ISOM3025
Business modeling and simulation

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Introduction

- Introducing simulation models
- Classifying simulation models
- Approaching a simulation-based problem

Introducing simulation models

Simulation Model — WHAT is

- Simulation uses abstract models built to replicate the characteristics of a system.
- The operation of a system is simulated using probability distributions to randomly generate system events, and statistical observations are obtained from the simulated system.

Simulation Model –EXAMPLES

- Weather forecast
- Stock prices prediction
- Risk management
- Queuing system
- Disease spreading
- Social network

Simulation Model — ADVANTAGES

- Ability to compress time, expand time
- Ability to control sources of variation
- Avoids errors in measurement
- Ability to stop and review
- Ability to restore system state
- Facilitates replication
- Modeler can control level of detail

Simulation Models–LIMITATIONS

- Analysis could be complex and identifying the best configuration could be difficult
- Provides indications but not exact results
- Implementation could be laborious and time consuming
- Quality of results depends on accuracy of input data
- Complexity depends on the complexity of the system

Terminlogy

Simulation v.s. Modeling

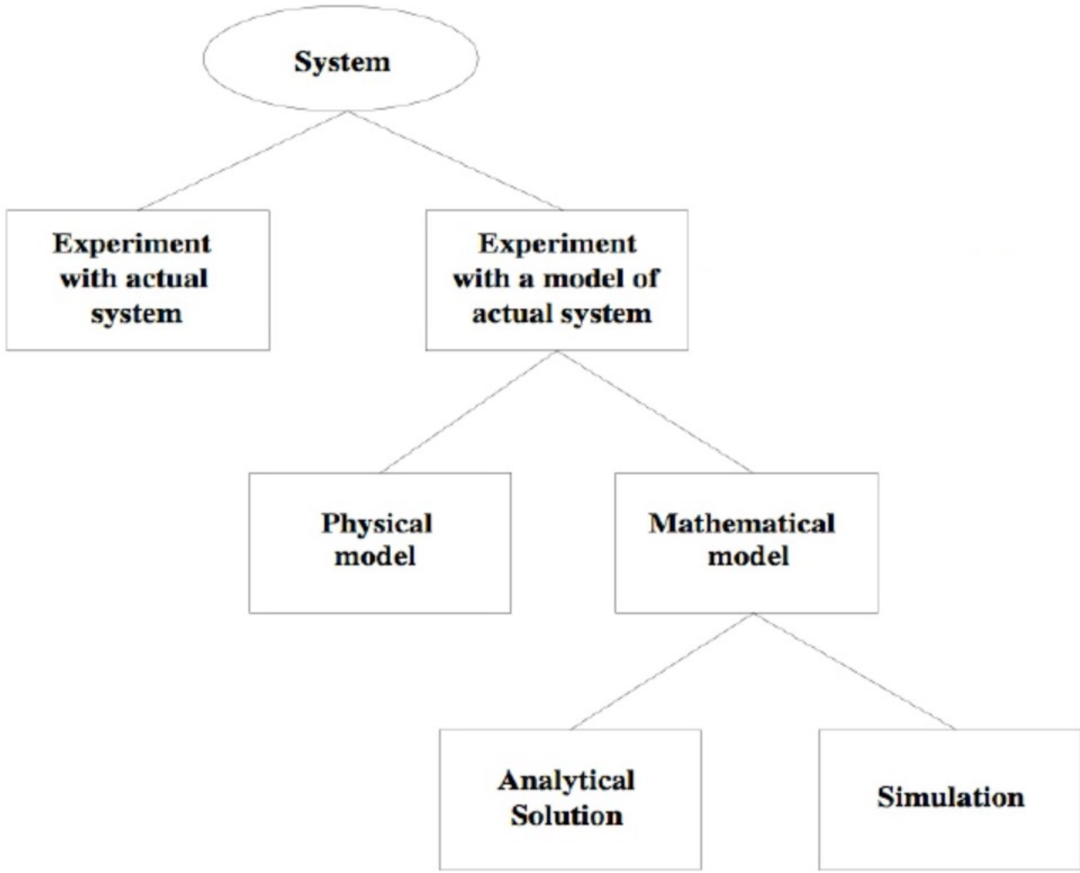
- Simulation: the process that puts the model into operation and allows you to evaluate its behavior under certain conditions.
- Modeling: a design methodology that is based on producing a model that implements a system and represents its functionality.

Terminlogy

System—– facility or process, actual or planned

- The set of elements that interact with each other.
- The main problem linked to this element concerns the system boundaries, that is, which elements of reality must be inserted in the system that represents it and which are left out and the relationships that exist between them.

Ways To Study A System*



Simulation, Modeling & Analysis (3/e) by Law and Kelton, 2000, p. 4, Figure 1.1

System— Examples

- Manufacturing facility
- Bank operation
- Airport operations (passengers, security, planes, crews, baggage)
- Transportation/logistics/distribution operation
- Hospital facilities (emergency room, operating room, admissions)
- Computer network
- Freeway system
- Business process (insurance office)
- Criminal justice system
- Chemical plant
- Fast-food restaurant
- And more.

