Modeling and simulation

First Chapter

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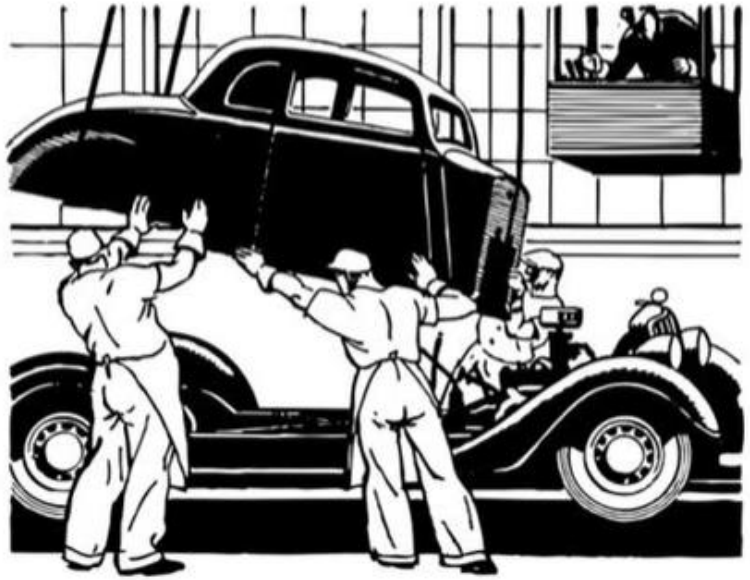
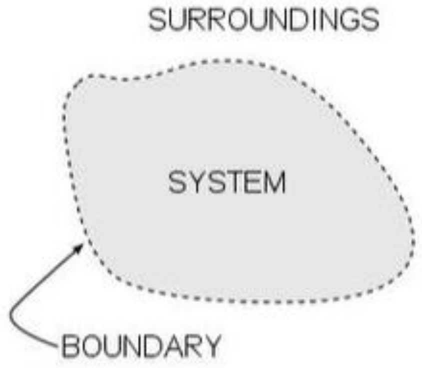
Systems

- Systems: a group of objects joined together in some regular interaction or interdependence towards the accomplishment of some purpose
- Example: A production system manufacturing automobiles. Machines, components and workers operate jointly to produce vehicles



