Computer system modeling and simulation

1- Introduction

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2012 E.C.

Introduction

- What is simulation ?
- Application areas
- System modeling
- Steps in simulation study

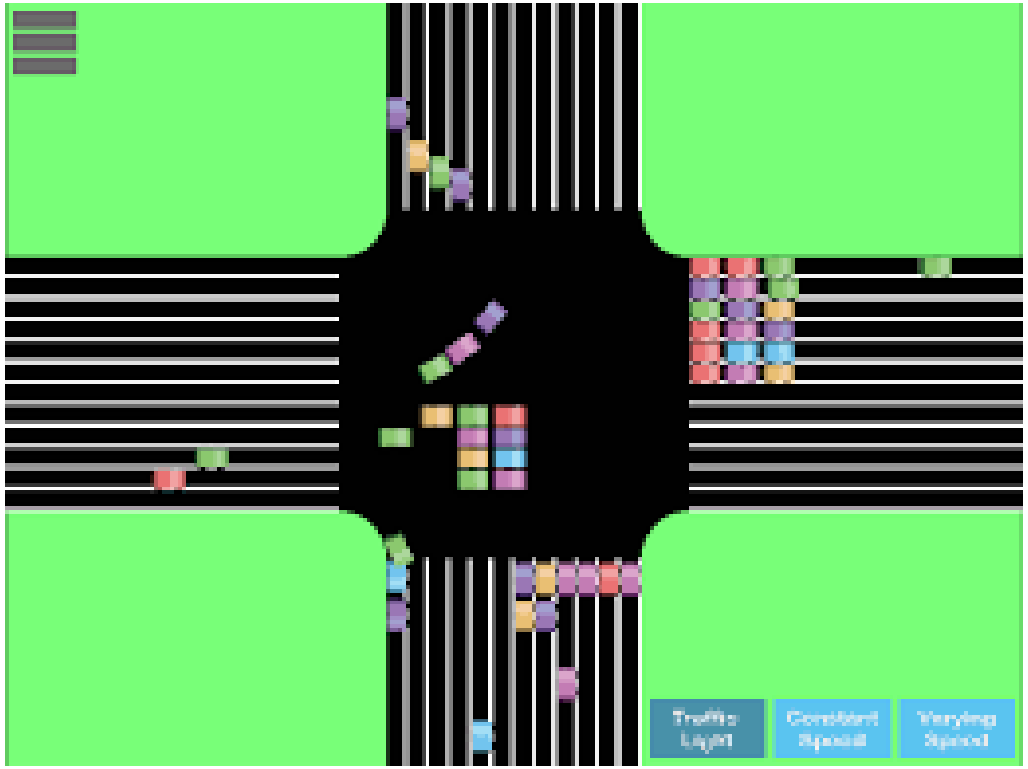
What is simulation ?

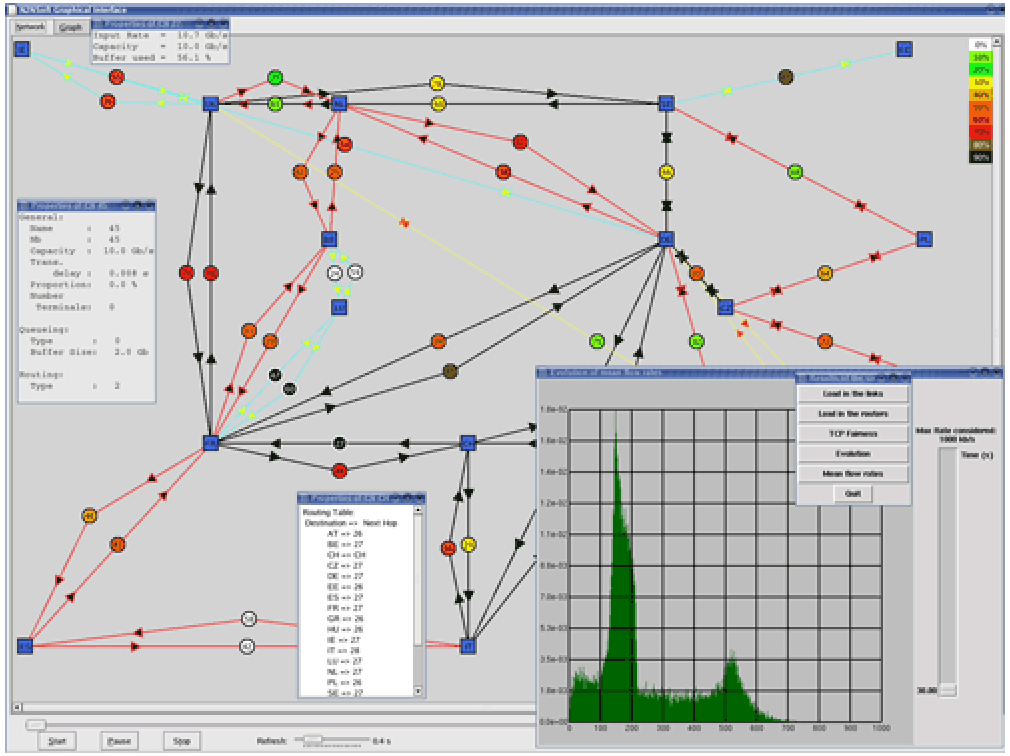
- **Simulation** is the process of imitating the operation of a system over a time using a mathematical model of the system implemented on a digital computer
  - The dynamic characteristics of a real world system is represented in a computer model

