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Course Title : **GEOSPATIAL DATA MODELLING AND INFORMATICS**
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Module-IV
Modelling and Simulation

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What is a SYSTEM?

The term system is derive from the Greek word systema, which means an organized relationship among functioning units or components.

System exists because it is designed to achieve one or more objectives.

We come into daily contact with the transportation system, the telephone system, the accounting system, the production system, and for two decades the computer system.

There are more than a hundred definitions of the word system, but most seem to have a common thread that suggests that a system is an orderly grouping of interdependent components linked together according to a plan to achieve a specific objective.

What is a Model ?

Simplified Representation of a Real or Theoretical System at some particular point of time and space intended to provide the understanding of the system.

Whether a model is good or not depends on the extent to which it provides understanding.

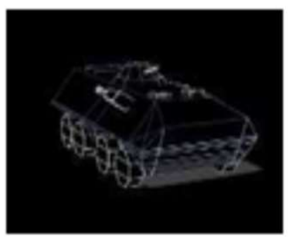
What Level of Model Detail ?

All the models are simplification of reality.
Exact copy of a reality can only be the reality itself.

There is always a trade off as to what level of detail is included in the model:

–Too little detail: risk of missing relevant interactions.

– Too much detail: Overly complicated to understand




What is a Simulation ?

- **It is an experiment in a computer where the real system is replaced by the execution of the program.**

- **It is a program that mimics (imitate) the behaviour of the real system**

- **A Simulation is the imitation of the operation of a real-world process or system over time. It can**

be done by hand or on a computer.

- **The behaviour of a system as it evolves over time is studied by developing a simulation model.**

- **This model takes the form of a set of assumptions concerning the operation of the system.**

- **The assumptions are expressed in**
  - Mathematical relationships
  - Logical relationships
  - Symbolic relationships between the entities of the system.

Modelling and Simulation

Discipline of understanding and evaluating the interaction of parts of a real or theoretical system by;

Designing its representation (model)

Executing (running) the model including the time and space dimension (simulation).

Why Simulation?

Accurate Depiction of Reality

Parts of the system may not be observable (e.g., internals of a silicon chip or biological system)

Insightful System Evaluations

It may be too difficult, hazardous, or expensive to observe a real, operational system

Uses of Simulations

1. Analyse systems before they are built

2. Reduce number of design mistakes

3.Optimize design

4. Analyse operational systems

5. Create virtual environments for training, entertainment

When to use Simulation

Over the years tremendous developments have taken place in computing capabilities and in special purpose simulation languages, and in simulation methodologies.

The use of simulation techniques has also become widespread.

Following are some of the purposes for which simulation may be used.

Simulation can be employed to experiment with new designs and policies, before implementing

Simulation is very useful for experiments with the internal interactions of a complex system, or of a subsystem within a complex system.

Simulation is very useful in determining the influence of changes in input variables on the output of the system.

Simulation helps in suggesting modifications in the system under investigation for its optimal performance.

Simulation can be used to verify the results obtained by analytical methods and reinforce the analytical techniques.

When Simulation is Not Appropriate

Simulation should **not be used when the problem can be solved using common sense.**

Not, if the problem can be **solved analytically.**

Not, if it is easier to perform **direct experiments.**

Not, if the **costs exceeds** savings.

Not, if the **resources or time are not available.**

No data is available, not even estimate simulation is not advised.

If there is no **enough time or the people are not available**, simulation is not appropriate.

If managers have **unreasonable expectation say, too much soon** – or the power of simulation is over estimated, simulation may not be appropriate.

If system behaviour is too complex or cannot be defined, simulation is not appropriate.

Goal of modeling and simulation

- A model can be used to investigate a wide verity of “what if” questions about real-world system.
  - Potential changes to the system can be simulated and predicate their impact on the system.
  - Find adequate parameters before implementation
- So simulation can be used as
  - Analysis tool for predicating the effect of changes
  - Design tool to predicate the performance of new system
- It is better to do simulation before Implementation.