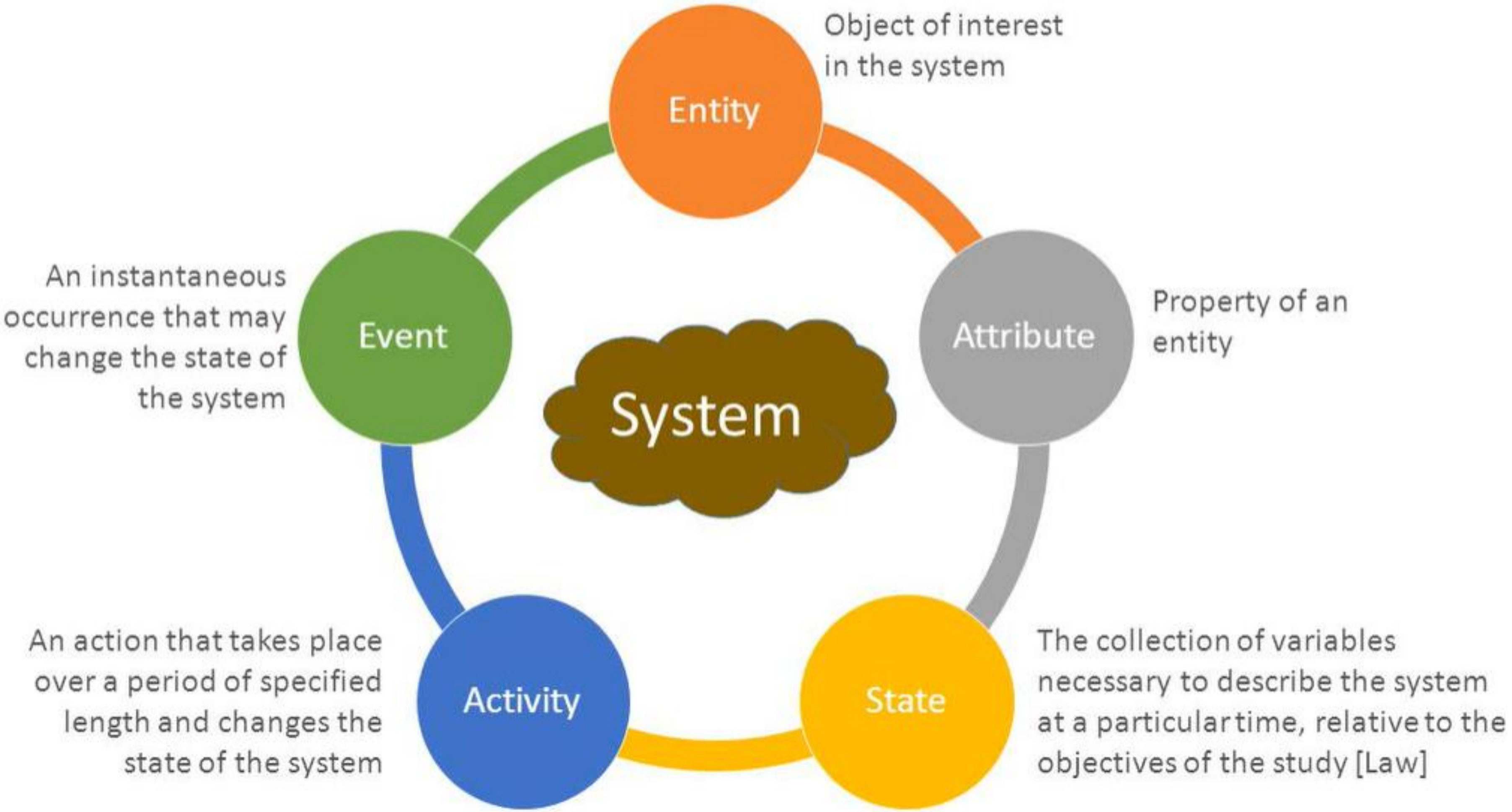
System Environment

- A system is affected by changes that occur outside its boundaries. Such changes are said to occur in the *system environment*
- The *boundary* between the system and its environment depend on the purpose of the study
- <u>Example:</u> *Bank System*



- There is a limit on the maximum interest rate that can be paid
- For a study of a single bank, this would be an example of a constraint imposed by the environment
- For a study of the effect of monetary laws on the banking industry, the setting of the limit would be an activity of the system

System Components



System Components

Exogenous:

Activities and events occurring outside the system

Endogenous:

Activities and events occurring within a system

Example

- Activity: making deposits, withdrawal of cash
- State variables: # busy tellers, #customers waiting in line or being served, the arrival time of next customer.
- Attribute: balance in the customers accounts.
- Entity: Customers.
- Events: Arrival, departure.

Examples

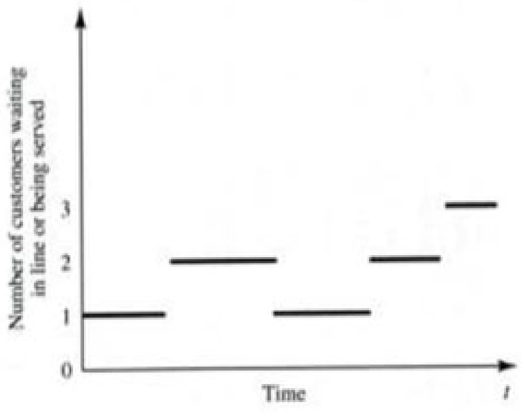
System	Entities	Attributes	Activities	Events	State Variables
Railway	Passengers	Origin, destination	Traveling	Arrival at station, arrival at destination	Number of passengers waiting at each station
Production	Machines	Speed, capacity, breakdown rate	Welding, stamping	Breakdown	Status of machines (busy, idle, shutdown)
Communications	Messages	Length, destination	Transmitting	Arrival at destination	Number of packets waiting to be transmitted
Inventory	Warehouse	Capacity	Withdrawal	Demand	Level of inventory

