological units along the vertical direction, in this case karstified marbles (Figure 8).

Acknowledgements

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ESTIMATE OF SOIL EROSION IN JORDAN BY USING GIS

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Abstract. Water erosion is a serious problem in semiarid and sub-humid regions of Jordan, mainly due to land mismanagement. The Universal Soil Loss Equation (USLE) was used to predict the annual soil loss of a representative area of about 108 ha in Balqa district before and after constructing soil conservation structures (SCS) talk place. From soil survey reports, site information, land capability, erosion hazard, existing and future land use were then compiled in a soil base map for the area. The map consists of six themes; four of it characterizes the soil loss before and after constructing soil conservation structures (SCS), ten and twenty years later using universal soil loss equation. Before constructing SCS about 32%, 7%, 61% of total area were characterised respectively by slight, moderate and high water erosion. Twenty years after constructing SCS, and after reaching 25% tree coverage, about 58%, 34%, 8% of the total land area respectively show slight, moderate and high water erosion.

Keywords: Jordan, Erosion, Universal Soil Loss Equation.

1. Introduction

Surface water erosion causes a loss in the topsoil, and the less fertile subsoil will be exposed. Since the topsoil is more suitable to plant growth, a decline in the soil productivity potential usually results from soil erosion. Water erosion is controlled by climatic characteristics; topography, soil properties,

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vegetation, and land management detachment of soil material caused by raindrop impact and drag force of running water. Detached particles are transported by overland flow (sheet or inter-rill erosion) and concentrated flow (rill erosion) and deposited when flow velocity decreases (Lal, 2001). Bewket and Strek (2003) estimated soil loss 100 Mg ha^{-1} yr^{-1} from cultivated fields. According to this study, some 50% of the highlands were already 'significantly eroded' and erosion was causing declines in land productivity at the rate of 2.2% per year. The study also predicted that erosion would have reduced per capita incomes of the highlands population by 30% by the year 2010. Sediment and chemicals resulting from the erosion process are the most important pollutants of water resources. This pollution causes deterioration in water quality with respect to domestic use, irrigation, and recreation in addition to the animal husbandry. Due to agricultural expansion and land mismanagement, soil erosion by water has increased in the semiarid and sub-humid regions in Jordan during the past decades. Satellite data can be applied to directly detect erosion or to detect erosion consequences. Direct detection has been achieved through identification of individual large erosion features, discrimination of eroded areas, and assessment of erosion intensity based on empirical relations. Detectable effects include the damage occurred due to major erosion events, and the sedimentation of reservoirs.

The purpose of this study is to estimate the impact of soil conservation structures in maintain soil using Universal Soil Loss Equation (USLE).

2. Background

The region of the projects has a semiarid and sub-humid Mediterranean climate. Rainfall season in the region normally extends from October to April. The region is often divided into high, medium, and low rainfall zones according to the mean seasonal rainfall. The high rainfall zone receives more than 500 mm of mean seasonal rainfall (Table 1). The medium rainfall zones receive between 200 and 500 mm, and low rainfall zone receives less than 200 mm of mean seasonal rainfall.

TABLE 1. Area (%) and agro climatic zones of Jordan.

Agro climatic zone	Precipitation (mm)	Area (%)
Semi desert	<200	89.3
Arid	200–350	6.4
Semiarid	350–500	3.2
Sub humid	>500	1.1
Total		100.0

Source: Ministry of Water and Irrigation (2004).

The mean yearly air temperature varies from 14.5°C in the west to almost 18°C in the southeast. The maximum mean daily temperature occurs in July or August ranging from 27°C to 33°C with absolute maximum between 37°C and 43°C. The minimum mean temperature is recorded in January ranging from 2°C to 3°C with absolute minimum of –3°C to –7°C. The lower records always refer to the western regions while the higher figures always refer to the southeast regions. The absolute minimum air temperature is lowest in the southeast regions and this indicates the general increase in aridity with the increase in temperature. The mean annual humidity approximately ranges from 60% in the hilly areas in the west to approximately 50% in the southeast areas. The maximum monthly reaches 75% in December or January and a minimum of around 40% in May or June. Average wind speed is vary from station to another in the projects area but the average speed ranges from 2 to 4 m s^{-1} with a minimum in late summer. Mean daily evaporation measured by Piche evaporation ranges from 6.5 mm in the hilly areas in the west to about 8 mm in southeast areas. The minimum is 2.5–3.5 mm recorded in December and the maximum reaches 10–12 mm during June and July.

3. Methodology

For many years and in many parts of the world, soil erosion by water has been assessed from data gathered from small plots extrapolated to the wider landscape. The most widely used method has been based on the Universal Soil Loss Equation (USLE) or the revised version of it (RUSLE) (Evans, 2002). USLE which is developed by United States Department of Agriculture, was the tool used to assess potential water erosion in the study area. The simplicity of the equation and the availability of data to apply the equation on a regional scale, were the primary reasons for this choice. Using this equation in conjunction with a geographic information system (GIS), a series of models associated with themes detailing erosion potential under a combination of conditions were built for the region. The USLE is:

$$A = R\ K\ L\ S\ C\ P$$

where:

- A is the mean annual soil loss (ton h^{-1} $year^{-1}$).
- R (Rainfall Erosivity Factor) reflects the erosive energy of rainfall and computed based on total rainfall.
- K (Soil Erodibility Factor) reflects how erodible a soil is under the worst conditions that are a bare soil tilled up and down the slope. K is a function of soil texture and structure. The soils of the projects region

are all the varieties of the Red Mediterranean soils that have the numbers 11, 12, 31–37, 41–44 of the local classification.

Specifically type 11 and 12 soils are red and dark colored cracking clays. These are by far the most common of the two clays in the projects region, which have dark reddish brown colors of 5YR hue. These are the heaviest textured clays in the region. Clay content increases from 45% in the top soil to 65% in the subsoil. The dominant clay mineral is montmorillionite which is responsible for its shrinking and swelling property, cracking when dry. The structure is fine, blocky, and moderately well developed in the topsoil. While in the subsoil the structure becomes more strongly blocky.

- Types 31 and 32 soils: Most likely 11 and 12 soils but not cracking.
- Type 33 soil: Most likely 32 with $CaCO_3$ content.
- Type 34 soil: Most likely 32 with more $CaCO_3$ content.
- Type 35 soil: Most likely 33 soil with more than 35% gravels content.
- Type 36 soil: Most likely 34 soil with more than 35% gravels content.
- Type 37 soil: Most likely 32 soil with more than 35% gravels content.
- Types 41–44 soils are the sandy soils.

Using soil survey information based on previous studies, with the assumptions of granular structure, and low content matter, K value in (Table 2) ranges from 0.06–0.36 from sand to heavy clay soils.

- LS (Slope length and steepness factor). In the USLE, the slope length (L) and the slope steepness (S) factors predict the effect of topography on soil loss. The steeper and longer a slope, the higher erosion potential. The values of LS in the study are 7.21 and 4.14 based on the assumptions that the maximum slope length is 90 m, and will be after building SCS 30 m. The average steepness was 20% because the value of (LS) adjacent to this slope percentage are almost equal after running USLE for each slope category from (0–35%) because in this slope range, SCS are allowable to build. Table 3 illustrated the relationship.
- C (cropping pattern factor). Figure 1, summarizes the present land use in the project area before implementing SCS. The assumption were made that the cropping was caused by long fallow which is related to low productivity which is the mostly dominant in the area that has the value of (1).
- P (conservation factor). Mechanical erosion control practices are nearly absent in the region. If present erosion rate has to be estimated at a site. This factor is assumed (1), since contouring, contour strip cropping

and contour banking in the region is not practiced in a way that a proper P-factor can be determined.

TABLE 2. Estimated K value for the different soil texture classes.

Texture class	K
Sand	0.06
Loamy sand	0.13
Sandy loam	0.30
Fine sandy loam	0.39
Loam	0.42
Silt loam	0.53
Sandy clay loam	0.30
Clay loam	0.31
Sandy clay	0.15
Light clay	0.28
Heavy clay	0.36

TABLE 3. Slope lengths and steepness and their topographic factor.

Slope lengthy		Slope steepness		Topographic
Value (m)	Factor (L)	Value (%)	Factor (L)	Factor (LS)
30	1.16	20	3.57	4.14
90	2.02	20	3.57	7.21

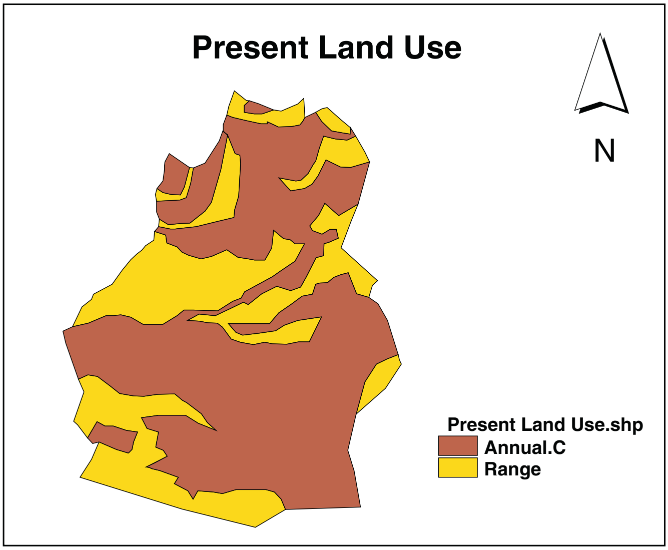

Figure 1. Present land use map.

4. The Base Map

A vector base map (land capability map) of the study area as shown in (Figure 2). This was produced through field visits depending on the local soil classification, using soil series, slope, depth, rock outcrops, stones and exposure as a parameters for the soil series.

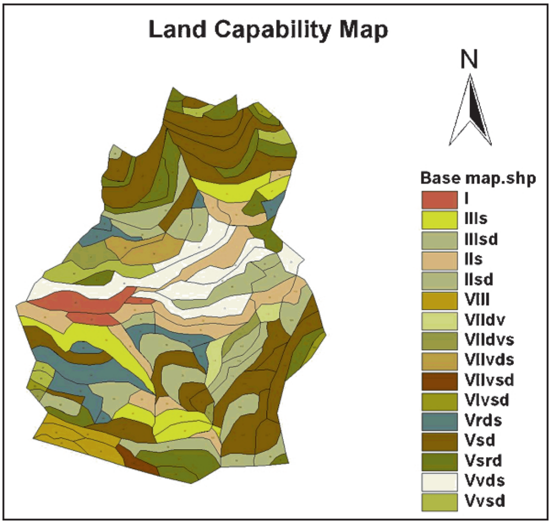

Figure 2. Land capability map.

Local land capability index (Table 4) and erosion hazards index (Table 5) were used to determine the land capability classes as well as erosion hazards categories for each soil unit produced. Land capability classes I–III and V–VIII out of eight classes were found in the study block while the eight classes were found in the projects area. Sixteen sub-capability classes of slope, rocks, and depth were all found.

TABLE 4. Land capability index.

Slope (%)	Rock (%)			
	<10	10–25	25–75	>75
<5	I	Vrd	Vvd	VIIvd
5–10	IIs	Vrds	Vvds	VIIvd
10–15	IIIs	Vrds	Vvds	VIIvd
15–25	Vs	Vsrd	Vvsd	VIIvds
25–35	Vsd	Vsrd	VIvsd	VIIvsd
35–50	VIsd	VIsrd	VIIvsd	VIIvsd
>50	VIII	VIII	VIII	VIII

TABLE 5. Erosion hazard index.

Erosion hazard	Class and sub-class					
Very high	VIIs	VIsr	VIsd	Vsrd			
High	Vs	Vsr	VIrs	VIIvsd			
Moderately high	IVs	Vsd	Vsrd	VIvsd			
Moderate	IIIs	Vsd	Vsrd	VIvsd			
Moderately low	IVvs	Vvsd					
Low	IIs	IVsr	Vrds	Vvds	Vvds		
Very low	IVr	IVv	Vrd	Vvd	VIr	VIvs	VIIvd

Erosion hazards, ranging from very low to very high, were found. Soil type 32 was the dominant soil type was found in the study area. Thirty-three and 12 soil types were found in a limit scale. Table 6 represents the standard soil mapping code which used in the study and were approved from Ministry of Agriculture.

TABLE 6. Standard soil mapping code.