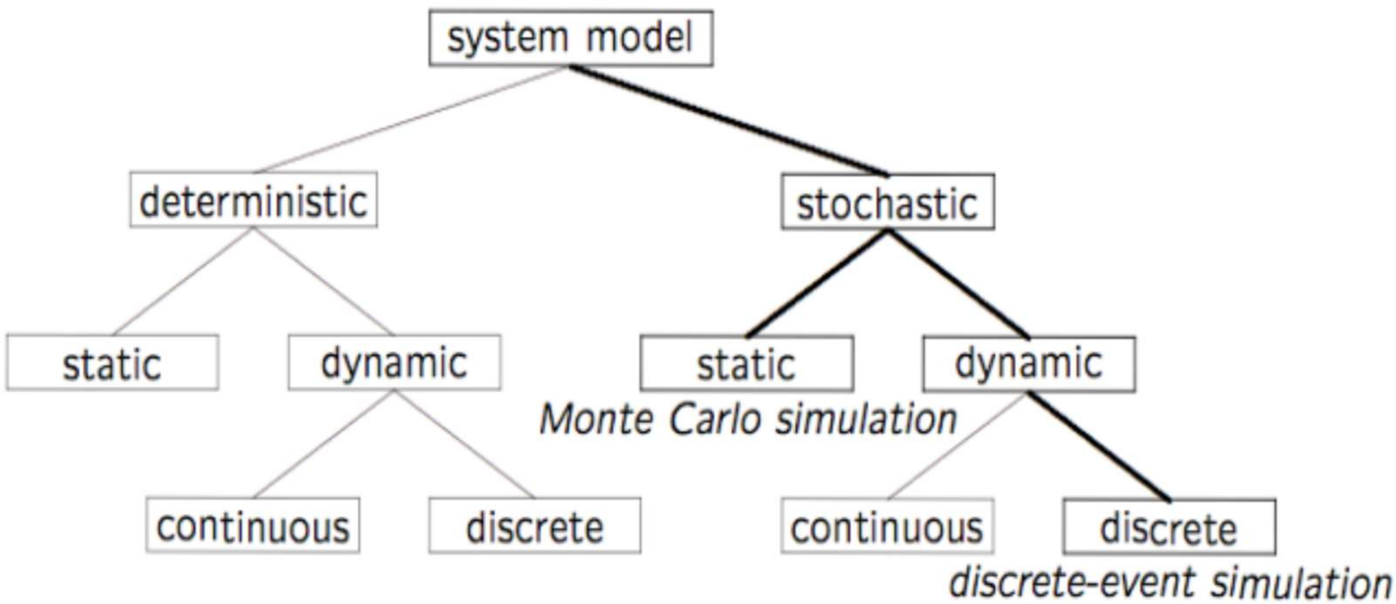
When Simulation Is the Appropriate Tool

- Simulation enable the study of internal interaction of a subsystem with complex system
- Informational, organizational and environmental changes can be simulated and find their effects
- A simulation model help us to gain knowledge about improvement of system
- Finding important input parameters with changing simulation inputs
- Simulation can be used with new design and policies before implementation
- Simulating different capabilities for a machine can help determine the requirement
- Simulation models designed for training make learning possible without the cost disruption
- A plan can be visualized with animated simulation
- The modern system (factory, wafer fabrication plant, service organization) is too complex that its internal interaction can be treated only by simulation

Characterizing a Simulation Model

- Deterministic or Stochastic
  - Does the model contain stochastic components?
  - Randomness is easy to add to a DES
- Static or Dynamic
  - Is time a significant variable?
- Continuous or Discrete
  - Does the system state evolve continuously or only at discrete points in time?
  - Continuous: classical mechanics
  - Discrete: queuing, inventory, machine shop models

Model Taxonomy



DES Model Development

How to develop a model:

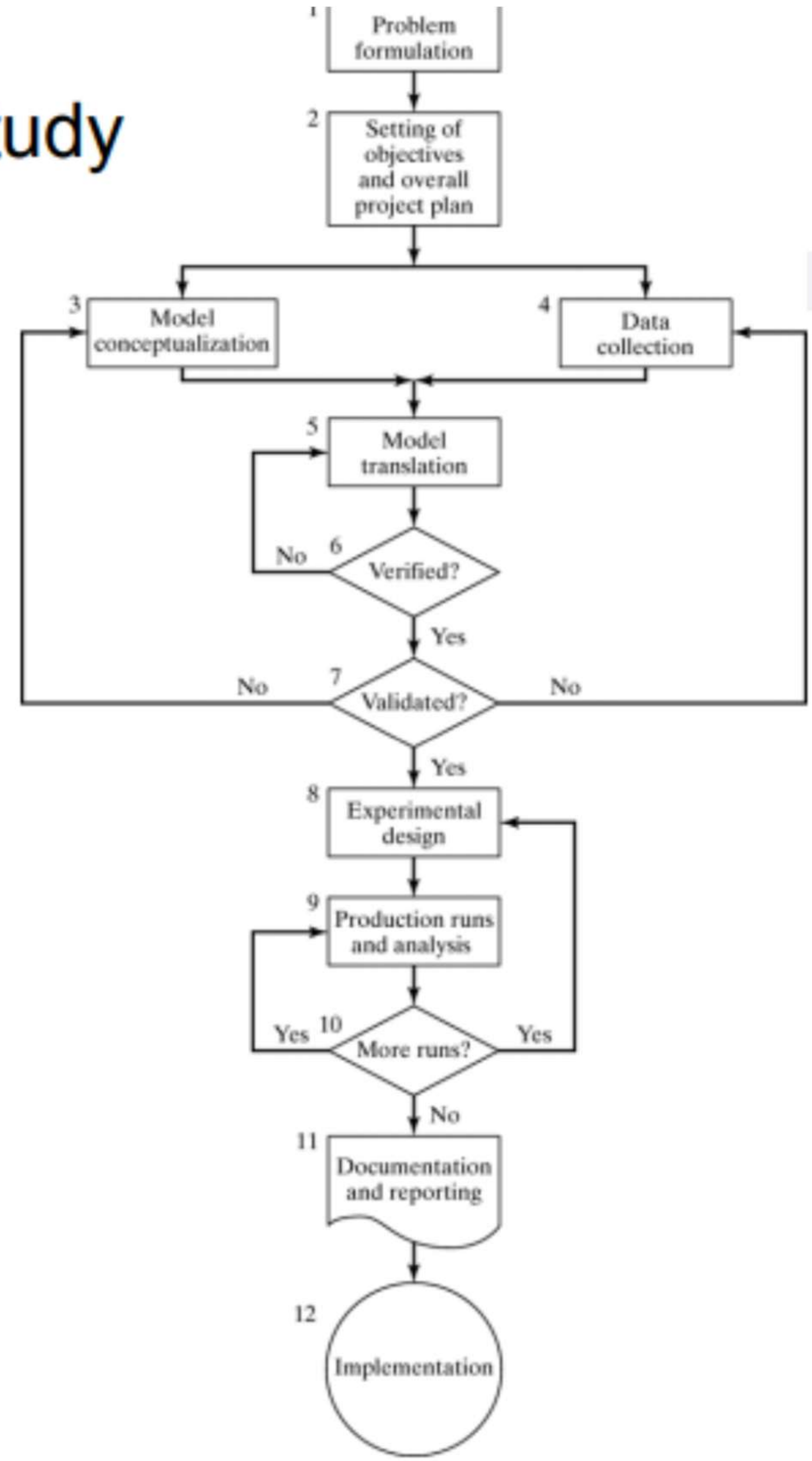
1) Determine the goals and objectives
2) Build a ***conceptual*** model
3) Convert into a ***specification*** model
4) Convert into a ***computational*** model
5) Verify
6) Validate

Typically an iterative process

Verification vs. Validation

- *Verification*
  - Computational model should be consistent with specification model
  - Did we build the model right?
- *Validation*
  - Computational model should be consistent with the system being analyzed
  - Did we build the right model?
  - Can an expert distinguish simulation output from system output?
- Interactive graphics can prove valuable

Steps in Simulation Study



Modeling and Simulation

- Modeling and simulation techniques have been employed in the environment sector for more than three decades.