Types of Systems

Discrete

State variables change instantaneously at separated points in time

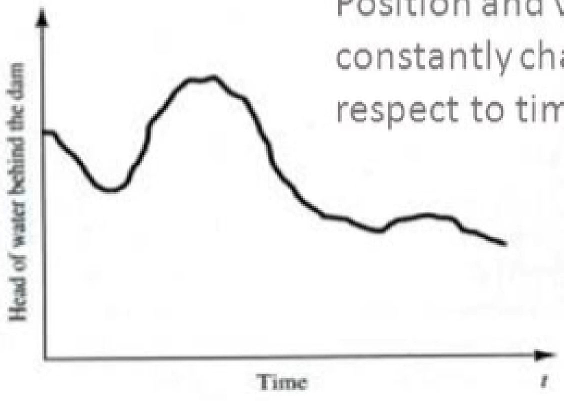
Example: Bank
Number of customers changes only when customer arrives or departs



Continuous

State variables change constantly with respect to time

Example: Airplane flight
Position and velocity are constantly changing with respect to time

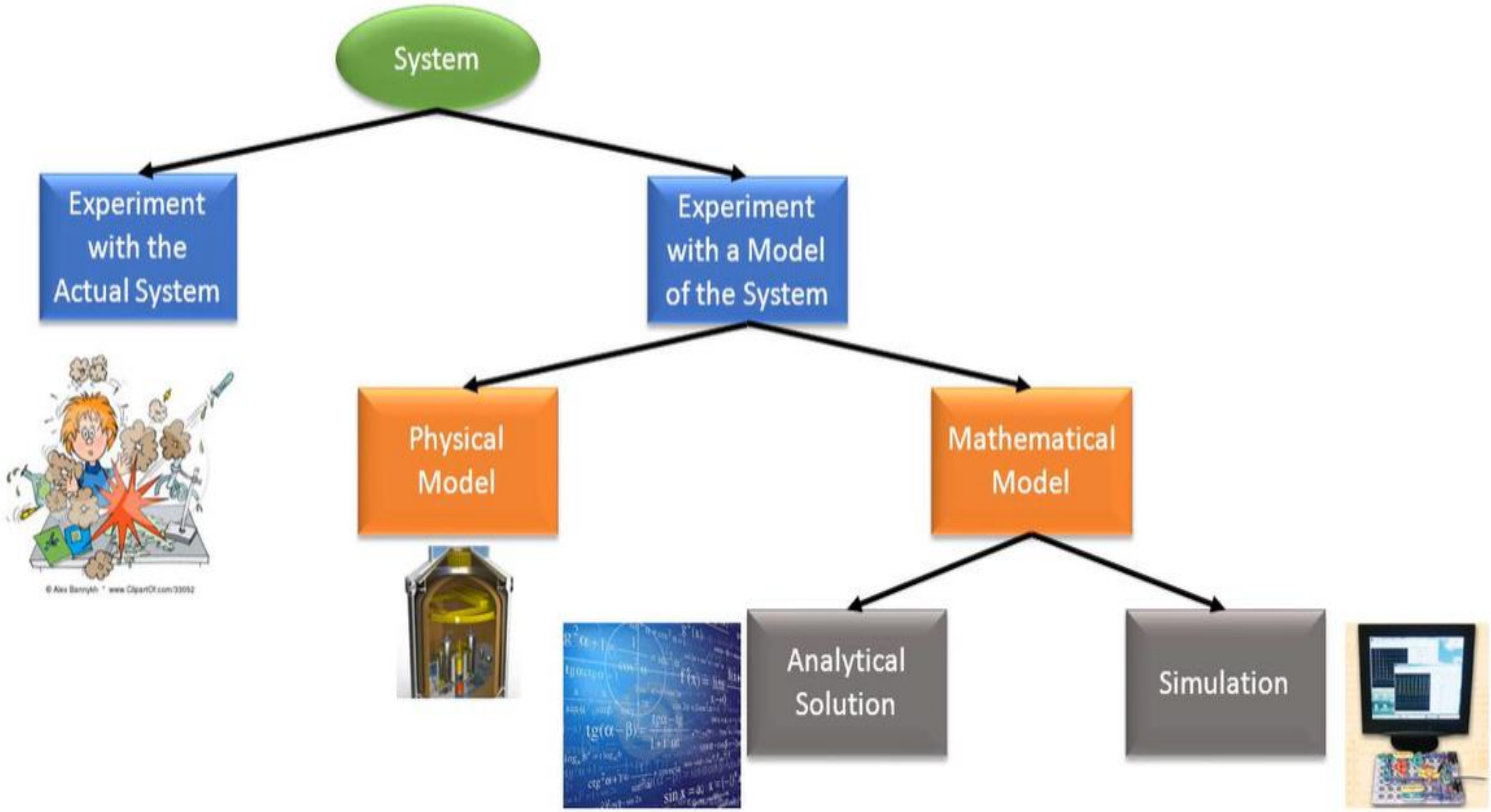


Note

- It is often possible to use discrete event simulations to approximate the behaviour of a continuous system. This greatly simplifies the analysis

" Few systems in practice are wholly discrete or continuous. But since one type of change dominates for most systems, it will usually be possible to classify a system as being discrete or continuous" [Law, 2007]

Ways to Study A System



Why are Models Used?

- It is not possible to experiment with the actual system, e.g.: the experiment is destructive
- The system might not exist, i.e. the system is in the design stage

Example: Bank