Item	Class	Description
Slope	A	0–5%
	B	5–10%
	C	10–15%
	D	15–25%
	E	25–35%
	F	35–50%
	G	More than 50%
Depth	d	Deep; more than 100 cm
	m	Moderately deep; 30–100 cm
	s	Shallow; less than 30 cm
	sm	Shallow, less than 30 cm with pockets
Rocks	0	Less than percent
	1	10–25%
	2	25–50%
	3	50–75%
	4	More than 75%
Stones	0	None stony
	1	Stony; stones may interfere with tillage
	2	Very stony; stones are sufficient to build walls
Exposure	N	North
	S	South

5. Estimating Soil Loss

The calculations in estimating soil loss were carried out using USLE parameters (Figure 3) with the following assumptions:

1. Rainfall
1.1 Average = 400 mm
2. Soil erodibility
2.1 Loam soil texture
2.2 Less than 0.5% organic matter
2.3 Granular soil structure
3. Slope length = 90 m
4. Slope steepness = 20%
5. Cropping pattern
5.1 Cropping
5.2 Continuous long term fallow
5.3 Low productivity level
6. Conservation practice
6.1 None

A 90 m slope length were used in USLE model as an indicator representing the average slope length of the lands before constructing soil conservation structures (SCS) talk place with a 20% average slope steepness to estimate the moderate soil loss in the study area. While there were seven

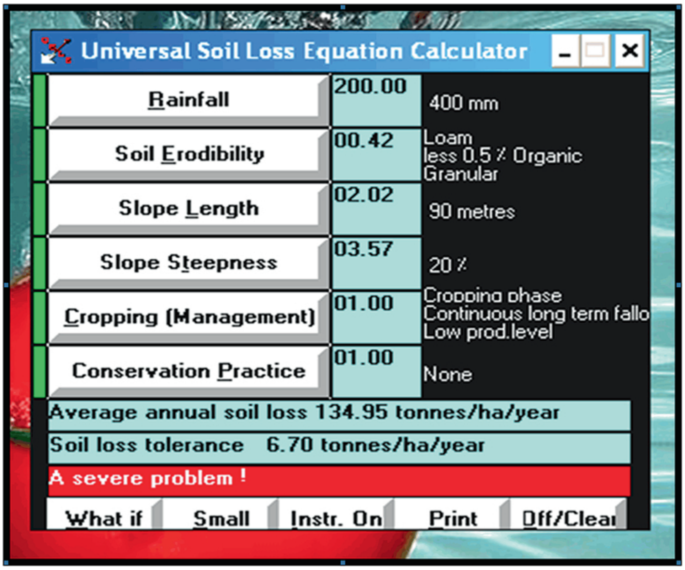

Figure 3. Image of universal soil loss equation calculator used for the project.

levels of erosion hazards representing identical seven levels of soil loss, a correction factor for the average soil loss (Table 7) were used to estimate the soil loss for each level.

TABLE 7. Soil loss correction factors.

Erosion hazard levels	Correction factor
Very high	2.000
High	1.667
Moderately high	1.333
Moderate	1.000
Moderately low	0.667
Low	0.333
Very low	0.000

USLE was then run based on the assumptions mentioned before, considering:

- An average rainfall equal 400 mm.
- Loam soil texture with less than 0.5% organic matter.
- Granular soil structure with slope length equal 90 m and slope steepness equal 20% of continuous long term fallow.
- Low productivity level and no conservation practice.

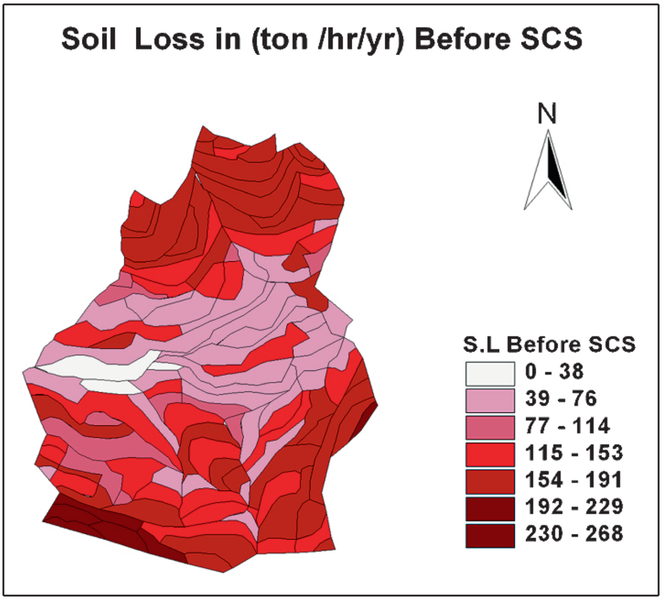

Figure 4. Average soil losses before including in the projects.

As a result average soil losses of 134 t ha^{-1} year^{-1} were estimated. Figure 4 (vector map) represents the average soil loss of each soil unit in the study area before building soil conservation structures.

Using the correction factor we can compute the exact estimation of soil loss in tons per hectare per year for each group of soil which represents the categories of erosion hazards. Table 8 provides details of the relationships between the erosion hazards groups, the correction factor, and the estimated soil loss.

TABLE 8. The estimated soil loss in ton per hectare per year.

Erosion hazard	Average soil loss (t ha^{-1} year^{-1})	Correction factor	Soil loss (t ha^{-1} year^{-1})
Very high	134	2.000	268
High	134	1.667	224
Moderately high	134	1.333	179
Moderate	134	1.000	135
Moderately low	134	0.667	90
Low	134	0.333	45
Very low	134	0.000	0

Again running USLE based on the assumptions mentioned before of

- Average rainfall equal 400 mm.
- Loam soil texture with less than 0.5% organic matter.
- Granular soil structure but with slope length equal 30 m which become the actual length for the land after constructing SCS and average slope steepness equal 20% of continuous long term fallow.
- Low productivity level and none conservation practice.

As a result an average soil loss of 78 ton year^{-1} ha^{-1} were estimated. Figure 5, (victor map) which represents the average soil loss of each soil unit in the study area after construction SCS in the lands.

After 10 years of construction SCS in the lands, and as a result of the agricultural development activity which support the farmers in planting their lands with trees, and based on the assumption that the coverage area will reach 10% of the total land and the previous mentioned assumptions related to the USLE parameters, the average soil loss will decreases to an average of 51 ton ha^{-1} year^{-1}. Figure 6 illustrate the change in the color order of the soil units.

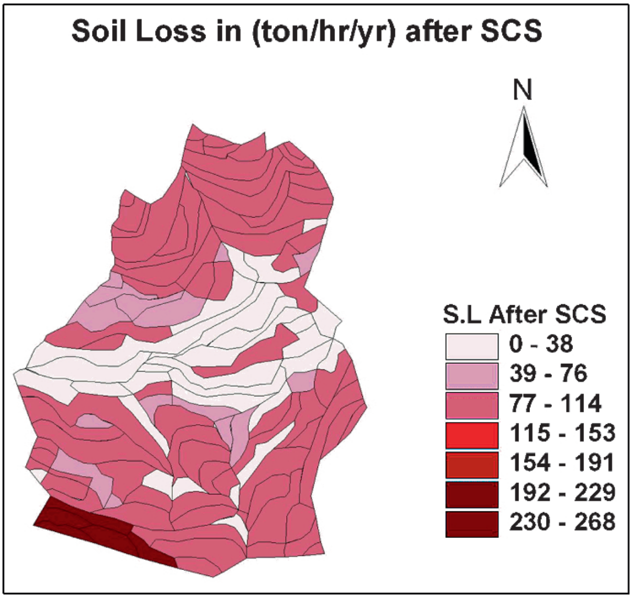

Figure 5. Average soil losses in ton per hectare per year after constructing SCS.

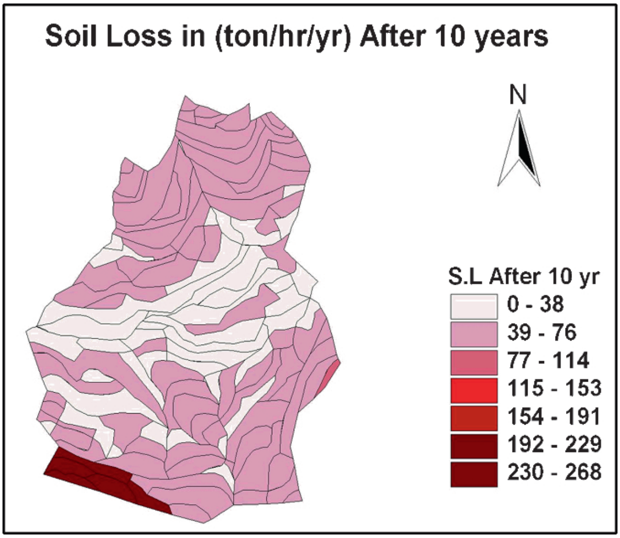

Figure 6. Average soil losses in ton per hectare per year after 10 years.

After 20 years of construction SCS in the lands, and based on the assumption that the coverage area will reach 25% of the total land and the previous mentioned assumptions related to the USLE parameters, the average soil loss will decreases to an average of 33 ton ha^{-1} year^{-1}, and Figure 7, illustrate the change in the color order of the soil units.

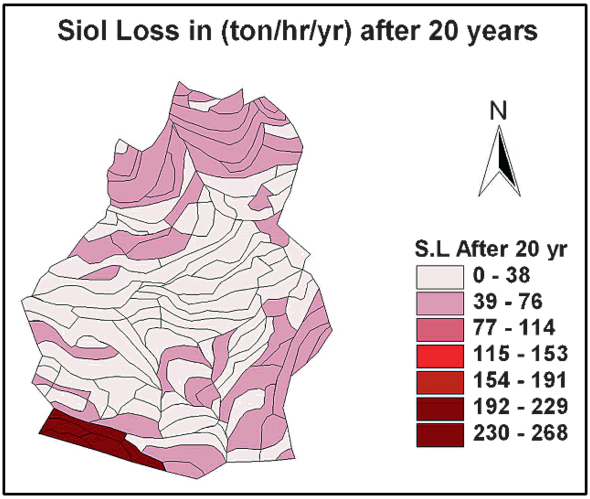

Figure 7. Average soil loss in ton per hectare per year after 10 years.

6. Conclusion

Soil erosion and its consequences are considered as a serious problem by policy makers, as well as farmers and land owners. Subsidies and grants as well as loans for soil erosion and combating measures for farmers have been developed since 1964. The four times running of USLE on the study area, before and after constructing SCS, and 10 and 20 years later of plantation by trees indicates that the soil loss decreases from 135 ton ha^{-1} $year^{-1}$ to 33 ton ha^{-1} $year^{-1}$, passing through 78 and 51 ton ha^{-1} $year^{-1}$. So research on soil erosion and improved methods for its control that incorporate technical, economic or socioeconomic and environmental factors in the region should receive a high priority. Developed erosion control methods should utilize recent thoughts in soil conservation which give greater importance to biological control and improving farming practices.

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DATA ACCESS FOR ENVIRONMENT PROTECTION AND ECONOMIC DEVELOPMENT

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Abstract. The article is focused on spatial data concerning the environmental protection and economic development. The first parts of the article describe datasets managed by state bodies and relations between them. Czech metainformation systems MIDAS, MIS and MIcKA and access to geodata in the Czech Republic are characterized in the second part.

Keywords: Spatial Data, Data Access, Czech Republic.

1. Introduction

All phenomena take place somewhere and therefore they are localized. Therefore there is a need to handle spatial information when the phenomena are analysed and their relationships are explored. Prior to the development of information technologies (IT) this question concerned only an inner cabinet of people working in geosciences and relative domains. Since the end of the 20th century the development of IT has speeded up. The domains of geographic information systems (GIS) and of data for GIS were influenced as well. Due to the new technologies the data measurement, update and editing of maps become easier. This causes massive production of map outputs and it simplifies spatial analyses (or spatial information based analyses) in more and more fields of human activities. Massive expansion of the Internet, e-government development and other services makes the GIS applications generally available to non-professional users. The wide-spread route planners or public transport connections on the Internet are two of these examples.

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Map maintenance in digital form and its distribution causes many questions. The analogue maps are only exploitable by anyone who has access to them. The question of data access comes up with the digital data – related to their format and other technical specifications.

Development of IT in the geographic information domain makes the update more effective and enables fast results to final users. On the other hand, problems connected with data management, technologic processing and last, but not least, data harmonization appear. The globalisation and integration of the world increases demand on the data interoperability – technical, cultural and linguistic, which blend together. For example, during the search in simple gazetteer you need to handle national specific marks – e.g., diacritics that the foreign user does not support. Furthermore, the information must be intelligible in different cultural environments, the geographic names should be standardized, handling exonyms must be solved, etc. Therefore initiatives as INSPIRE, building of national data infrastructure appear and the data interoperability effort are developed.

2. Environment Protection and Economic Development Data

The advantages of digital geographic data are highly valuable especially in domains where, based on spatial information, fast, effective and right resolutions are needed. And it concerns the domain of environment and long-term investments for economic development.

As for environment – complex solution from prevention to solution of actual situation in risk management is the most appropriate case. The background data usually come up from terrain models topographic and geologic maps, respectively. In specific cases thematic maps such as nature protection, inundation, meteorological and climatic maps support the general topographic maps.

The topographic maps represent the background for economic development too. They should be completed by maps dedicated to bearers or subjects of economic processes – people. Therefore the cadastre of real estates is crucial source of information. Regarding other thematic maps, maps of town and country planning, maps of regional development, agricultural maps, demographic statistics, etc. can be mentioned.

3. Topographic Maps of the Czech Republic

Topographic maps are produced by two institutions: national mapping agency – the Czech Office for Mapping, Surveying and Cadastre (ČÚZK) and, for military purposes, by the Military Geographic and Hydrometeorologic

Office (VGHMÚř). They both produce topographic maps at several scales from small to medium. Furthermore, the ČÚZK manages cadastral maps.

3.1. CZECH OFFICE FOR MAPPING, SURVEYING AND CADASTRE – SURVEY OFFICE

The main products of the Survey Office (ZÚ) are basic maps at medium scales, state map series at scale 1:5,000, Fundamental Base of Geographic Data of the Czech Republic – ZABAGED®, database GEONAMES and others.

3.1.1. Basic maps

The basic maps are produced at scales 1:10,000, 1:25,000, 1:50,000, 1:100,000 and 1:200,000. These maps cover the whole state territory and contain WGS-84 geographic grid and the grid of the national coordinate system S-JTSK. They are distributed in printed form or in raster form (so called RZM nn, where nn is the scale denomination in thousands). The layers of the RZM 10 – RZM 50 are generated from the ZABAGED®. They were created by scanning of single map print bases. This technology is still used for the RZM 200. The raster output of the Basic Map 1:100,000 is not provided (Survey Office, 2007b). Basic maps are updated in 3–5 year-cycles (Survey Office, 2008).

Figure 1. Examples of basic maps 1:10,000, 1:50,000 and 1:200,000.