State variables

A system is described in each instant of time by a set of variables. These are called state variables.

For example, in the case of a weather system, the temperature is a state variable. In discrete systems, the variables change instantly at precise moments of time that are finite. In continuous systems, the variables vary in terms of continuity with respect to time.

Events

An event is defined as any instantaneous event that causes the value of at least one of the status variables to change.

For example, the arrival of a blizzard for a weather system is an event, as it causes the temperature to drop suddenly.

Parameters

Parameters represent essential terms when building a model. They are adjusted during the model simulation process to ensure that the results are brought into the necessary convergence margins. They can be modified iteratively through sensitivity analysis or in the model calibration phase.

Calibration

Calibration represents the process by which the parameters of the model are adjusted in order to adapt the results to the data observed in the best possible way.

When calibrating the model, we try to obtain the best possible accuracy. A good calibration requires eliminating, or minimizing, errors in data collection and choosing a theoretical model that is the best possible description of reality. The choice of model parameters is decisive and must be done in such a way as to minimize the deviation of its results when applied to historical data.

Accuracy

Accuracy is the degree of correspondence of the simulation result that can be inferred from a series of calculated values with the actual data, that is, the difference between the average modeled value and the true or reference value. Accuracy, when calculated, provides a quantitative estimate of the quality expected from a forecast. Several indicators are available to measure accuracy.

The most used are **mean absolute error (MAE), mean absolute percentage error (MAPE), and mean squared error (MSE).**

Sensitivity

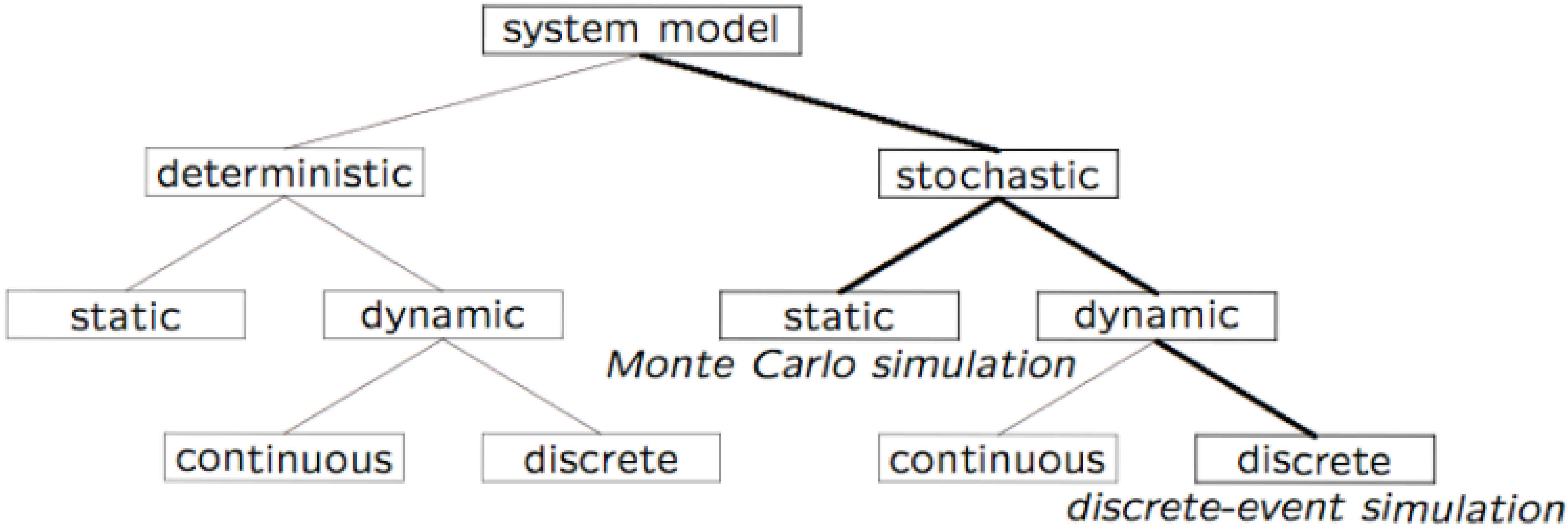
The sensitivity of a model indicates the degree to which the model's outputs are affected by changes in the selected input parameters. A sensitivity analysis identifies the sensitive parameters for the output of the model.

It allows us to determine which parameters require further investigation so that we have a more realistic evaluation of the model's output values. Furthermore, it allows us to identify which parameters are not significant for the generation of a certain output and therefore can possibly be eliminated from the model. Finally, it tells us which parameters should be considered in a possible and subsequent analysis of the uncertainty of the output values provided by the model.

Validation

This is the process that verifies the accuracy of the proposed model. The model must be validated to be used as a tool to support decisions. It aims to verify whether the model that's being analyzed corresponds conceptually to our intentions. The validation of a model is based on the various techniques of multivariate analysis, which, from time to time, study the variability and interdependence of attributes within a class of objects.