- Reducing the number of tellers to study the effect on the length of waiting lines may annoy the customers such that they will move their accounts to a competitor

Models

- A model is a representation of a system for the purpose of studying that system
- It is only necessary to consider those aspects of the system that affect the problem under investigation
- The model is a simplified representation of the system
- The model should be sufficiently detailed to permit valid conclusions to be drawn about the actual system
- Different models of the same system may be required as the purpose of the investigation changes

Types of Models

- ***A Mathematical Model*** utilizes symbolic notations and equations to represent a system
  - Example: current and voltage equations are mathematical models of an electric circuit
- ***A Physical Model*** is a larger or smaller version of an object

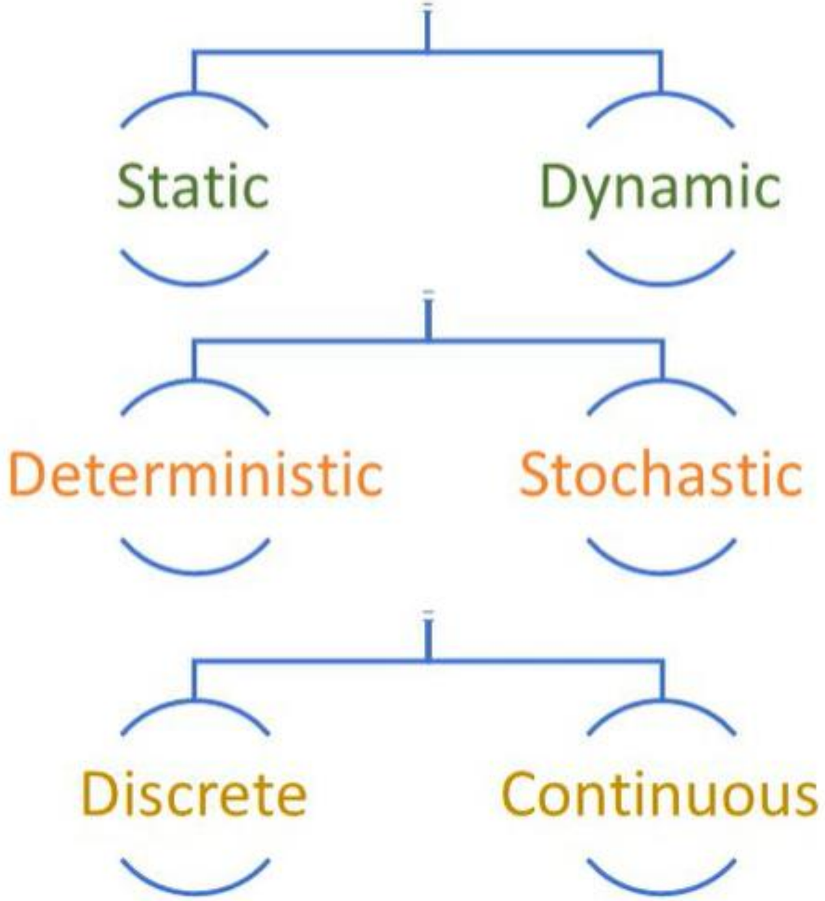
OR

A physical model is a constructed copy of an object that is designed to represent that object.