3.1.2. State map 1:5,000

The State Map 1:5,000 – Derived (SMO 5) is the most detailed state map series that contains altimetry. Cadastral maps are the basic planimetric component of the map. The altimetry is derived from the Basic Map of the Czech Republic 1:10,000. The planimetric components are completed from other graphic background, first of all from the aerial photos. The SMO 5 is being progressively substituted by State Map 1:5,000 (Survey Office, 2007b).

The State Map 1:5,000 is a successor of the SMO 5. The main difference is that the cadastral component originates from vector cadastral maps and planimetric component is the orthophotomap (Survey Office, 2007a).

For digital processing purposes, the map is provided in raster and vector forms. The vector version covers 23% of the Czech territory. The data are provided in the datum S-JTSK in map sheets.

The SM 5 in raster form contains three components – the cadastral one is created by raster of planimetric components of the SMO 5 last version and the altimetry is represented by raster file of the last SMO 5 altimetry. The last component is orthophoto. Both versions support the S-JTSK datum and the Adjusted Baltic Vertical Datum. The georeferencing files in global system WGS-84 can be provided, but the transformation is supposed to be done on the client side (Survey Office, 2008).

Figure 2. An example of the State Map 1:5,000.

3.1.3. ZABAGED®

The Fundamental Base of Geographic Data of the Czech Republic – ZABAGED® is a digital terrain model created on the accuracy level of Basic Map 1:10,000. Its content is composed of 106 features with attributes (Survey Office, 2007a). It is created and maintained as other state map series in datums S-JTSK and Adjusted Baltic Vertical Datum (Vaniš, 2006) but can it be provided transformed in WGS-84 or UTM (Survey Office, 2008).

According to Surveying Act (Collection of Law, 1994), this database (digital model) is a component of public administration information system and is mandatory for creation of state map series at scales 1:10,000 and less. ZABAGED® must be used as a background for creation of public administration information systems that contain other data with exceptions for state defence and risk management.

Features are listed in the Survey Office (2007a) including definitions, data sources and attributes. Another component of the ZABAGED® is a 3D vector file with contour lines and basic interval of 2 m.

ZABAGED® data are saved in seamless database and are updated in 3-year periods on the base of new aerial photos and colour orthophotos.

ZABAGED® data are provided in map sheets of Basic Map 1:10,000 as vector files of planimetric components (2D) and altimetry (3D) (Survey Office, 2008).

Figure 3. An example of vector data ZABAGED®.

3.1.4. Orthophotomap of the Czech Republic

Colour orthophotomap is provided for the whole territory of the Czech Republic in division into map sheets by the division of SM 5. The resolution is 0.5 m per pixel. The data are georeferenced in the map sheets for the datum S-JTSK or UTM/WGS-84. The update frequency is 3 years – each year a third of the state territory (Survey Office, 2007a).

3.1.5. Cadastral maps

Essential, and maybe the most important, the source of spatial information for environment protection and economic development is the cadastre of real estates (Czech Office for Mapping, Surveying and Cadastre, 2008). The cadastre contains information on the type and form of real estate/parcel protection. It includes protection of the environment, land resources, mineral resources, historic monuments (Collection of Law, 1992a), internal protection zones of water resources and internal territory of health resorts (Collection of Law, 2001).

The data from the cadastre are provided by cadastral offices as public documents upon a request. The data maintained in digital form can be provided on the Internet.

The vector file can be the Digital Cadastral Map (DKM) or the Cadastral Map Digitized (KMD) (Czech Office for Mapping, Surveying and Cadastre, 2008). The DKM is created by detailed survey methods in the datum S-JTSK. The KMD is less accurate and is processed by digitization of analogue cadastral map (VÚGTK, 2008). The KMD can be maintained in old datums used in Austria-Hungary Empire.

3.2. MILITARY GEOGRAPHIC AND HYDROMETEOROLOGIC OFFICE

The Military Geographic and Hydrometeorologic Office (VGHMÚř) is designed for geographic and hydrometeorological securing of state defence and direct geographic and hydrometeorological support of army. Besides, the VGHMÚř assists the Civil Service tasks in survey domain for needs of the state defence (Military Geographic and Hydrometeorologic Office, 2008).

The VGHMÚř produces analogue military topographic maps at scales 1:25,000, 1:50,000 and 1:100,000. The aerial photos have been taken since 1936 and they serve as base for creation of orthophotomap.

Digital terrain models represent digital image of features as combination of 2D coordinate localisation and list of attributes. There are two basic versions of DTM (DMÚ). The DMÚ25 contains topographic layers divided into seven thematic layers (hydrography, cities, communications, other networks, boundaries, vegetation and land-use and terrain relief). The accuracy depends on the feature type and ranges between 0.5 and 20 m. The DMÚ100 is based on the topographic map 1:100,000. The accuracy ranges between 40 and 80 m. All DMT products are primarily in WGS-84. The VGHMÚř provides the data in datum S-42 or S-JTSK (Cajthaml et al., 2006).

Further production is focused on military purposes.

Figure 4. An example of military topographic map 1:50,000.

4. Maps for Environment Protection

The environment protection is shared by several bodies. The central one is the Ministry of the Environment of the Czech Republic. The Ministry has a subordinated body the Agency for Nature Conservation and Landscape Protection of the CR (AOPK ČR) that manages the Administrations of Protected Landscape Areas. The Administrations of National Parks are subordinated directly to the Ministry. At the regional level these bodies cooperate with the Regional Authorities.

4.1. AGENCY FOR NATURE CONSERVATION AND LANDSCAPE PROTECTION OF THE CR

The main activity of the AOPK ČR is represented by care and management of the landscape in the Czech Republic.

The AOPK ČR manages the Nature Conservancy Central Register (ÚSOP). The ÚSOP contains specially protected areas, i.e., national parks, protected landscape areas, natural relicts, natural reservations national natural relicts, national natural reservations and memorial trees. Additionally, this list comprises protected areas in frame of Natura 2000 – Special Protection Areas. It contains not only territorial extension, but also records to the protected areas. The data are provided in the vector SHP file and are processed in the national datum S-JTSK, based on the ZABAGED® and cadastral data. The large protected areas are documented on the base of technical-economic map (Agency for Nature Conservation and Landscape Protection of the CR, 2008a).

From 2001 to 2004 the biotopes survey was carried out. The output was a polygonal vector layer and database of biotopes segment characteristics that are used for analysis in GIS. Twelve-year stage was decided for data update (Agency for Nature Conservation and Landscape Protection of the CR, 2008b).

4.2. MUNICIPALITIES WITH EXTENDED AUTHORITY

4.2.1. Territorial system of landscape ecologic stability

The Territorial System of Landscape Ecologic Stability (ÚSES) is defined in the Environment Protection Act No. 114/1992 Sb. (Collection of Law, 1992b) in § 3 a) as interconnected set of natural or human-influenced but natural ecosystems that are balanced. Elements of the ÚSES are biocenters, biocoridors and interaction elements. There are four levels of the ÚSES – provincial and biospheric (more than 100 km2), superregional (more than 10 km2), regional (more than 10, respectively 50 ha) and local.

The mapping of existing and proposed biocenters and bicorridores with distinguished especially protected parts of nature is done at scale 1:50,000 and larger for the superregional and the regional ÚSES and at scale 1: 10,000 and larger for local one. A table and descriptive part are added to the graphic file. The Plan of ÚSES is a background for the ecologic stability systems projects, land adaptations, processing of landscape planning, forestry plans, water management and other documentation for landscape protection and recultivation. The Plan of ÚSES is used for setting of local, regional and superregional ÚSES.

Another form of the Plan of ÚSES is the ÚSES General Plan that defines ÚSES based only on the natural criteria. The purpose of the ÚSES General Plan is to prepare a background for protection of unambiguously defined ÚSES elements and territorial reserve protection for completion of proposed missing elements in a short period. The General plan is prepared for large territories (one complete biochora minimum) and at scales 1:10,000 respectively 1:25,000.

4.2.2. Significant landscape feature

The Significant Landscape Feature (VKP) is a part of landscape that is valuable for ecologic, geomorphologic or aesthetic point of view and forms a typical landscape character or helps to keep its stability. The VKP registry is managed by the Municipalities. The VKP database is centralised in the AOPK ČR (Agency for Nature Conservation and Landscape Protection of the CR, 2008a).

4.3. NP ADMINISTRATIONS

The National Parks (NP) Administrations are independent bodies of natural protection not governed by the AOPK ČR. There are four NPs in the Czech Republic. Their activities are very similar to activities of the AOPK ČR. i.e., that the NP Administrations manage natural protection registry, eventually data for forestry at the NP territory. With respect to specifics of nature protection at the territory of NPs, their Administrations maintain the information on national parks zonation (National Park Czech Switzerland, 2008; National Park Šumava, 2008; Podyjí National Park, 2008; The Krkonoše Mts. National Park, 2008).

4.4. REGIONAL AUTHORITIES

According to the Environment Protection Act No. 114/1992 Sb. § 77a (Collection of Law, 1992b), the Regional Authorities prepare a Concept for Nature Protection at their territorial scope (except national parks or protected landscape areas and other protected areas). The results are usually published at the web sites of individual Regional Authorities (Vaniš, 2006).

5. Maps Connected with Economic Development

5.1. CZECH STATISTICAL OFFICE

The Czech Statistical Office is a central body for public administration of the Czech Republic. The Office manages statistic registries for statistic purposes for the whole state statistic service of the Czech Republic. One of these registries is the Register of Enumeration Districts (RSO). The RSO contains geographic products of the Czech Statistical Office that comprise digital geographic layers, addresses evidence and statistic structures of the state (Cajthaml et al., 2006).

Furthermore, the Czech Statistic Office processes statistic demographic, economic, cultural, agricultural and similar data. These data are usually in form of tables but can be displayed in cartograms. The information is sold (Czech Statistical Office, 2008).

5.2. LANDSCAPE PLANNING

According to the Building Act No. 183/2006 Sb. (Collection of Law, 2006a), the Ground Plans are created by the Municipalities with Extended Authority upon request of communities in their territorial scope. The landscape planning background is created by Regional Authorities in deputed competency as well.

In addition, the landscape analytic backgrounds being a part of the landscape planning backgrounds comprise graphic display of the topographic component of technical infrastructure drawn in the cadastral map or more detailed maps.

The Ground plan defines basic concept of municipality development and it refines the aims of the regional landscape planning. The designs are a part of the graphic part of a ground plan and are created on the map background at scale of cadastral maps or, in justified cases, smaller one. These designs are published at scales 1:5,000 or 1:10,000, eventually at scale of cadastral map (Collection of Law, 2006b).

The Ministry for Regional Development of the Czech Republic (MMR) takes up a special position. This ministry ensures administration of regional politics, habitation and housing-resources politics, landscape planning and touristic (Ministry for Regional Development, 2008). The MMR creates territorially technical backgrounds (further adopted by Regional Authorities) at scale 1:400,000. However, these and nor other data are directly used.

However they solve to monitoring and scoring the state and possibilities of the regional development (Hojdar and Martínek, 2004).

5.3. MINISTRY OF AGRICULTURE OF THE CZECH REPUBLIC

The Ministry of Agriculture manages several basic registries. As for spatial data for economic development and environment protection it is especially the Land Parcel Identification System (LPIS). This register contains records on farmland exploitation and it serves for validation of data in applications for funding. The system contains detailed data of less favourable areas and factors needed for agro environmental arrangement. Moreover, the LPIS is exploited as a background for register of ecologically managed land, as a Horizontal Rural Development Plan monitoring tool and as a tool for simplification of farming restrictions due to nitrate directive. The LPIS is based on modified cadastral data – the owner is not important for funding; important is the person who uses the land. Fundamental units of the LPIS are farm blocks, which are really exploited coherent parts of farmland with one plantation managed by one user under one management regime. The farm blocks in the SHP format are available only for authorised users. Farmers can look into documentation concerning their blocks and make print outputs (Ministry of Agriculture, 2008).

6. Access to Maps Using Up-to-Date Communication Means

The Development of Internet technologies rapidly increases possibilities to produce and of data providing and access to them. On one hand it is the data publishing on the Internet and on the other hand it is the ability to search the data using metadata portals. Recently several portals have been created. These are database systems of different organizations. Metadata portals and map services complement each other in very favourable way or the metadata portals at least make possible to get information on existing data sets and to link to the data source. National data infrastructure and the INSPIRE initiative act a crucial role in data providing and publishing.

6.1. DATA ACCESS IN THE CZECH REPUBLIC

The raw data are provided for a consideration, eventually free of charge for activities of public administration bodies. Some data are not available for public – especially data of confidential character and data that could endanger security.

Providing of map outputs as Web Map Service (WMS) is relatively wide-spread. Data of general topographic maps or orthophotos (ČÚZK, VGHMÚř, eventually private subjects that produce their own maps but based on backgrounds of the ČÚZK or the VGHMÚř) are the most often available. The data published at portals as Yahoo are usually completed with other information layers from the portal database – usually touristic information as restaurants, pubs, bus and train stations, gas stations, etc. In present days each administration manages a spatial data infrastructure (see above) where a number of WMS service expose all or part of their data. Data from their territorial scope are published by the Regional Authorities. In this case the contents and number of data differ.

6.2. METAINFORMATION SYSTEMS

Metainformation systems are exploited for handling the metadata and their search and management. There are two metainformation systems in the Czech Republic that are part of the National Geoinformation Infrastructure – MIDAS and MIS.

6.2.1. MetaInformation database system – MIDAS

The MIDAS is a Civil Service metainformation system on information sources. The system has been developed and is operated by the Czech Association for Geoinformation. The system supports only Czech language. The metadata are structured in classes according to the described source types.

The system provides information on data files in the Civil Service bodies or private entities and other important information on the organizations, persons, events, services, application software or documents. The system makes defining relationships among all these classes possible.