- By imitating the system behavior, we artificially recreate its evolution

- From the system evolution we can deduce a lot of information on the system itself

What is simulation ?





Simulation objective

- **System design**: testing a new concepts and systems before implementation
- **Evaluation**: dimensioning of the system components to satisfy requirements
- **Prediction**: forecasting the effects of the improvements or changes of system components on the overall system performance
- **Comparison**: comparing different system designs
- **Optimization:** Determining exactly which combination of factor levels will produce the optimal overall behavior of the system

System simulation

- When do we need to simulate?

- During the design phase
  - no existing implementation or prototype of the actual system
  - E.g. What is the best design for a new telecommunications network?

- On systems already existing
  - To study the system in special conditions, like critical or future scenarios
  - To design improvements for the system components
  - E.g., How will a telecommunication network perform when the traffic load increases by 50%?

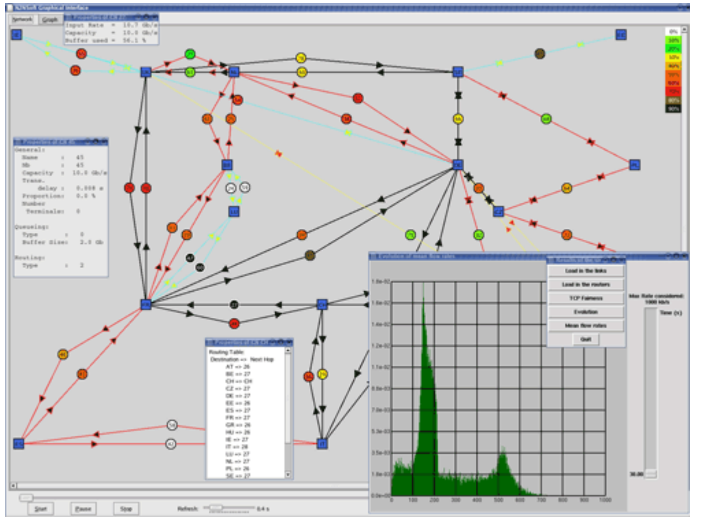
Why simulation?

- Inexpensive way to learn how a system’s operation and performance responds to changes
- System changes may be impossible or expensive to observe in practice
- Allows what-if analysis
- Can be used for off-line training
- Suitable for problems in which there are no closed-form analytical solutions

Application areas

- Transportation modes and traffic
- Telecommunication
- Computer system
- Manufacturing
- Construction engineering and project management
- Business process simulation
- …..and many others

Example: application to networking



System dimensioning

- Effects due to the increase of the link capacities in the network
- Effects on the network due to the introduction of new nodes/routers

Protocol design

- Performance comparison between different protocols
- Selection of protocol parameters as a function of the network conditions and the traffic load

Network design

- Verification of network reliability and resilience
- Performance analysis of networks with different topologies

When to avoid simulation

- when a problem can be solved analytically or by using common sense
- when a problem can be solved more cheaply using direct experimentation
- lack of ability to verify or validate the model
- system behavior is too complex or hard to define

Simulation models

- A simulation model is a formal representation of a system
  - derived from the theoretical knowledge of the system or from empirical observations
  - A model should be a close approximation to the real system and incorporate most of its prominent features
  - A model is similar, to but simpler than the system it represents
- We need to identify the boundary between the system and its environment
  - The system environment, even if it not the object of our model, will have effects on the model and on the system behavior