Classifying simulation models



Classifying simulation models

Deterministic models and Stochastic models

- Deterministic models: the output is well determined once the input data and the relationships that make up the model have been specified, despite the time required for data processing being particularly long.
- Stochastic models: can be evolved by inserting random elements into the evolution.

Static systems and Dynamic systems

- Static models are the representation of a system in an instant of time, or representative models of a system in which the time variable plays no role. An example of a static simulation is a Monte Carlo model.

- Dynamic models, on the other hand, describe the evolution of the system over time. In the simplest case, the state of the system at time t is described by a function x (t). For example, in population dynamics, x (t) represents the population present at time t. The equation that regulates the system is dynamic: it describes the instantaneous variation of the population or the variation in fixed time intervals.

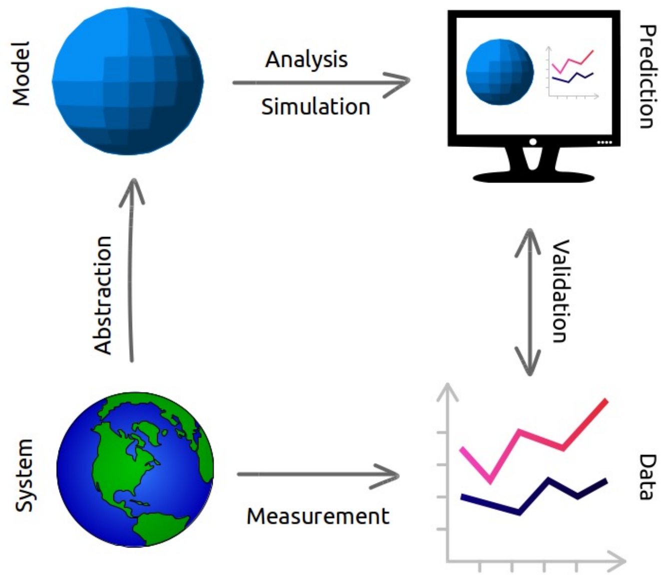
Continuous models and Discrete models

- Continuous models: the state of the variables changes continuously as a function of time.
  - For example, a car moving on a road represents a continuous system since the variables that identify it, such as position and speed, can change continuously with respect to time.
- Discrete models: the system is described by an overlapping sequence of physical operations, interspersed with inactivity pauses. These operations begin and end in well defined instances (events). The system undergoes a change of state when each event occurs. This type of operation is easy to treat with the simulation approach. We will primarily focus on discrete models in this course.

Approaching a simulation-based problem

Simulation process workflow:

1. Problem analysis
2. Data collection
3. Setting up the simulation model
4. Simulation software selection
5. Verification of the software solution
6. Validation of the simulation model
7. Simulation and analysis of results



Problem analysis

In this initial step, the goal is to understand the problem by trying to identify the aims of the study and the essential components, as well as the performance measures that interest them.

Data collection

Quality of the simulation model depends on the quality of the input data.

Once the objective has been identified, data are collected and subsequently processed.

Processing the collected data is necessary to transform it into a format that can be used by the model.

Setting up the simulation model

Referring to simulating discrete events, constructing a model involves the following steps:

1. Defining the state variables
2. Identifying the values that can be taken by the state variables
3. Identifying the possible events that change the state of the system
4. Realizing a simulated time measurement, that is, a simulation clock, that records the flow of simulated time
5. Implementing a method for randomly generating events
6. Identifying the state transitions generated by events

Simulation software selection

- Simulators: TMATLAB, COMSOL Multiphysics, Ansys, SolidWorks, Simulink, Arena, AnyLogic, and SimScale, etc.

- In this course, we will use **Python**. This software platform offers a series of tools that have been created by researchers from all over the world that make the elaboration of a numerical modeling system particularly easy. In addition, the open source nature of the projects written in Python makes this solution particularly inexpensive.

Verification of the software solution

Debugging: ensuring that the code correctly follows the desired logical flow, without unexpected blocks or interruptions.

Validation of the simulation model

Check whether the performance measurements of the real system are well approximated by the measurements generated by the simulation model.

It is necessary to establish whether the model adequately represents the behavior of the system. The value of a model can only be defined in relation to its use. Therefore, validation is a process that aims to determine whether a simulation model accurately represents the system for the set objectives.

Simulation and analysis of results

Simulation is a process that evolves during its realization and where the initial results help lead the simulation toward more complex configurations.

A simulation does not produce the exact values of the performance measures of a system since each simulation is a statistical experiment that generates statistical observations regarding the performance of the system.

These observations are then used to produce estimates of performance measures. The simulation results return statistical estimates of a system’s performance measures.

In summary

We have learned

- What is simulation models
- Advantages and limitations
- Terminology
- How to approach simulation-based problem

References:

- *GC Chapter 1; LN Chapter 1;*

Next: Math and Stats Review

Next

- Review of preliminary mathematics concepts
- Review of programing software Python