The metadata structure of this system is European standards CEN for metadata compliant. The transfer to the metadata structure by ISO 19115 is prepared. The MIDAS system is one of the components of the created National Geoinformation Infrastructure.

Search is possible by typing the specific text or using the hierarchic structure in individual data categories. Other possibilities of catalogue search are display of all records in alphabetic order, or all organisations and in map – according to the spatial localisation.

The system supports advanced search as a combination of ways mentioned above. Other restrictions are temporal validity and in case of maps some scales (MetaInformation DAtabase System, 2008).

6.2.2. Metainformation system of the ministry of environment – MIS

The catalogue services network was also established in the domain of the Ministry of Environment of the Czech Republic. Since 2007 this system has been compliant with INSPIRE standards when national standards were cancelled.

In 2007 metadata catalogues MICKA were installed on nine servers of the environment domain bodies. Other bodies share another collective catalogue. The metadata are published on one central portal at http://mis.cenia.cz using the catalogue service (CSW 2.0.2). Found public web services can be instantly displayed in an incorporated viewer in the map form. Other Czech CSW servers – the Regional Authorities, the Forest Management Institute and in addition, the Slovak Environmental Agency and the INSPIRE Pilot Catalogue are connected to the MIS portal.

Currently there are about 300 public metadata records of the environmental domain and about 500 records from other organisations in the Czech Republic published in this system. This amount includes about 50 WMS. Metadata update and adding is still running.

The portal provides overview of data sets that are related (not only) to the environment in the Czech Republic. The system will make information from European metaportal after launching of the INSPIRE Portal accessible (Kafka, 2008).

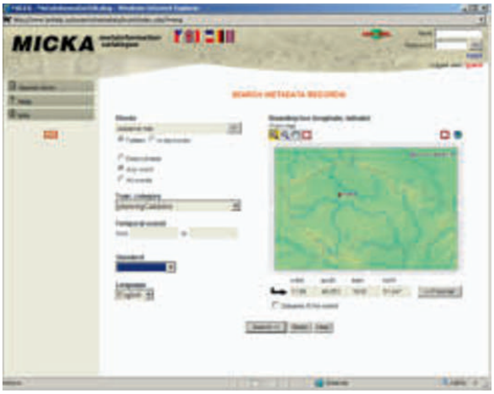

Figure 5. A screenshot of Micka interface.

6.2.3. MIcKA

MIcKA is one of the complex metainformation systems in Czech Republic. It was developed by a private company providing services associated with building of geoinformation systems (Help Service Remote Sensing, 2008). In present days the European metadata standard ISO 19115, Feature Catalogue Standard ISO 19100 and Metadata Dublin Core are implemented in MIcKa (MIcKA, 2008). The extension of metadata is possible through configuration program. The environment of this program is English, German, French, Czech, Polish and Latvian. The system supports metadata import from ISO 19139 standard compliant XML format and from the program ArcCatalog. Metadata acquisition and maintenance can be processed in the web browser in formats HTML or ISO 19139 compliant XML. The system supports not only metadata search, visualisation and edit, but also management of users, metadata items and Open Geospatial Consortium specifications compliant web catalogue service (Help Service Remote Sensing, 2008). Handling feature catalogues, gazetteers and thesauri is supported too (Kafka, 2008).

The system supports search by entered terms and options as evident from the Figure 5. The result is displayed as a list containing standard, name of the data set, contact point of the metadata and its description. The complete metadata will be displayed by clicking at the data set name (MIcKA, 2008).

7. Conclusion

Data management is distributed between competent public bodies of individual government departments. The topographic data are worked up by two bodies – the ČÚZK and the VGHMÚř. The Fundamental Base of Geographic Data (ZABAGED®) from production of the ČÚZK is defined as mandatory background for creation of public administration information systems. Other thematic geodata are managed by individual offices and resort bodies on national or regional level. These bodies are established in accordance with the Acts or Codes. These legislative documents, and eventually regulations of the bodies, contain a part of national data infrastructure, i.e., who and how can receive the data and the data structure. The data are usually provided for public administration reasons free of charge, other users pay for them.

Up-to-date communication means open and an access to the data for public. Several metainformation search services operate for search of information on data in the Czech Republic.

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REMOTE AND IN SITU SENSING FOR DIKE MONITORING: THE IJKDIJK EXPERIENCE

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Abstract. The IJkdijk is a test facility for dike monitoring systems in the Netherlands. It is used for proof of concept tests for new technologies for dike inspection and also for studying geophysical processes within dikes. TNO, as one of the partners in the IJkdijk foundation, uses it as a so called "field lab" for the TNO research program Intelligent Sensor Networks. A number of projects within this research program use the IJkdijk as a test case for the practical applicability of their results (visualization techniques, control rooms). For this reason the focus of this chapter is rather on practical applicability of technology than on scientific results. The chapter describes the development of the IJkdijk, the setup of the first experiment as well as the visualization of, and the interaction with the data during normal operation and in crisis situations

Keywords: Remote Sensing, Sensors, Dike Monitoring, Control Rooms, Multi-touch Interaction, Visualization.

1. Introduction

With the expected climate changes, the land subsidence, the increased economic value of the low-lying areas as a result of economic prosperity, and the declining acceptance of calamities by the general public, The Netherlands need to invest substantially in flood protection to keep the risk and consequences of flooding at an acceptable level. In other parts of the world similar situations occur. Moreover, due to population and economic

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growth in second world countries millions of kilometres of dikes will be constructed. These too require immense investments.

Developments in communication and sensor technology have advanced so far that it seems possible to use this new technology to effectively support the management and monitoring of flood protection in an economically efficient manner. This seems to open up ways to offer cheaper and better alternatives for the traditional methods of dike monitoring, maintenance and improvement. However, most of the recently developed sensor technology still needs to be tested under field conditions, to prove its applicability.

2. The IJkdijk

The IJkdijk ('Calibration dike') Foundation (2008) is an initiative of TNO and Deltares, STOWA, NOM and IDL. The plan emerged to build test dikes to enable the systematic testing of various types of new sensor, actuator and communication technologies, both during construction and the entire lifetime of a dike. The dikes and the corresponding data infrastructure are set up in such a way that ensures that any future technologies can be tested. It will be possible to overstress dikes, using a diversity of realistic methods, until they fail in a controlled manner. This will provide insight into:

- The applicability of sensor, actuator and communication technology for dike monitoring
- The failure mechanisms and the prediction of the onset of failure on the basis of the sensor measurements
- The validity of computer models for these failure mechanisms
- The economical feasibility of the tested systems for use in large-scale applications
- The practical installation related technological problems in sensor, actuator and communication technologies
- The possible scenarios for large-scale application of sensor and communication technology, in terms of both technology and organization
- The interaction between the different organizations monitoring dikes and acting upon dike failures

Thus, the IJkdijk provides valuable insights and technologies for organizations dealing with water management, e.g., regional water boards and public work departments everywhere in the world.

2.1. FLOOD RISKS

Flood protection is determined partly by the height of the dikes, but often the strength of the dikes is more important. Most of the weak spots in the dikes collapse because of a lack of strength with regard to stability or internal erosion rather than be flooded. The key to a better utilization of the existing dikes and thereby reduction of the flood risks is to find ways to determine the very processes which undermine the strength of dikes with a high degree of certainty. Such monitoring systems must ultimately be able to sense weaknesses in tens of thousands of kilometres of dikes, way before a failure might occur.

Determining failure processes of dikes is still a research field in development. Clear is that the strength of dikes depends on a large number of parameters which are hard to determine. Calculation methods for dike strengths are available, but there seems to be a significant uncertainty, or gap, between the calculated strengths and the actual ones. Because of the huge investments involved and the increasing costs of maintenance and management for the regional water boards this is a very unsatisfactory situation. Systematic experiments are needed to calibrate the models. This enables the design of right-sized dikes. Furthermore, once available, such models are able to calculate the short and long term future of the dike system based upon real time data from sensors in dikes. Most importantly they can report if immediate safety issues are present.

2.2. TESTING NEW TECHNOLOGIES

Several new (sensor) technologies may contribute to a more accurate, cheaper and/or faster determination of the relevant parameters in the various processes which may lead to dike failure, resulting in a better picture of the actual strength and the current protection level of the dike and enabling measures in a more timely and location-specific manner. This is of great importance. Intensive monitoring of the strength:

- Reduces costly over dimensioning of dike reinforcements.
- Enables transparent and reproducible decision-making during calamities.
- Enables improved determination of the effectiveness of innovative reinforcement technologies.
- Increases the accuracy of periodical safety assessments of dikes and provides a continuously up-to-date picture of the actual safety situation.

There is a growing need for new methods to measure the various key parameters related to dike safety. These solutions exist and new ones are under development, but at the same time there is too little knowledge to evaluate the favorability of current technologies. This is partly because there are no generally accepted criteria for applying a specific technology. Another reason is that most available technologies may have a proven track record in laboratory conditions or in other domains, but not in real field situations relevant to the water boards. And finally there is insufficient clarity for the district water boards about the cost effectiveness of the different technologies. In view of this gap between the suppliers for dike technologies on one hand, and the regional water boards with their questions on the other, the test facility of IJkdijk is being set up. As a "field lab" it shows and evaluates technologies for an audience of water management bodies. Furthermore the new insights in the geophysical processes of dikes and dike monitoring systems can be translated to accurate actions, dike designs and maintenance planning.

Figure 1. Small scale wave overtopping experiment using a wave simulator.

3. Experiments

From 2008 until 2013 a series of experiments is planned in which the failure mechanisms which are to be monitored will be central. The commercial partners in the IJkdijk focus on development of the technologies, while the research institutions concentrate on development of knowledge about a wide range of geophysical processes in dikes. Experiments are always combinations of a failure mechanism to be studied, a loading scheme, and several measuring methods. At present, experiments are in preparation related to stability, erosion due to wave overtopping (see Figure 1), sliding due to steady state overflow and internal erosion (piping). To support these experiments the IJkdijk provides an infrastructure to connect various sensor and actuator systems. It supplies them with energy and fixed and wireless communication. It consists, among others, of an application platform with a number of basic applications (GIS visualization, dashboard, …) and a multiparty data acquisition, data publishing and analysis infrastructure. Over time, the infrastructure will grow based on the demands and requirements of the experiments to be conducted.

The first large scale experiment will be carried out in September 2008. The failing mechanism to be studied is Macro instability. In the case of Macro instability a part of the dike slides inwards because of saturation of the dike body with water (Figure 2). For this experiment a dike of 100 m in length and about 6 m high is built in the IJkdijk area. More than 10 industrial partners are installing their sensors and other instruments in the dike, measuring all kinds of parameters.

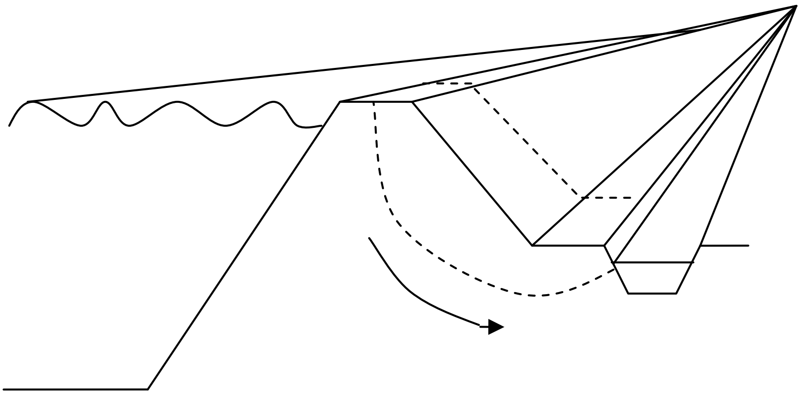

Figure 2. Dike failure because of macro instability.

The commercial partners will use the following instrumentation in or around the test dike:

- Hydrophones/microphones (TNO, Landustrie, Volker Wessels).
- Active glass fibre for temperature measurement (Kappelmeijer).
- Fibre for measuring deformations (Dike Survey).
- Hydrodect glass fiber (Ten Cate).
- Inverted Pendulum measuring movement (IFCO, BCC).
- MEMS measuring deformations (USAC, RPI, Measurand).
- Geobeads measuring various parameters (Alert service).
- Reference monitoring, measuring movement, moist and water tension (Deltares).

- Thermo graphic cameras (Intech).
- Remote sensing by a miniature helicopter (Miramap).

All these sensors produce a tremendous amount of data, which must be processed and visualized to enable end users to make sense of these data. The next chapter describes a project which studies the ways the data from these sensors can be visualized and interacted with during normal operation and during possible calamities.

4. Visualization and Interaction in Control Rooms

4.1. INTRODUCTION

Control rooms are pre-eminently places where large quantities of data streams from diverse sensor networks and sensor sources come together. Important decisions have to be made based on these data streams and critical systems, or even lives, are dependant from it. Since sensor data comes in high volumes, is unstructured, time-critical, and comes from different types of sources, visualization techniques are very useful in giving the overview and insight needed in efficient and effective decision making. At the same time the interaction with the data through the visualization can help explore and interpret the large amount of data available for the end user. The work that is described here explores the use of multi-touch technology and data visualizations for future control room designs.

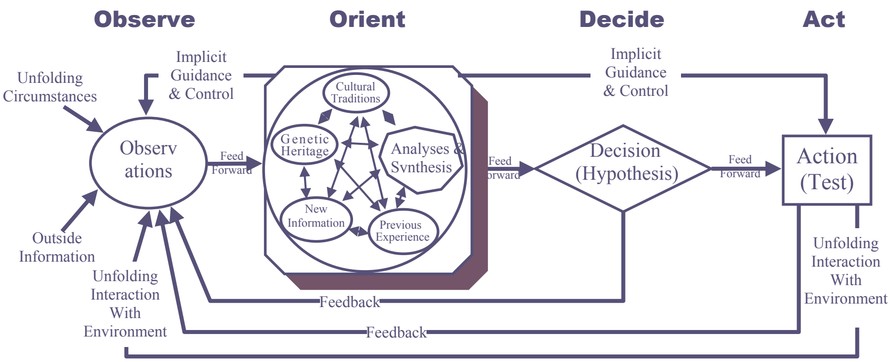

Figure 3. The OODA loop model.