- Modeling and simulation in the environmental domain today is used to determine the dynamic behaviour of systems in order to make decisions or to test the impact of human actitivities

(e.g. the use of solar energy for heating, construction, production processes, traffic and logistic planning and decisions) on the environment.

Further questions will be added in the near future because of the increasing complexity of the systems:

- the assessment of alternative decisions and activities,
- the examination of sceneries, the analysis of eco-economical and of socio-economical systems.
- Additional future assignments would be the evaluation and optimization of the whole life-time cycle of products related to their impacts on the environment.
- The life-time cycle of a product consists of its production, use, and finally, the recycling process.
- To solve these assignments, new experimentation approaches, simulation methods, computation methods, and software tools are needed

The first application was from water resources management. Today the following types of simulation models are used for advanced data analysis task, for decision support planning or for process control.

- Dispersion and quality models for air, water, or soil
- Ecosystem models and models in ecological economics
- Process models as a part of process control systems.
- Models for the prediction of traffic emissions.

Problems of Modeling Environmental Systems

- The modeling and simulation of environmental systems requires the consideration of a lot of special system properties which complicate the analysis considerably.
- complexity of the environmental systems (e.g. the biological, ecological, economical properties) and the other group results from the degree of the user's qualification in managing these problems (using the models, storing and preparation of data, interpretation of results and, the making correct decisions).

1. lack of theoretical knowledge
2. causal relations between system components are frequently unknown .
3. most of the real systems can be observed by experiments, but frequently there isn't any possibility for controlled experiments
4. ecological systems very often possess long reaction times (up to years or centuries) and in contrast, other components possess very short reaction times
5. system complexity is high because of the strong relations between the system components
6. nature is an open self-organizing system with adaptable components
7. inaccurate data and ill-defined system components exist
8. there is an increasing set of data: spatial data and spatial data with time dependence.
9. often it isn't possible to define exact and unique optimization aims for ecological and environmental systems
10. the model description must be realized by analytical and non analytical (rule based) methods.

Fields of Application

In the environmental domain, simulation models are especially used in four fields:

- emission computation (air, water, ground pollution)
- process control
- groundwater - economical and flow investigations
- ecosystem research.

- But further applications become more and more important:
- e.g., models on the use and balance of resources (e.g. water, ground, materials, energy, food); models of the carrying capacitiy and of loading limits of ecological systems with an input, which has been caused by human activities; quality models; product-life-time-cycle models and ecobalances;
- socio-economic models; combined tasks: the use of simulation and optimization methods or experiments consisting of coupled economical and ecological models.

Models of pollution extension

- computation of pollution values at geometrical points where we don't have any measurement results
- detection of pollution sources by simulation experiments
- supporting position planning and permission processes for objects with emissions (e.g. of factories, production processes, traffic projects, buildings)
- determination of reactions to accidents (e.g. of chemical processes, of oil transports).

Water models

- investigations of the influence of structures, buildings and other human activities on the amount and flow of groundwater
- investigations of the levels of groundwater depending on irrigation, draining, and soil erosion.
- waste water models and water cleaning processes.

Models for process control simulation

- Models are used to evaluate the consumption of recources of technical processes and the emission of these processes. The primary target is the minimizing of the environmental influence. Models are used during the planning phase and the model supported process control to get an optimal process behaviour.

Modeling of ecosystems

- The two fields of environmental protection and ecosystems are strongly connected. But today a broad use of simulation is still difficult. Simulation is used only in selected parts, e.g. community ecology in water, ground, forest; nitrogen balance; steadiness and elasticity of ecosystems - that means the capability of taking up harmful substances without any effects on the ecological balance; effects of chemical substances in ecological systems.

MODERN STRUCTURES OF SIMULATION SYSTEMS

- The following considerations are restricted to the modeling and simulation of ecological problems, that means the consideration of combined systems which are described by systems of ordinary differential equations of first order (system state equations). Computer science can support the modeling and simulation in three important tasks:
- building and managment of models and experiments
- supervision of simulation experiments by adequate simulation system architectures
- simulation result analysis and visualization.