Example:

One of the more common examples of physical models are crash test dummies. Before a car makes it onto a road they're tested by simulating all kinds of crashes, and seeing the effect it has on human-sized dummies in the car.

Classifications of Simulation Models



Static

- i.e. Monte Carlo Simulation – Represents a system at a particular point in time
- Example: Simulation of a coin toss game

Dynamic

- Represents systems as they change over time
- Example: The simulation of a bank from 9:00am – 4:00pm

Deterministic and Stochastic Models

Deterministic	Stochastic
• Contain no random variables • Has a known set of inputs that will result in a unique set of outputs • Example: Patients arriving at the dentist's office exactly at their scheduled appointments	• Has one or more random variables • Random inputs lead to random outputs • Random outputs →only estimates of the true characteristics of the system • Example: random arrivals at a bank. Output may be average number of waiting customers, average waiting time. This output is only a statistical estimate of the system

Discrete and Continuous Models

Discrete	Continuous
• Not always used to simulate a discrete system • Example: Tanks and pipes may be modeled discretely, even though the flow is continuous	• Not always used to simulate a continuous system

- The choice of whether to use a discrete or continuous model depends on the characteristics of the system and the objectives of the study

Introduction to Simulation

- ❑ Simulation is the imitation of a real-world process or system over time [Banks et *al.*]
- ❑ It is used for analysis and study of complex systems
- ❑ Simulation requires the development of a *simulation model* and then conducting computer-based experiments with the model to describe, explain, and predict the behaviour of the real system

When is Simulation Appropriate

- Simulation enables the study of, and interaction with, the internal actions of a real system
- The effects of changes in state variables on the model's behaviour can be observed
- The knowledge gained from the simulation model can be used to improve the design of the real system under investigation

When is Simulation Appropriate

- Changing inputs and observing outputs can produce valuable insights about the importance of variables and how they interact
- Simulations can be used to experiment with different designs and policies before implementation so as to prepare for what might happen
- Simulations can be used to verify analytic solutions

When is Simulation not Appropriate

- ❑The problem can be solved by common sense
- ❑The problem can be solved analytically
- ❑It is less expensive to perform direct experiments
- ❑Costs of modeling and simulation exceed savings
- ❑Resources or time are not available
- ❑Lack of necessary data
- ❑System is very complex or cannot be defined

Advantages of Simulation

- Effects of variations in the system parameters can be observed without disturbing the real system
- New system designs can be tested without committing resources for their acquisition
- Hypotheses on how or why certain phenomena occur can be tested for feasibility
- Time can be expanded or compressed to allow for speed up or slow down of the phenomenon under investigation
- Insights can be obtained about the interactions of variables and their importance
- Bottleneck analysis can be performed in order to discover where work processes are being delayed excessively

DISADVANTAGES OF SIMULATION

- Model building requires special training
- Simulation results are often difficult to interpret. Most simulation outputs are random variables - based on random inputs – so it can be hard to distinguish whether an observation is the result of system inter-relationship or randomness
- Simulation modeling and analysis can be time consuming and expensive

OFSETING THE DISADVANTAGES OF SIMULATION

- ❑Utilize simulation packages that only need input for their operation, e.g.: SIMULINK, MS-Excel
- ❑Many simulation packages have output analysis capabilities, e.g. MATLAB, Excel
- ❑Simulation has become faster due to advances in hardware

STEPS IN SIMULATION STUDY

Phase I

- Problem formulation: statement of the problem
- Setting of objectives and overall design: questions to be answered by the simulation

Phase II

- Model conceptualization: abstract the essential features of the problem, select and modify basic assumptions that characterize the system, start with a simple model, enrich and elaborate the model
- Data collection: start early because it may take a lot of time
- Model translation: programming
- Verification: is the computer program functioning properly
- Validation: does the model accurately represent the system

Phase III

- Experimental design: which alternatives (designs) to simulate
- Production runs and analysis: to estimate measures of performance for the system designs that have been simulated. Measures of performance may depend on statistical analysis, e.g.: average, probability, frequency, etc.
- More runs? a sufficient number is needed to guarantee statistical accuracy

Phase IV

- Documentation
- Implementation