4.2. CONTROL ROOMS

Control rooms are used for different purposes and by different professions: e.g., security, weather, traffic and military purposes. This project focuses on flood control rooms and operational crisis teams that have to act in (imminent) flooding situations. A flood control room assists all relevant participants in making decisions during crisis situations. Where the current way of working mostly relies on traditional means of gathering information and communication, our objective is to investigate how multi-disciplinary visualization and interaction techniques can help improve decision making in control rooms. One of the models that is used is the OODA Loop (Boyd, 1987). The premise of this model is that decision making is the result of rational behaviour. Problems are viewed as a cycle of Observation, Orientation (situational awareness), Decision, and Action (see Figure 3).

4.3. VISUALIZATION OF SENSOR DATA

The aim of visualization techniques is to give an overview of, and insight in, large amounts of possibly unstructured data (Stuart et al. 1999). Data is represented in a graphical way so that it can be interpreted by the human visual system which is very powerful in discovering trends, patterns, anomalies and making comparisons. A good visualization not only presents the data but also allows for interaction with the data. Shneiderman (1996) describes the tasks a visualization tool should support in order to give a user quick insight in data. Translated to dike monitoring, these tasks are:

- *Overview* – give an (aggregated) overview of all measurements
- *Zoom* – zoom in on interesting parts of a dike
- *Filter* – filter out uninteresting measurements
- *Details-on-demand* – select one or more sensors, and get detailed information about their measurements
- *Relate* – View relationships between dike sections or individual sensors

According to these guidelines, the system that we envisage gives an overview of the status of dikes in a large area (e.g., the whole country). The system allows the user to switch between this high-level view in which data is aggregated and lower-level views of small sections of dikes showing more detailed information (e.g., cross sections, different types of soil the dike is made of, acceptable water pressure levels, and measured values of individual sensors).

In addition to the measured sensor data, other data needs to be visualized as well in a control room environment. In a crisis situation, decisions are not taken by one, but by several parties, each with their own interests and priorities. The interest of the mayor of a city that is close to a bursting dike is to protect its citizens, while the responsible person for drinking water quality is probably more concerned with preventing the flooding of a chemical factory. The interests of the parties, as well as consequences of actions ('what-if' analysis) need to be visualized, thus supporting the decision processes in a crisis situation.

During a crisis situation, it is important that feedback on the actions and decisions taken, is visualized as well. Examples are: status of the evacuation of people, status of the work on repairing the dike, the location of fire trucks and ambulances, the current number of casualties, etc. By using sensor technology (e.g., GPS sensors), a large part of this information can be gathered automatically.

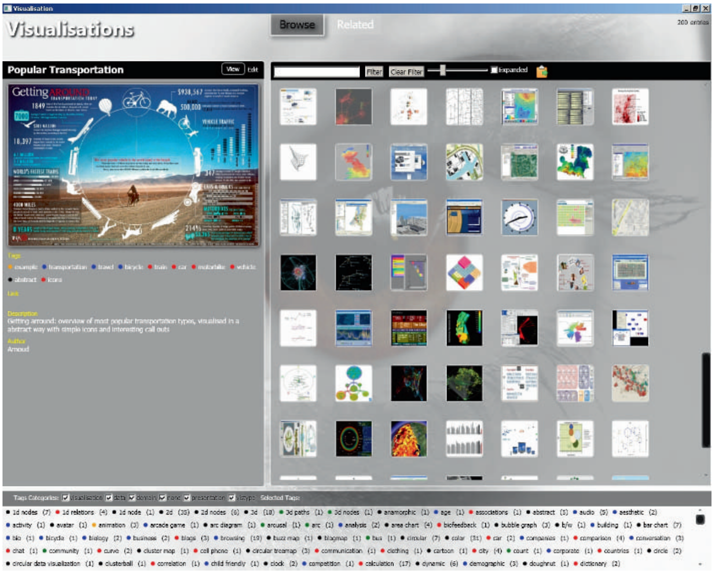

Figure 4. Screenshot of a tool for searching through a large collection of visualizations.

We developed a tool that supports the selection of proper visualizations. This tool discloses a large library of different types of visualizations (see Figure 4). The tool allows for quick search of visualizations for different types of data (1D, 2D, 3D, temporal, network), different types of visualization techniques (tree maps, scatter plots, graphs, heat maps, and many more), and different domain (traffic, energy, social networks, etc.).

This was used selecting visualizations for a flood control room. A first visualization realized within IJkdijk is shown in Figure 5. As a first experiment, we used Google Earth, and the accompanying data format KML, for visualizing sensor data. Google Earth is free, it is known by a large audience, and allows for adding both geographic data (place marks, overlays, metadata) and geometric data (lines and polygons). The visualization shows in real time the water pressure in a dike as a 3D-plane. It also allows for playing historical data as an animation giving insight in the course of the water pressure in time.

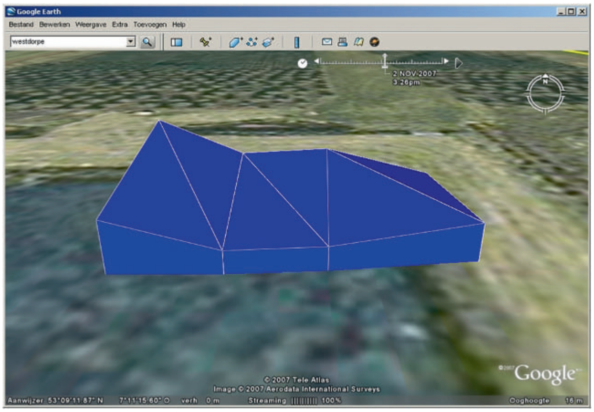

Figure 5. Visualization of water pressure in a dike as a 3D plane in Google Earth.

4.4. MULTI-TOUCH INTERACTION

Operating a mouse consists of series of discrete events and single point input. Contrary to 'single-touch' interaction, multi-touch interaction offers the possibility to interact with multiple fingers and at the same time it enables multiple users to interact with the same item. Multi-touch interaction allows for more parallel interaction, it reduces task complexity of single input techniques and parallelism in multi-finger interaction saves time. Here we focus on multi-touch interaction with multiple users that work together to support their group decision making.

Figure 6. Multi-touch table by NUI Group Sweden. http://nuigroup.com/

Ever since the presentation of the Multi-touch concept of Han (2006) and the introduction of the iPhone by Apple there has been worldwide interest for this man-machine interaction technology. Although the technology has been around for quite a while (Buxton, 2008), large industry vendors such as Microsoft, Dell and Apple are only now adopting this technology into their products. Multi-touch now exists in many different forms: from a small multi-touch phone, laptop to a table (Microsoft, 2007) or even a large wall (Hewlet Packard, 2007).

We are developing a flood control room application for the multi-touch table from the Natural User Interface Group in Sweden (Figure 6). This application is based on a general multi-touch framework. This framework uses Touchlib (2008), an open source solution for finger recognition, which allows developers to create multi-touch software using Windows Presentation Foundation, a graphical subsystem of the .Net framework. Currently the focus is on developing a collaborative environment where multiple participants can work together allowing each of them to present their knowledge and expertise. The main entrance of the application is a shared map that shows relevant information needed for the tasks at hand. Participants can control data filters, simulations and navigate using intuitive gestures and finger movements.

4.5. FLOOD CONTROL EXPERIMENT

In October 2008 the regional crisis centre for the province of Groningen is participating in our research to find out how information overload (caused by a combination of communication channels and sensor sources) can be handled by using information visualization and multi-touch interaction. A scenario is developed for a flood crisis and this will be simulated in a crisis exercise in October 2008. The water board district, emergency services (police, fire and health dept), municipalities, and other related organisations have to work together in this flood crisis situation, using a multi-touch table and our visualization and interaction software.

5. Conclusions

From our experience with the IJkdijk until now it is obvious that large scale sensor networks can benefit enormously from proper visualizations. The techniques that are used in the water world are often quite traditional and much can be gained from using new technologies, like the multi-touch interface described in this chapter. In crisis situations large amounts of data have to be handled and interpreted in real time by multiple parties. During normal operation it is often helpful to be able to access historical data and to look at trends in time. Both situations are relevant and both put different demands on the type of visualization that is needed. Moreover in both situation, support by multi touch systems can be highly beneficial

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POLITICAL, ECONOMICAL AND SOCIAL FACTORS IN THE PROTECTION OF THE ENVIRONMENT

ENVIRONMENTAL PROTECTION VS. ECO & ENVIRONMENTAL TERRORISM: THREATS, IMPACT AND CONTINGENCY PLANS

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Abstract. Exploitation of natural resources, environmental pollution and destruction has resulted in dramatic ecological and climatic changes. The traumatic event of the WTC in 2001, where more than 3,000 people were killed, gave the world a warning of what the global terrorism is capable of. Global terror turns into environmental terrorism of which the results might be much more devastating than we have encountered so far. Globalization effect and growing "Green" awareness, have led to fast development of radical environmental activist movements some of which have chosen "direct action methods" aimed at property destruction in the name of "saving the world". Some of these movements were declared terrorists; their leaders were put behind bars. However, the question remains – are these movements really terrorists? Chasing radical environmentalists without opening a dialog with them might result in pushing them into the arms of global terror. We all can still gain control to preserve and improve our environment by changing our priorities along with activities aimed at increasing security and environmental protection while keeping the balance between the two.

Keywords: Environment, Globalization, Global Terror, Protection, EMESCO.

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1. General

Earth is the greatest essential source of human life, which is constantly being exploited and damaged by human beings. Industrialism and irresponsible consumption of natural resources, while disregarding the ecological impact, resulted in continued decline of the ecosystems.

There are numerous factors that can further aggravate the condition of the global environment:

- Natural Disasters
- Man made Environmental Disasters
- Accidents and Industrial Mishaps
- Global and Domestic Terrorism
- Eco & Environmental Terrorism
- Sabotage

The aim of this chapter is to highlight the main issues referring to the threats, their impact on the environment and contingency planning related to the Eco & Environmental Global Terrorism.

2. La Raison D'être

No doubt that environmental and ecological protection has become the main challenge of the 21st century. However, the more these issues become important to our and to the next generations' proper way of life, the more it becomes target to those individuals and organizations who consider the proper world order as totally improper.

While many countries have spent a large efforts for protecting their main infrastructures, key installations and mass transportation systems against terror attacks, not enough attention has been given to protect environmental sites. These are an easier target for attacks by terrorists who aim at achieving greater loss of life, disrupt daily life and get great publicity by causing great damages, sometimes with irreversible effects on both the population and the environment.

3. Terminology

There are terms used in the literature dealing with Terrorism and its connection to ecology and environment, some of which are used in this chapter as follows:

- Global Terrorism: global terrorists networks share a vision of global ideology – war against the free world and its regimes they perceive to be inappropriate. These terrorists have a mindset that is not receptive to alternative views, and it does not recognize the sacred nature of all human lives, values and environment preservation.
- Domestic Terrorism: criminal acts, including against civilians, properties, animals and the environment, with the purpose to provoke a state of terror in the general public or in a group of persons, intimidate a population or compel a government or an international organization to do or to abstain from doing any act. This definition is based on FBI's Congressional Testimony conducted on February 2002.
- Environmental Terrorism: using, the environment or natural resources in order to cause disorder, cognitive & physical damage.
- Ecological Terrorism: illegal activities conducted by radical environmental groups for the sake of "defending" ecological and environmental causes or animal rights.
- Natural Disaster: the consequence of a natural disaster hazard, such as: earthquakes, volcanic eruptions, hurricanes, flooding, forest fires or landslide.
- Man-Made Environmental disaster: a disaster that is either an accident resulting from natural or technological induced factors or due to human activity or of combination of the above that causes or threatens to cause severe environmental damage as well as loss of human lives and property. In this case, the impact of human's alteration of the ecosystem has led to widespread and/or long-lasting consequences.
- Sabotage: deliberate action aimed at weakening an "enemy", oppressor or employer through subversion, obstruction, disruption, and/or destruction.

4. Globalization and Global Terrorism

Globalization might facilitate world-wide spread of Global Terrorism – following are some observations:

- Globalization augments the Economical differences between rich and poor countries. This drives people and regimes in poor countries to feel exploited by the rich countries and sometime it results in their resentment to cooperate or worse, to become an easy "prey" for organized terror groups who can find supporters among the "exploited" population and the ruling regimes.

- In his Column on Global Affairs (2001), Dr. Khan (2002) noted that Globalization is essentially a measure of the ease with which, labour, ideas, capital, technology and profits can move across borders with minimal governmental interference, this process was facilitated by the liberalization of trans-border transactions by the dilution of sovereignty. The great sense of insecurity that terrorism now inspires in the global economy has resulted in a reassertion of sovereignty by the "free world" nations. The fear that liberal standards are facilitating terrorism is causing the US and the European Union members to control trans-border transactions.
- Fast transportation, communications systems, internet, media, tourism, capital transaction, etc., facilitate easy access to "targets" by organized terror groups or individuals. The efforts to prevent terrorists from moving their resources is leading to greater scrutiny of banks and setting up of new measures that slow down the flow of capital.
- Open borders, such as among the EU countries, enable terrorists who managed to enter one country to move freely among all the countries comprising the Union. The fear that "porous borders" allow terrorists to enter target countries is leading to new rules about border patrol, VISA regulations, and monitoring of foreign travellers. New security measures at airports have already raised the costs of travel and are affecting the profitability of the airline industry.
- Sensitive information is becoming public domain as more agencies share it – (with the "kind" assistance of the global media).