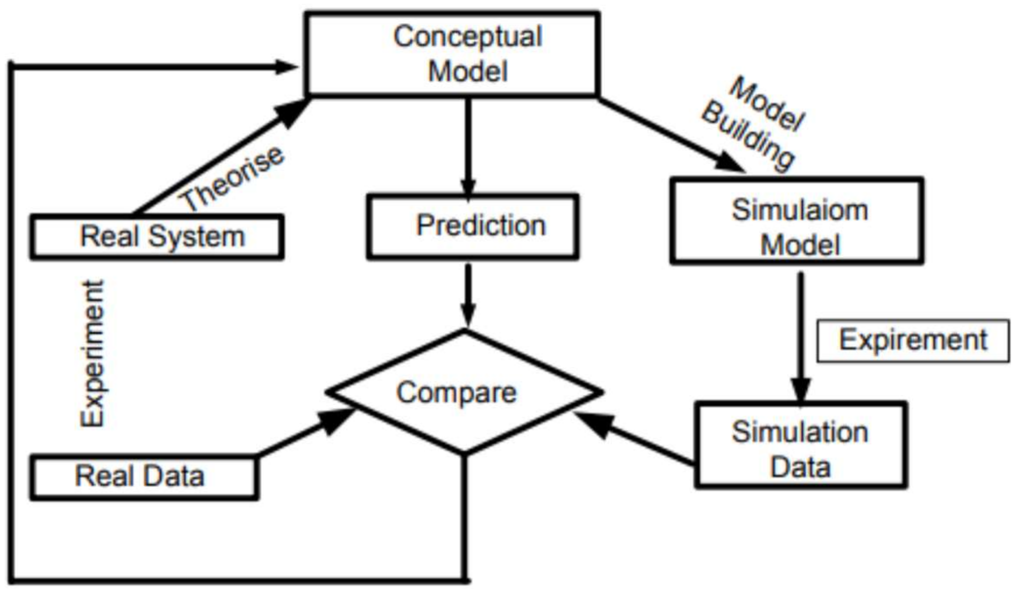
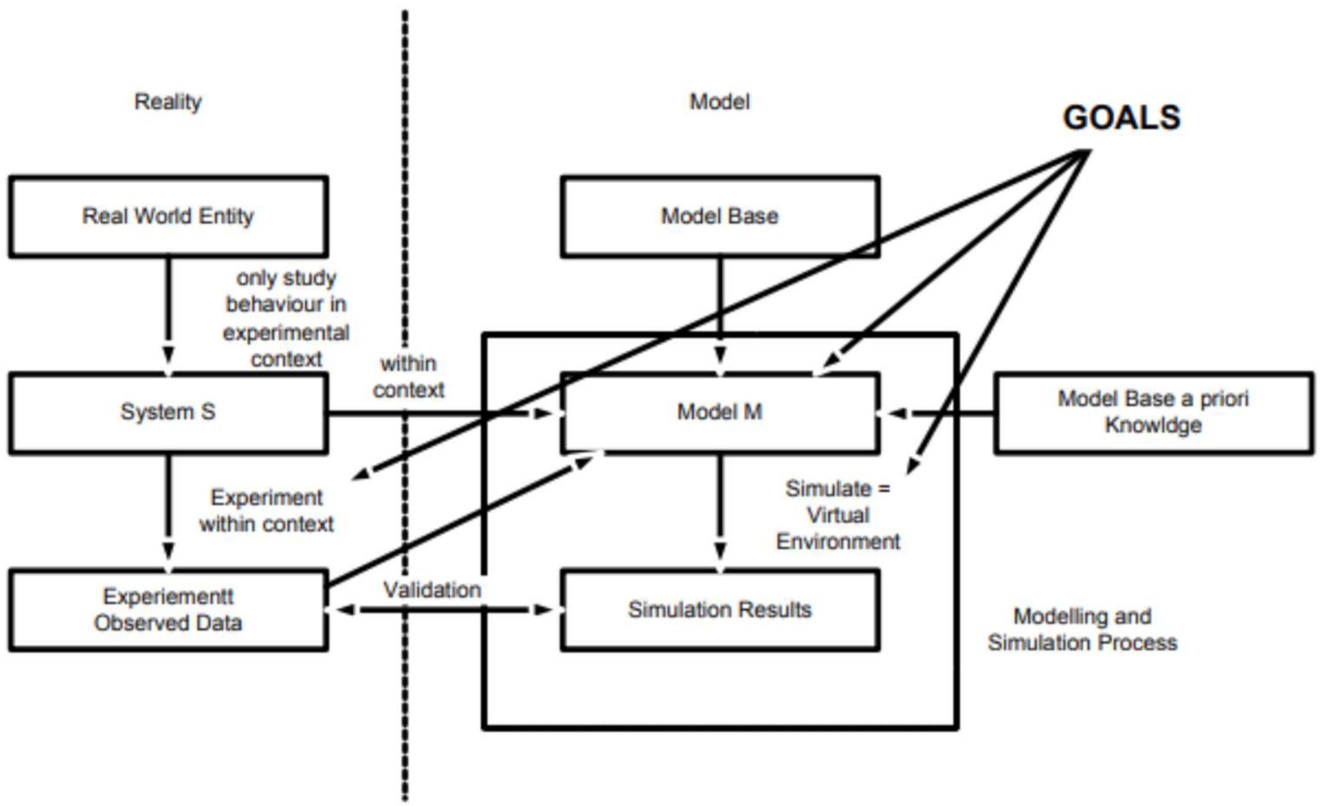