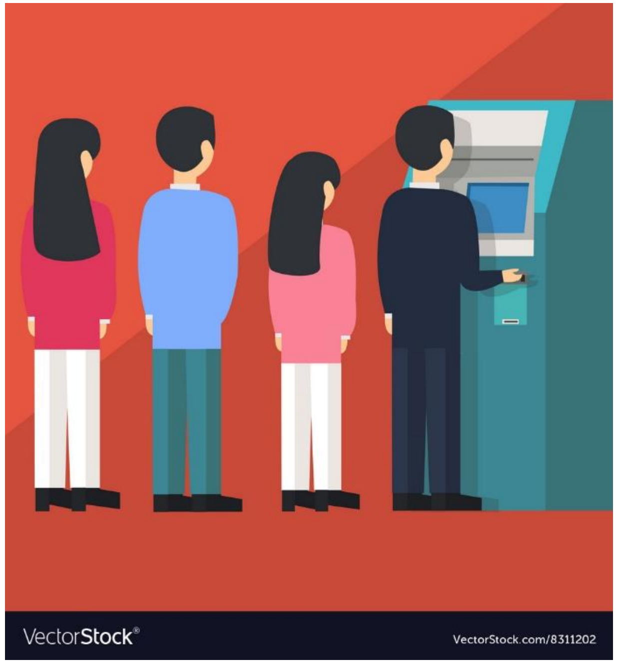
Elements of simulation model

- *State*: describes the system behavior in any time instant
- *Entities*: objects of interest in the system
- *Attributes*: properties of an entity
- *Activity*: a time period dedicated to a specific operation
- *Event*: an instantaneous occurrence that changes the system state
  - *Internal:* events occurring within the system
  - *External:* events and activities in the environment that affect the system

System model example

- **A queueing system**

- *Entities:* server, waiting line (queue), customers
- *State*: number of costumers in the system,
  status of the server (idle or busy)
- *Events*: arrival or departure of customer



Type of models

- Models can be classified as being mathematical or physical

- **Mathematical models** uses symbolic notation and mathematical equations to represent a system (simulation models are special mathematical models)
- **Physical models** are simplified physical systems that try to reproduce some of the characteristics of the original system

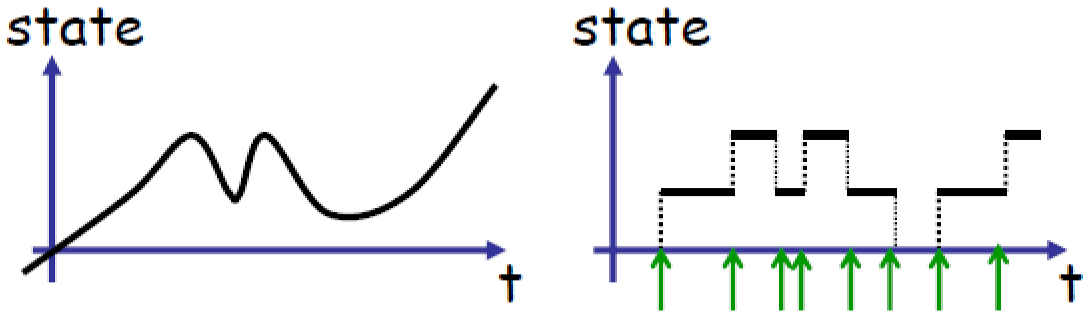
Static vs. Dynamic model

- **Static**: the system behavior does not change in time or it is a representation of a system at a particular point in time
  - This kind of simulation is usually referred as a monte Carlo simulation

- **Dynamic**: the system behavior changes in time

Discrete vs. continuous

- **Continuous model**: the system state changes continuously in time (fluid models)
- **Discrete**: the system state changes only in a discrete set of points in time
  - E.g, a queuing system- a state changes on the arrival or departure of a customer



Deterministic vs stochastic

- **Stochastic**: exhibits random effects
  - inputs are represented by random variables, so the outputs are random processes

- **Deterministic**: the model does not contain random variables, therefore a set of input values will produce a unique set of outputs

Simulation process and steps

- *Problem formulation*
  - *Identify and understand the problem precisely*
- *Setting of objectives*
  - *The* problem to be addressed
  - What to investigate? which Scenarios?
- *Model conceptualization*
  - Ability of abstracting the essential features of the system
    - ✓ Mathematical and logical relation ships
  - Selection of simplifying hypothesis at a suitable **level of details**

Simulation process and steps

- Level of detail
  - A simulation model with too many details
    - ✓ Requires longer development time
    - ✓ Requires a higher running time
    - ✓ Produces complex results difficult to be interpreted
  - A simulation model with too little details
    - ✓ Be unsuitable to observe some interesting and particular behavior of the system
    - ✓ Be unrealistic and produce wrong conclusions on the system behavior

Simulation process and steps

- *Data collection*
  - To learn about the system behavior
  - Selection of the input parameters considered to be important for the model
  - Study and characterization of the parameters
- *Model translation*
  - developing a computer program
- *Model verification*
  - Is the program is doing what it is supposed to do?
  - Consistency with specification model

Simulation process and steps

- *Model validation*
  - Determine whether the model realistically represents the system or not
  - Consistency with the system being modeled
- *Experimental design*
  - Conduct experiments using the model
  - Length of simulation runs, number of simulation runs
- *Analysis*

Common issues

- Wrong level of detail
- Unsuitable programing language or level of detail
- Short simulation run
- Few simulation runs
- Wrong parameter choice – random number generator