5. Global Terrorism Trends

The main characteristics of the Global Terrorism are the ideology and the values which stand behind and motivate its activities:

- Spreading their "truth" and belief
- Sanctification of the death – neglecting the value of life sanctity
- Identifying the modern civilization in general, and the Western countries and affiliates in particular, as its enemies
- Global terrorism does not differentiate between civilian, military, private, governmental, environmental or ecological targets. Even hurting their own people and property is part of the ideology and heritage
- The more they interrupt the world order, the bigger is their "success"
- Terrorists groups became increasingly sophisticated, not only in their ability to conduct coordinated large scale attacks but also in their

ability to manage complex financial and logistical networks, spreading their influence from anywhere to any other location.

- As indicated by Chalecki (2001), terrorists become more creative and resourceful, their approach to achieve their goals for greater loss of life, greater damages and greater publicity incline more toward unconventional weapons and methods.
- International war on terror and stringent security measures applied by the nations world-wide are reducing "traditional" terrorism targets such as: airports, seaports, public transportation, public facilities, sensitive and key installations, infrastructure, schools, etc.
- Global terrorism employs worldwide networks to recruit supporters, especially in places where radical or anarchist protestation groups are active and are a potential recruiting source.
- The possibility of a terrorist attack involving unconventional weapons of mass destruction – i.e., Chemical, Biological, Radiological, Nuclear (CBRN) explosive weapons, which will not only achieve their goals but might also severely devastate the environment – is the world's current major threat.
- On the other hand Environmental Terrorism is a much easier means of achieving the terrorist goals without the difficulty and, presumably, the massive retaliation that would follow from the use of CBRNE weapons.

6. Environmental Terrorism

The International war on terror as described in the paragraphs above is only one of the reasons why the Global Terrorism is turning now to use the environment as means of terror to achieve their goal. The other reasons that can be considered for the global terrorism to shift into Environmental Terrorism are:

- The environment provides the terrorists with a large variety of "convenient" possible "targets" to hit.
- Most possible Environmental "targets" are accessible to all and therefore become "Easy to hit".
- It is impossible to apply counter measures and protection means to protect all possible Environmental "targets".
- Hitting an Environmental "target" may affect/devastate large geographic area and population.

- On top of direct human health and life related effects, Environmental Terrorism has powerful sociological and economical effects.
- International media attention and coverage of Environmental Terrorism draws the International public awareness and thus serves as “effect multiplier”.
- Environmental Terrorism was used in the past by terrorists groups or by countries that sponsored terrorism. However, since the declaration of a Global War on Terrorism following the September 11, 2001 Terror attack on the USA terrorists have “re-discovered” the great potential in using Environmental Terrorism as means of achieving their goals. Environmental Terrorism may be directed against a large variety of “targets”, that can be sorted into four categories:
- Water resources (e.g., water catchments, water-works, reservoirs, dams, etc.).
- Agriculture and forests (e.g., Livestock and Harvest poisoning, nature reserves, etc.).
- Petrochemical sites (e.g., nuclear plants, petrochemical plants, fuel farms, refineries, oil & gas pipes, etc.).
- Wildlife and Ecosystem.

7. The Devastating Potential of Environmental Terrorism

Hereafter are have listed a few past Environmental Terrorism incidents which demonstrate the devastating potential of Environmental Terrorism:

- Water Resources Incidents:
  - 1999 – Engineers discovered a homemade 15 kg bomb in a water reservoir near Pretoria, South Africa. The dam personnel felt that the bomb, which had malfunctioned, would have been powerful enough to damage the 12 million litre reservoir, thereby depriving farmers, a nearby military base, and a hydrological research facility of water.
  - 2000 – A breakdown in the chlorination of the drinking water of Walkerton, Ontario, contaminated the water supply with Escherichia coli O157:H7. This sickened over 2,000 people and killed seven people.
  - 1993 A Cryptosporidium contamination of the water supply of Milwaukee, Wisconsin, sickened over 200,000 people and killed almost 100 people.

- Agriculture Poisoning and Forests Fire Incidents:
    - Crop poisoning – A well-known example of this type of attack was the cyanide poisoning of some Chilean grapes in 1989. While this particular incident caused no identifiable sickness, it was psychologically and economically effective: it caused panic in supermarkets and ultimately cost the Chilean fruit export industry millions of dollars in lost revenue by destroying consumers' trust.
- Forest Fires:
    - 2007 Greece – a series of massive forest fires broke out in several areas across Greece throughout the summer of 2007, some of these firestorms are believed to be the result of arson, which might have been motivated by economical reasons.
- Petrochemical Incidents:
    - 1997 – Colombia – over 45 separate attacks on the Cano Limon-Covenas pipeline, reputedly by leftist guerrillas from the National Liberation Army (ELN), caused Colombia's national oil company Ecopetrol to declare force majeure on all exports from the Cano Limon field.
    - 1998 – Colombia – Oil pipeline sabotaged by National Liberation Army (ELN), spilling over 30,000 barrels of oil and triggering a blaze which killed more than 70 people when the fire spread through nearby villages.
    - 2005 South Middleton, Pennsylvania – U.S.A. Three counties and 20,000 customers lost electrical power when activists shut out a transformer on at a power substation. Damage estimate US$300,000.
- Wild life and Ecosystem Incidents:
    - 1998 – The Earth Liberation Front (ELF) set arson to a ski resort in Vail, Colourado, causing $12 million in damages. This event is the costliest act of environmental terrorism in American history at the time.

8. Protection against Environmental Terrorism

Two categories out of the four Environmental Terrorism "Targets" – Water Resources and Petrochemical sites – seem to be the most attractive "Targets" in the terrorists' eyes. These "Targets" have the greatest potential for loss of life and for long lasting damages that will bring to vast publicity to the terrorists and their goals. High priority should be given to protection of water and oil related targets and yet other environmental targets should not be neglected.

Applying of the following methodology is recommended in order to help protecting the environment against potential terror:

- Define the potential and most probable Water Resources and Petrochemical Sites, which might be targeted by Global or Domestic terrorist groups.
- Categorize these sites for different level of protection – considering the sites' sensitivity, severity of probable effects and implications if damaged/destroyed, etc.
- Conduct risk analysis to every site that it has been decided to protect against terror attacks.
- Plan and establish security plans for each of the selected sites.
- Establish security procedures and contingency plans.
- Enhance and maintain updated existing security procedures and contingency plans by conducting a variety of exercises – Table Top, Workshops, Staff & Control Centers' exercises and field exercises.

The more the potential targets are protected, the less attractive they become to terrorists. The main measures to taken to protect the environment aimed at reducing the environmental hazards are:

- Setting adequate regulations and apply stringent enforcement.
- Increasing taxes and especially punishment on polluting industries and polluting products.
- Promoting incentives for environmental protection industries such as recycling, developing solar energy, etc.
- Intensifying the conduct of public awareness campaigns.
- Using technology aimed at reducing pollution.
- R&D: Identification of alternatives for "pollution generators".

Since the threat is realistic, there is a need to take immediate actions and apply the necessary measures to protect the "potential targets" – before it's too late.

9. GIS Role in Environmental Terrorism Protection and Management

GIS systems have a major role in Environmental Terrorism protection and management, enhancing threat assessment capabilities, facilitating protection planning, identifying and tracing of activities and management of incidents.

The ability to track history of Environmental Terrorism on GIS maps, compare "Before" and "After" activities on GIS layers, enables faster identification of environmental hazards, trends and modus operands.

An example of this was the is the 1,193 incident on Casselan River incident, when a highly acidic water gushed out of an abandoned mine killing large quantities of fish in the River.

For many years, the Casselman River and its tributaries, Pennsylvania, have been impacted by nonpoint pollution sources. During the assessment phase, GIS was used to determine the location, types, extent, and impacts of the most severe abandoned mine drainage discharges and identify areas with high potential for agricultural runoff. Data sources included United States Geological Survey topographic mapping, aerial photography, historic water quality and quantity results, and field-generated data.

10. Ecological Terrorism

In recent years, the world has been encountering radical environmentalist groups who marked on their flag to "defend ecological, environmental, or animal rights" by carrying out illegal activities, sometime resembling/copying a modus operandi applied by terrorist groups. This phenomenon was already described by Henry David Thoreau (1817–1862) in his book Civil Disobedience. As it happened many times, the "positive" ideology becomes a movement and some movements have converted themselves to some kind of "holy sect" as it could be seen in The Monkey Wrench Gang of Abbey (1975).

According to The Legacy of Luna (J. B. Hill) the most famous eco-terrorist has been Theodore Kaczynski, also known as the Unabomber, who was convicted of murder in the mail-bombing of the president of the California Forestry Association. On the other hand of the spectrum of environmental protest is Julia Butterfly Hill, whom ecoterrorists and ecoanarchists would do well to emulate. Hill is an activist who lived in a California redwood tree for 2 years to prevent it from being cut down by the Pacific Lumber Company. Hill practiced a nonviolent form of civil disobedience, and endured what she perceived as violent actions from loggers and timber company actions. Her peaceful protest brought national attention to the issue of logging in ancient growth forests, and a compromise was eventually reached between environmentalists and the timber company. Unfortunately, the tree in which Hill sat, which she named Luna, was damaged by angry loggers.

The activities carried out by these groups and their method of operation raised a serious question: whether or not these groups can be considered terrorists? Such serious doubts were raised and analyzed by Smith (2008) in her critical analysis "Ecoterrorism?"

There are points raised to name these groups as Terrorists whereas others suggest avoiding labelling them as such. Those who support labelling these groups as terrorists claim:

- These groups conduct illegal activities and use terrorists' methods to justify their objectives.
- These groups cause damages sometime even sever damages, to public and private properties and disrupt people's lives.
- These groups use local citizens to act on their behalf in their own countries.

Radical environmentalist groups might be exploited by terror organizations. This idea was presented by Dr. Rohan Gunaratna during 2008's Annual Gathering of the Counter-Terrorism Community in Herzliya, Israel. Dr. Gunaratna indicated that Al Qaeda uses unwitting tools, to infiltrate, and to manipulate a variety of organizations. Radical environmentalist groups might become a target for such efforts.

Those who recommend avoiding labelling these groups as Terrorists, claim :

- Is the "Eco-terrorism" definition widely accepted by the public or is it the authorities' invention?
- "Environmentalists" are accepted and justified by most people, with slight distinction between "good" and "bad" organizations.
- Public opinion may not support considering Environmentalism as terrorists, it may even cause naïve individuals to join them.
- Treating Environmentalists as "Terrorists" could push them to the arms of Global Terror organizations – resulting in local citizen's cells of terrorism.
- And how can we define moving polluting industries to third world countries?

11. Conclusions

A number of conclusion can be drawn:

- Environmental protection leaders should consider not only the economic needs and the effects on the quality of life of the present and future generations, but they should also consider the implications of environmental protection policies and measures that might encourage global environmental terrorism to create ecological chaos.
- Handling radical environmentalists should be deal more with applying political, social and psychological measures and less with outlawing these groups.
- Radical Environmentalists' collaboration with terrorists, in order to achieve their "cause", is much more dangerous than their protesting

activities. Collaboration with terror organizations may result in breeding grounds for terror groups among local population.

- Current investments and means allocated for environmental protection are definitely insufficient.
- Finally: the battle for "Earth Survival", which is actually our struggle for a better life, for present and future generations, becomes more and more complicated. There are numerous issues to confront with, concurrently: population increase, shortage of food and energy sources, growing poverty, political and religious confrontations, corporations and capital interests, growing industrial pollution and mishaps, wars, radical environmental groups, local and global terror organizations and more!

What the world needs now is a determined leadership to lead us all to triumph!

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GEOPOLITICS AND ENVIRONMENTAL SECURITY

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Abstract. This chapter introduces the issue of geopolitics at the global level and how this relates to environmental security. Different historical perspectives are presented and analysed in light of today's geopolitical situation.

Keywords: Geopolitics, Environmental Security.

1. Introduction

Geopolitics is one of the main components of the modern world. Referring to the environment, we cannot refrain from focusing on geopolitics and its role in terms of environmental security.

Three basic factors are the main drive of our countries: (1) society (population), (2) economy and (3) geopolitics, with the latter being of highest importance. In fact geopolitics heavily influence the economy and it can cause its growth or fast fall. The well-being of society, the state of the public opinion and several factors related to development also depend on it. However there is no general rule as the world is far from being homogeneous, especially in economic and social terms. Speaking of the influence of geopolitics on the environment we can define separate components within society and economy, according to their role in the preservation of environmental security.

2. Monopolar vs. Polypolar Perspective

Looking back to recent history we can certainly acknowledge that, before the collapse of the USSR, the world was bipolar. In other worlds, as it was generally accepted, two world systems existed: socialist, led by the Soviet

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Union, and capitalist, under the leadership of the USA. At that time the global geopolitics depended on these states and it was mainly determined by their political choices.

The situation in the world changed greatly in the 90s when the pendulum of geopolitics began to swing from monopolar to polypolar. This process was mainly caused by the goals and rising economical interests of industrially developed countries playing a leading role in the world.

When analysing global and national interests, we need to classify different attitudes towards the environment which characterise different countries. The countries pursuing globalism, that is the aspiration to achieve global profits for the benefit of small groups of population, wish to get national, economic, financial and other advantages at any cost, paying no attention to anything, least of all to the environment. Countries adhering to such approach in their geopolitical strategy can be fairly accounted for supporting a monopolar world.