Figure 1 : Three Methods of Science

Concepts of modeling and simulation

- system and model, events, system state variables, entities and attributes, list processing, activities and delays, and finally the definition of discrete-event simulation.
- The process of making and testing hypotheses about models and then revising designs or theories has its foundation in the experimental sciences. Similarly, computational scientists use modeling to analyze complex, real-world problems in order to predict what might happen with some course of action.


Reality
Model
GOALS
Real World Entity
Model Base
only study behaviour in experimental context
within context
System S
Model M
Model Base a priori Knowldge
Experiment within context
Simulate = Virtual Environment
Experiementt Observed Data
Validation
Simulation Results
Modelling and Simulation Process

- Step 1. Identify the problem. Step 2. Formulate the problem. Step 3. Collect and process real system data. Step 4. Formulate and develop a model. Step 5. Validate the model. Step 6. Document model for future use. Step 7. Select appropriate experimental design. Step 8. Establish experimental conditions for runs. Step 9. Perform simulation runs. Step 10. Interpret and present results. Step 11. Recommend further course of action

Requirements Analysis

- Overall Objectives and Philosophy
- Analysis Rules of Thumb
- Requirements Modeling Approaches

Scenario-Based Modeling

- Creating a Preliminary Use Case
- Refining a Preliminary Use Case
- Writing a Formal Use Case

UML Models That Supplement the Use Case

- Developing an Activity Diagram

Data Modeling Concepts

- Data Objects
- Data Attributes
- Relationships

Class-Based Modeling

- Identifying Analysis Classes
- Specifying Attributes
- Defining Operations
- Class-Responsibility-Collaborator (CRC) Modeling
- Associations and Dependencies
- Analysis Packages

Types of models

- **Time scale**
  - Probability
  - Steady state
  - Event
  - Continuous
- **Spatial representation**
  - Lumped
  - Semi-lumped
  - Distributed
- **Determinism**
  - Deterministic
  - Stochastic
- **Mathematical solution**
  - Conceptual
  - Empirical
  - Mechanistic

Modelling Terminology

- **System**
  - a limited part of reality containing interrelated components
- **Model**
  - simplified representation of a system
- **Boundary**
  - edges of the system
- **Simulation**
  - mathematical representation of a system
- **Environment**
  - set of conditions outside the system being modelled
- **State and rate variables**
  - State of components
  - Rate of change
- **Parameters**
  - Constant values for a system
- **Driving variables**
  - External variables driving change
- **Feedback**
  - negative, positive