A second group of countries, less numerous, is more moderate in their goals and in the ways to achieve them. These countries tend to solve problems of national interests, for the well-being of the country and of the majority of the population. They rely on long-term prospects of development and are concerned about the environmental security. We can say that such countries adhere to the polypolar world.

Unquestionably, within both groups of countries there are moderate and aggressive leaders with their supporters however, when referring to the majority of the countries, two principle tendencies emerge in terms of interaction of geopolitics, economy and society.

The states belonging to the first group are economically more independent. When solving geopolitical problems they try to unite the population and to preserve the economy of the country making use of aggressive measures. In this case national, religious and financial circles are involved in the process and led by governmental institutions. Various doctrines, concepts, programs and projects are invoked with the ultimate goal to gain advantages over the other states and coalitions.

Although today in most cases problems of this nature are solved peacefully, there are still cases where this does not occur as testified by the number of armed conflicts, local warfare and large-scale terrorist acts worldwide. The issue that these events jeopardize the ecological security the local environments is not taken into great consideration at the international level. Damages to the global Earth ecology are not taken into account either.

Finally the evidence that a damage caused to components of the environment in one region cannot be constrained at the local level is also ignored. Due to trans-boundary transfers contaminants are carried over the

Earth by air and water, with the accident in Chernobyl being a remarkable yet dramatic example of this. As result of the accident, radionuclides were spread across the Arctic, to Canada, Scandinavian countries and other regions with long-term influence on several generations through fallouts, vegetation contamination and within food chains.

In fact it the number of accidents with trans-boundary pollutants transfers is rather large. Vicious geopolitics tendencies, as well as inappropriate ambition of politicians, can considerably reduce the ability of environment to self-recover and endanger its crucial role within the life of humanity.

3. The Role of Geopolitics for the Environment

While highlighting the negative effects of aggressive tendencies in geopolitics, on the other hand we should not ignore moderate and positive geopolitical factors which can cause appropriate reactions at the economical and at the social level. In this case it is important to underline local, national tendencies at the social and economical level.

Most countries, playing an important role in the world's development process, including Scandinavian countries, a number of European countries, countries in Asia and in the Middle East, have their own specific positions in geopolitical terms. The main goal of these countries is to provide political independence, economical and national security. It is natural that these countries pay great attention to the environment and engage to a great extent to ensure better ecological security. For this reason they have established various international, national and public organizations which provide monitoring of the environment not only on neighbouring territories but across different regions.

Most importantly the resistance to aggressive and progressive tendencies is one of the main drives of geopolitics, as destructive tendencies can have profound effects at the social, economical level, with great implications also in terms of environmental consequences. However today the balance of forces within these coalitions is rather fragile as well as the overall countermeasures deployed by them. Such scenario may not last for long and, if any aggressive coalition will prevail, it will typical result during the most unfavourable situations, as it happened on World War I and World War II.

Today there are not the conditions for large-scale wars, with millions of soldiers sitting in trenches, trying to annihilate each other. Precision weapons and other modern means of destruction in fact allow attacking objectives locally, avoiding large-scale damages to the environment as it happened during the wars in Vietnam, Korea and other regions. Nonetheless the damage may be considerable in case of attacks on oil and gas complexes as testified by the events which occurred in the Middle East during the "Desert

Storm" campaign. In the past two decades ecological terrorist acts, resulting from aggressive geopolitics, have acquired a global relevance and present a particular challenge to the environment as proved by the separate acts of terrorism which took place in Spain, Great Britain, Russia and United States.

4. The Main Factors Affecting Environmental Security

Three main factors characterize and determine the state of environment; these are: (1) geopolitics, (2) society and (3) economy and each factor has its own development process. Social development, for instance, depends on numerous factors such as density of population, historical background, national interests, religion, level of intelligence, the number of ethnic groups, their size, etc. Geopolitics can be profoundly affected by the growth of doctrines depending from particular features of the population, their historical background, etc. Finally economy is the result of the current political situation of the country, prospects of development, coalitions of states and world economy in general, etc.

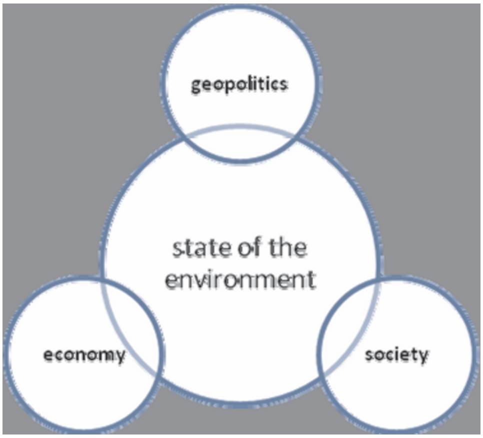

Figure 1. The three main components which characterize and determine the state of environment.

However even though all three factors are significant, we shall only focus on the implications of geopolitics on the environment from two viewpoints: global and national, considering their possible influence on the environment, different types of negative effects and methodology for neutralizing them. Before doing so it is essential to agree upon a common terminology.

- With the term global scale we shall refer to effect spreading across an entire continent or to several continents, for example, Europe, North and South America, Central Asia, Far East, etc. At this level no emphasis is put on political systems, economy, climate, raw materials, etc.
- At national scale we shall consider issues such as social order, political structure, and economy of an individual country or group of countries close to their political activities.

Global and national interests are intrinsic to each factor, some countries historically are inclined to control the world and, while the majority of them bound their plans within their own territories, occasionally some countries clash for territories with neighbouring states. However this is not a global trend and clashes are not necessarily evidence of global geopolitical expansion, on the contrary these are most often result of local political conflicts.

Different examples clearly show a precise attitude towards the environment and its protection. Countries supporting global approach to geopolitics try to achieve global plans and are not concerned about the state of environment, which is not considered of primary relevance. Particular importance is paid instead to global goals: that is to acquire authority at the global level, or at least to be able to influence global issues with all the consequences this may cause.

Means of destruction before World War I could not have disastrous effects on the environment, on water supplies and on the atmosphere. During World War II chemical weapons were not used as it was clear, after World War I, that damage could be caused to all parties, with disastrous effect beyond expectation. At the end of World War II, when nuclear weapons were used in Hiroshima and Nagasaki, environmental issues became the matters of international concern. The same conclusions were made, as we see it, after World War II when it became obvious that atomic weapons could affect not only belligerents but the entire planet. Additionally numerous nuclear weapon tests in different countries and accidents on atomic power stations, showed that achieving global geopolitical tasks with the help of armed forces can cause serious environmental problems.

5. Terrorism and Geopolitics

In more recent times the focal point has moved to local aggressive activities and different types of terrorist acts. Although these are local from the point of view of global geopolitics, they can potentially cause hundreds or thousands casualties. The causes of contemporary terrorism are well-known and numerous researches in this field are carried out in different countries.

Although this is not the subject of this work we believe that methodology issues related to the support of environmental security are of primary importance in the current scenario.

Today we are facing a difficult condition characterised by geopolitical competition and globalization. Terrorist acts are not caused by a single event. They are the result of complex social, political, economic, national and religious factors to name but a few. The aim of terrorist acts is to deeply affect population in their culture additionally they violate national spiritual values, and decrease economic potential.

In a number of cases global geopolitics is implemented under the pretext of spreading pseudo-democracy all over the world. Often the ideas brought forward by Trotsky on the persistency of revolutions in the world are adopted. However these are merely legends, camouflages while the real goal often remains unchanged: global economic leadership.

In a number of cases terrorists use peaceful measures, such as:

- To pay salary to dissidents in a certain country to ruin it
- To deprive a country of the leader
- To spread fear among population
- To prevent rival states from domination

6. New Scenarios

Today aggressive geopolitics can be seen in political decisions taken by the most stable countries that have gone against UN resolutions and other international institutions for instance recognising Kosovo's sovereignty. Although it can be referred to as an episode of marginal importance, it marks the beginning of a new tendency, a first step in changing the current status quo. In this case "dominoes" effect can emerge, when a shift of dice can cause the collapse of the whole construction. With regards to this the most critical issue is that in several countries there are regions with poor or no stability, with population anger fuelled by separatist activists. Recognition of one such region will inevitably cause the rising of new crisis. Among these countries there are, among others, Cyprus, Caucasus, Turkey, Spain or Canada.

Geopolitical forces supporting such governments are interested in the division of these countries into small states as this creates a more favourable scenarios to rule at the global stage and to control the world's economy on all continents. The idea is simple and clear: large-scale wars are not needed while any developed country with stable political system supporting new small states can easily solve new problems.

Political map of the world will turn into multi-coloured patch-work quilt. Surely, the efforts of global geopolitics are designed in this case to change social principles of the whole regions and continents. Here an important fact should be emphasized. In this case terrorist activities rise and obstinate leaders should be isolated or annihilated with precise action to increase social pressure in terms of ideology, morale, etc.

Table 1 shows three main geopolitical models and their possible influence on the environment and illustrates how aggressive geopolitical ambitions can lead to irreversible negative effects on the environment.

TABLE 1. Classification of geopolitical models and possible consequences on the environment.

N/N	**Geopolitical models**	**Level of aggression**	**Manifestation of aggression**	**Counteraction of supporters of other models**	**Influence on the environment**
1	2	3	4	5	6
1	Monopolar	Aggressive	Classic military operations	Classic military operations, global terrorist attacks	Grave consequences with slow self-recovery of the environment
2	Bipolar	Moderately aggressive	Local military operations	Classic military operations, limited terrorist acts	Medium consequences with quick self-recovery of the environment
3	Polypolar	Moderate	Chaotic armed conflicts	Chaotic terrorist attacks	Moderate influence on the environment without grave consequences

7. Conclusions

We must underline that many countries and public organizations have committed to reduce the danger of aggressive terrorist influence on the environment. This is being done within the framework of UN, NATO-Russia Council, etc. Particular attention is paid to informational cooperation in cases of ecological terrorism as well as to the development of systems for environmental monitoring, as reported in other sections of this volume. We would like to believe that common sense will prevail and geo-politicians will understand that the Earth is our home and we must take care of it together.

ILLEGAL TRAFFICKING OF WASTE IN THE LIGHT OF NATIONAL AND INTERNATIONAL LEGISLATION

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Abstract. The chapter illustrates an overview on International and European legislation concerning environmental protection, followed by a brief presentation of a special unit belonging to Italian Carabinieri, whose mission is to fight environmental crime. Through their experience it is possible to assess the future strategies of environmental protection under the point of view of a LEA and to depict the future, potential flows of illegal environmental crimes, with particular regard to the illegal trafficking of waste. The unit, founded in 1986 by decree of the Ministry of Environment, nowadays is a landmark in Italy and abroad for environmental issues and can take two strategic tools into account: the radioactivity section and S.I.T.A. (intelligence system for environmental protection and photo interpretation). Many officers and NCOs attend national and international meetings where the environmental issues are discussed; as expertise they give their contribution in University Environmental masters and in planned activities of "culture of environmental legality" in high schools.

Keywords: Illegal Trafficking of Waste, International Legislation.

1. Introduction

With the term "environment" it is highlighted a broad concept including water conditions, air, soil, flora and fauna and territory. Environmental protection policy developed since the "Sixties" because of an increase of attention showed by the public opinion and environmental NGOs (non governmental organisations). It is important to stress that an environmental

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policy must be necessary transnational. The consequences of a polluting accident, in fact, could involve the neighbouring States. This is a particularly relevant aspect involving, e.g., nuclear plants. One of the most important problems faced by technicians, planning such a kind of plant, is the winds direction which could imply severe consequences for border states and populations. But also a plant, whose production requires to be built close to a river, faces similar problems (*21/05/1997 New York ONU customary law on different use from shipping of international rivers*).

In the late 1970s, international environmental policy increased so that, since 1973 up to 1991, some important cornerstones have been fixed through the signature of important conventions:

- 1973 Washington convention on "international trade in endangered species" (CITES)
- 1987 Montreal protocol on "ozone depleting substances"
- 1989 Basel convention on "control of cross border shipment of hazardous waste and other waste and their disposal"
- 1991 the Bamako convention which bans the import of hazardous waste into African, Caribbean and Pacific countries

The illegal cross border shipment of waste in the late 1980s was systematically directed to Africa and some other emerging countries. More than 50 million tons of hazardous waste were shipped to that continent every year with devastating consequences for the environment and the surrounding populations. It was the time of strong unrest against the dismantling system of waste in western countries through the system of landfill; many of the biggest industries solved the problem dismantling their hazardous waste at a very low cost, moving it to the poorest countries all over the world.

In Western countries the cost of one ton of hazardous waste ranged from 100 US dollars up to 2,000 US dollars. The same material dismantled, e.g., in Africa instead, varied from a minimum price of 2.50 US dollars up to a maximum price of only 50 US dollars.

To face these problems the first environmental policy approach was that of "command and control policy": reduction of polluting substances is performed through an aimed regulation adopting common standards and oriented to the big industries considered as the major responsible of environmental pollution. So a reinforced system of more stringent rules, at international level, opened the possibility to intervene in a more efficient and effective manner in case of critical situations.

The early 90s defined the general system of environmental protection; the "Command and control policy" was followed by a second generation policy based on prevention of environmental damages which required the cooperation of major industries in terms of “eco efficiency”. This approach was proposed in the light of the market vision which is free to decide what kind of measures are to be taken considering the consumers choices. Western countries oriented their action to a prevention policy, encouraging industry to plan a more cautious withdrawal of resources. The consequence is a smaller production of polluting elements; this can be achieved through increase of best available technologies and a better planning of recycling and saving resources and energy (principle of prevention). The effort was balanced with a premium system also based on a marketing campaign: in other words a consumer is more attracted by a trustworthy eco product and, consequently, industry gets profits by its virtuous behaviour.

Without doubt, the current environmental policy has reached an adequate level of environmental protection, on the ground of regulation and preventive controls. But differences still exists among the different states. If western countries pay a significant attention to the respect of rules[1], the same can not be assessed for the emerging countries notwithstanding many of them signed the Basel Convention. The economic interests, connected with lower costs to dismantle hazardous waste, still continue to create difference in the practical activities of dismantling and land filling waste. The enormous request of energy by emerging countries like China or India, involved in a process of industrial growth with no restraints, has opened new routes for recycling waste, unfortunately not all legal. In this process unprejudiced organizations, corrupted public administrators and industries still continue to perform illegal traffics to save money in a total indifference for consequent potential damages to environment and populations.

So eco terrorism, often with no reason, increases in western countries as a form of protest against defined industrial or governmental policies (e.g., energy from waste) while, at the same time, illegal transhipment of waste becomes business of the third millennium. Under LEAs point of view, the cornerstone in prosecuting these crimes is a better coordination. Speaking at government level, a common, significant repressive approach can be difficult to apply due to different applications of rules. This happens either for national interests or a low perception of danger level.

Notwithstanding EU (European Union) environmental common policy can be considered as one of the best examples of “koinè dialectos”, a common language, spoken by all the member states, nevertheless problems arise when trans frontier criminal investigations, concerning illegal trafficking of waste, take place. The Italian Carabinieri experience could be

[1] Introduction of Eco-Label and Eco-audit system is on a voluntary basis. Eco-labeled European products guarantee consumers a high quality standard level of human health protection and a very low level of pollution.

an interesting case of study because, at European level, Italy has been the only member state of the Union to increase the required minimum standard of environmental protection in the spirit of art.130T (now 176 "the protecting measures […] do not prevent any Member State from […] introducing more stringent, protective measures"), stating as a penal crime "organized activities of illegal trafficking of waste "punished with arrest and imprisonment up to 8 years (art. 260 of the Italian environmental text). This could seem a paradox if compared with the inconceivable Naples waste emergency, whose images travelled all over the world through the main international media for several years. But, thanks to this important legislative tool, repressive action achieved excellent results. In other EU member states, punishments are less severe and therefore it is not possible to arrest and to definitively confiscate goods, terrains and plants exploited to illegally managed waste.

2. UE Environmental Policy

The official birth of UE environmental policy can be fixed in 1972. Chiefs of Member States, after Stockholm conference of United Nation, pointed out the need of a homogeneous environmental legislative system tasking communitarian institutions to draw up an action program, promulgated in 1973. The First Action program referred to Premise and art.2 of the original European Community Treaty (which established to improve life quality of communitarian population), it was not binding but only programmatic and connected with art.100 and 235 (now 94 and 308 of the Treaty). This officially acknowledged the communitarian institution with the generic power to harmonize existing different legislations and regulations, to adopt all the necessary measures to improve the market functioning. Apparently weak, the legal cornerstone produced, along years, excellent results.

In 1986 the Single Act dedicated a specific regulation to environment (art 130R, S and T now 174,175,176) further integrated by Maastricht treaty which established "the necessities, connected with environment, should have been integrated inside other communitarian policies definition and actuation".

Now art 174 establishes aims and four binding principles of environmental communitarian policy. The first is the precautionary principle which states: "with the aim to protect environment, are adopted preventive measures before a pollution process could take place"; the second is "preventive action should be taken"; the third is principle of correction "environmental damages should as a priority be rectified at source" and the last one is "the polluter should pay". Art. 175 refers to procedure to be followed to accomplish the mission in accordance with the above mentioned statements;

art.176 gives the member States the power to recognize a better environmental protection than that disposed by the Treaty.

The Action programs now operate in the respect of the above mentioned rules and delineate the communitarian strategies. The current program, which will be operating until 2012 foresees four priorities, among which, management of natural resources and waste, have a fundamental importance.

As mentioned above, EU promulgates environmental directives (which are not immediately binding for member states but require a transposition inside the national legislation) and regulations, immediately binding for member states. Through the application of environmental directives each member state has organized its own environmental "corpus iuris". In 1997, Italy defined the bulk of punishments for illegal actions against environment with fines, as the majority of member states. But in 2001, after long discussion, a new penal punishment was introduced to face organized crime activities against environment. At present, in Italy, "organized activities of illegal trafficking of waste" can be punished with the arrest and imprisonment up to 6 years, if traffic concerns hazardous waste, up to 8 years if traffic concerns radioactive material. With this brand new prevision, police forces supported by technical investigations (i.e., call phone interceptions, GPS tracking of waste movements and so on) can detect, with favourable outcome, criminal organizations.

3. Illegal Aspects of Waste Management

Environmental crime is a vast category of illegal actions: illegal logging and trade in timber, illegal fishing, illegal trafficking of endangered species, illegal trafficking of waste and radioactive material and so on. They cause environmental pollution, pauperization and negative consequences for community livelihood. Further, they are financial crimes because they avoid taxes, alter the regular market conditions and allow illegal profits originated by different costs afforded to dismantle hazardous waste as normal waste. Punishments are not adequate as they are largely fines, therefore criminals consider it at low risk. Illegal trafficking of waste appears as the worst of all these crimes; and this is the reason why many white collars and corrupted public administrators are involved in it. Usually, in Europe, a truck transporting waste is accompanied by a document declaring type, quantity and hazardousness of waste, highlighted by the European code[2]. If documents are false and state something different from the reality, a normal

[2] European Code. Dir. 75/442/ECC art.1 a and Dir. 91/689 EEC art.1 par.4 hazardous waste.

police control does not notices the difference. A deeper control requires a specialized analysis, qualified personnel and time.

This is not only convenient for waste producers, who save a lot of money avoiding taxes on urban waste dismantling it in a landfill, but also comfortable; it is easier to spread, e.g., liquid hazardous mud originating from industrial processes directly on fields available for the organization or along the streets than dismantling it inside water purification plants. Mud are mixed with Earth and easily hidden.

At last, supported by corrupted administrators, it is possible to dismantle hazardous waste in landfills not available for that kind of waste by just pay a certain sum of money. To spread hazardous waste on the fields implies a severe danger for human health because heavy metals are adsorbed by plants and animals.

The further problem is the transnational dimension assumed by illegal trafficking of waste.[3] This is a sensitive challenge for LEAs because, e.g., what is stated as a crime in Italy, can be considered in a different manner also inside the same EU. This is the reason for the new directive licensed by European Parliament and Council on the protection of the environment through criminal law": *"The Community and the Member States have adopted numerous acts of legislation aiming at protecting the environment. However, various studies show that the sanctions currently in place in the Member States are not always sufficient to effectively implement the Community's policy on environmental protection. Criminal sanctions are not in force in all Member States for all serious environmental offences, even though only criminal penalties will have a sufficiently dissuasive effect for several reasons"*. It is a further step on the way to a common perception of criminal behaviours against environment and, consequently, of a common punishment which could make more difficult for criminals to take advantage of illegal trafficking of waste.

4. Carabinieri Environmental Care Experience

In 1986 Italy was the first EU member state to organize a special unit whose mission was to prevent, to control and to repress environmental crimes. Carabinieri Environmental care Command is now a structured unit of specialized investigators very well trained in environmental legislation.

[3] Regulation 1013/2006 EC concerns transhipment of waste: differently from directives it is immediately binding for all member countries in the light of major concern of European community for transfrontier movements of waste.

Italy was followed by Spain service (SE.PRO.NA)[4] and French service (OCLAESP).[5] In Europe now, many LEAs have designated some investigative units to detect environmental crimes. International police forces maintain strong liaisons through Interpol and Europol and a necessary data base on environmental crimes is operative in Lion (FR).

In the field of illegal trafficking of waste investigations, Italian Carabinieri obtained, in the last 5 years, remarkable outcomes with a continuously positive trend. Only in 2007 more than 170 persons were arrested. Some of them were criminals, also belonging to dangerous organizations like camorra, some were white collars like chemists, necessary to falsify waste analysis, but some of them were also corrupted public administrators. Among the arrested some were Chinese and from other countries like Iran and Syria. This highlighted the international involvement in waste trafficking.

The "modus operandi" is always the same: it is necessary a stable organization where chemists and analysis laboratories have a fundamental role. Then it is necessary to locate a plant for dismantling or transforming waste and eventually find a number of trucks. In several cases support by corrupted administrators is basic to obtain authorizations to regularly manage waste. A criminal organization dismantled by Carabinieri in Campania Region was a typical practical example, perfectly faithful to the above mentioned model. Criminals acquired the right of spreading mud on agricultural land by paying modest sums of money to several farmers. Mud originated by industrial processes passed through two big plants, whose owners were persons close to the clan (but with no criminal prejudices). Inside the plants, whose regular and authorized mission should have been that of producing "compost" from humid waste, no modification of waste took place but only a fictitious passage on false documents. The third step was to exploit two limited companies (belonging to the criminal group) whose trucks "close the circle" with spreading hazardous waste on the fields and in the rivers. In accordance with Carabinieri investigation, Public prosecutor arranged warrants of arrest for "clan members" and confiscation of plants and trucks. Further, Public Prosecutor stated "environmental disaster" as additional penal crime whose expected punishment is up to 12 years of imprisonment.

At international level there are also intermediates who connect demand and offer; this is, in particular, the case of transnational shipment of waste. Investigations highlighted the importance of plastic waste, necessary for

[4] SE.PRO.NA (Servicio de protecion de la naturaleza).
[5] OCLAESP (Office central environnement santè publique).

several products but also for burning in energy from waste plants. Last year, in many Italian ports, Environmental Care Carabinieri, in cooperation with local customs, confiscated hundreds of containers, whose point of arrival were several ports in emerging countries. The investigation was concluded with the arrest of the persons responsible and confiscation of plants. Plastic waste was sent abroad with no treatment but covered by false documents which stated there was not plastic waste but reconditioned plastic.

In the field of transnational movement it is also necessary to have special sections of very high level experts in the environmental field. Carabinieri Environmental Care Command supports its "investigative detachments" with two strategic tools: Radioactive special section and Information system for environmental protection (S.I.T.A.). The first one is a section specialized in investigation on "orphan sources of radioactivity" and its characteristic is the "double hat" of experts in the field and policemen. In other worlds, they provide through mobile laboratories to monitor "warm areas". If some suspected persons are to be detected in the area, they intervene directly. In other countries there are specialists on radioactivity but they are not policemen and, to operate, they need to be supported by police forces.

They are responsible for monitoring all the lost and abandoned sources of radioactivity and are linked with the Prefects of Provinces in the entire Country for calls on the spot. Their first massif employment was during the Torino winter Olympic games where they aroused the interest of several foreign LEAs teams. In 2004, tasked by the Ministry of Environment, they conducted a national investigation with the aim of assessing the exact quantity of radioactive material and waste (uranium, thorium and plutonium) spread on nuclear sites, nuclear depots, researches centers, hospitals and industrial sites. They have recently investigated on several illegal trafficking of contaminated steel coming from abroad and have produced a study urging the higher authorities, to facilitate administrative and preventive controls with more stringent rules.

The second outcome is an information system which can help the operational units with risk analysis, intelligence and sites interpretation so that a crisis can be prevented or a hidden landfill of hazardous waste can be discovered.

S.I.T.A. system was built with the European funds and will be extended to the entire peninsula. The aims of S.I.T.A. are various: to control environmental conditions and the evolution of potential environmental changes; to detect dangerous phenomenon of environmental degradation through physical and chemical ground analysis and to optimize prevention capability and opposition to organized crime. It is an innovative tool supplied by information of tactical units, Ministry of Environment and several environmental agencies and Administrative Regions. A 3D GIS component extends system capability to create, to visualize and to model data. Site involved in environmental occurrence are highlighted both with GPS coordinates and localized on the map with associated photos collected by a fling unit equipped with multispectral infrared and visible imaging spectrometer (MIVIS) and by satellite. These information with all the further relevant documents, are directly transmitted to the operational centre, supported by a photo interpretation centre, located in Naples. Here, Carabinieri and technicians belonging to Italian National Centre of Researches, compare aircraft and satellite imaging to detect critical changes of the investigated sites, simulate possible environmental accidents and plan interventions. It is also possible to compare thematic maps with aircraft and satellite imaging/ map-making to detect illegal activities, hazardous areas and to foresee environmental impacts on specific areas.

In short, the above mentioned capabilities and tools are the answer to the future challenges in the environmental protection, where prevention and repression are two sides of the same medal.

5. Constraints and Future Scenario

The analysis of illegal trafficking of waste, in the last 5 years, showed an increasing of the transnational phenomenon which requires a better coordination among the LEAs. Links with European police forces, working in the same field, confirmed a general increase of movements with a complete disregard of the principle of proximity, stated by UE directives. Low penalty risk and connected relevant profits will facilitate a considerable increase in environmental crimes, as stated in several meetings. For many member states, the brand novelty of the phenomenon and its cross border dimension, have pointed out the lack of adequate tools of repression and punishment. The Carabinieri Environmental care Command experience has been considered of high interest and this is the reason why, in Europe, many different environmental police forces wish more tailored and dissuasive punishments like we have in Italy, to better control the illegal aspects connected with waste trafficking. Right now, lack of coordination, sharing of intelligence and differences in EU legislation, do not support the police forces efforts in this sensitive field. Borders are not a problem for criminal organizations involved as a “multi national industry” in illegal transhipment of waste.

Rules harmonization, development of renewable energies, waste recycling and energy from waste are the preventive actions to reduce the illegal trafficking of waste at a physiologic level. Quick sharing of intelligence and common investigative practices, based on the same perception of this crime all over Europe, can increase the repressive action of environmental police forces, in accordance with art.174 of the Treaty, where the aims of European Community are clearly described: environmental protection, increase of environmental quality but, above all, protection of the human health.