VERIFICATION AND VALIDATION OF SIMULATION MODEL

UNIT 4

Verification and validation of simulation Model

- One of the most important and difficult tasks facing amodel developer is the verification and validation of the simulation model.
- It is the job of the model developer to work closely with the end users throughout the period development and validation to reduce this skepticism and to increase the credibility.

The goal of the validation process is twofold:

- To produce a model that represents true system behavior closely enough for the model to be used as a substitute for the actual system for the purpose of experimenting with system.
- To increase an acceptable, level the credibility of the model, so that the model will be used by managers and other decision makers.

The verification and validation process consists of the following components:-

- Verification is concerned with building the model right. It is utilized in comparison of the conceptual model to the computer representation that implements that conception. It asks the questions: Is the model implemented correctly in the computer? Are the input parameters and logical structure of the model correctly represented?
- Validation is concerned with building the right model. It is utilized to determine that a model is an accurate representation of the real system. It is usually achieved through the calibration of the model.

Model of a system

- A model is a representation of an object, a system, or an idea in some form other than that of the entity itself.
- A model is defined as a representation of a system for the purpose of studying the system. It is necessary to consider only those aspects of the system that affect the problem under investigation. These aspects are represented in a model, and by definition it is a simplification of the system.

Model of a system

- A model is similar to but simpler than the system it represents.
- One purpose of a model is to enable the analyst to predict the effect of changes to the system.
- A good model is a judicious tradeoff between realism and simplicity.

Analytical and Numerical Model

- In case of mathematical model they can be categorized according to how they solve the problems. In **analytical model**, they use the deductive (logical) reasoning of mathematical theory to solve a model. Actually only some problems can be solved through these deductive (logical) reasoning. E.g. For analyzing RLC circuit, we use linear differential equations where mathematical formula $d^2y/dx^2 + P_1\, dy/dx + P_2 y = Q$, where $P1$ and $P2$ are constants and Q function of x.
- **Numerical Models:** Uses numerical methods for computation procedure. Here computation is done for a set of values or tables. E.g. To find an integral value between a certain interval, we may divide an integral in certain parts and use any numerical methods.

Deterministic Vs. stochastic models

- Simulation models that contain no random variables are classified as **deterministic.** Deterministic models have a known set of inputs, which will result in a unique set of outputs. Deterministic arrivals would occur at a dentist's office if all patients arrived at the scheduled appointment time.
- A **stochastic simulation** model has one or more random variables as inputs. Random inputs lead to random outputs. Since the outputs are random, they can be considered only as estimates of the true characteristics of a model. The simulation of a bank would usually involve random inter arrival times and random service times.

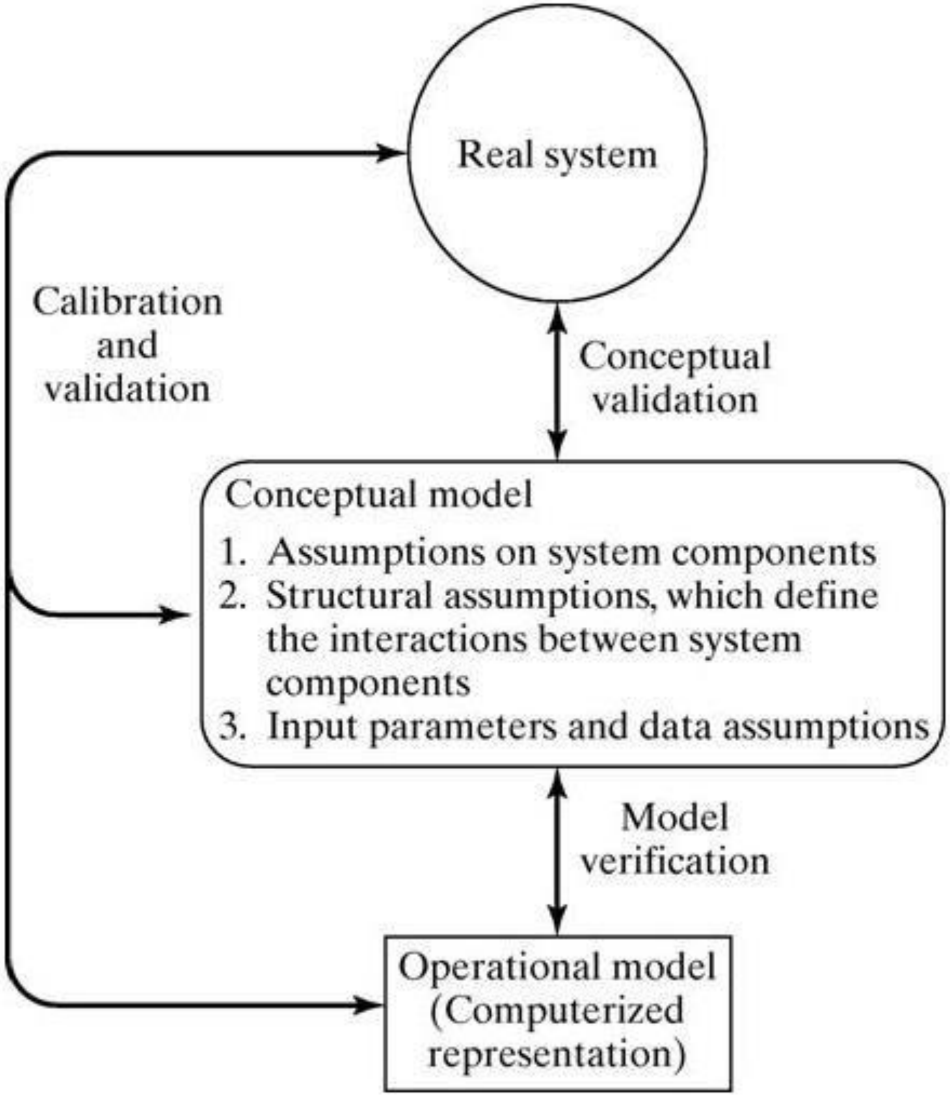
Deterministic Vs. stochastic models

- Thus, in a stochastic simulation, the output measures-the average number of people waiting, the average waiting time of a customer-must be treated as statistical estimates of the true characteristics of the system.
- Discrete and continuous models are defined in an analogous manner. However, a discrete simulation model is not always used to model a discrete system, nor is a continuous simulation model always used to model a continuous system. Tanks and pipes are modeled discretely by some software vendors, even though weknow that fluid flow is continuous.

Deterministic Vs. stochastic models

- In addition, simulation models may be mixed, both discrete and continuous. The choice of whether to use a discrete or continuous or both (discrete and continuous) simulation model is a function of the characteristics of the system and the objective of the study. Thus, a communication channel could be modeled discretely if the characteristics and movement of each message were deemed important. Conversely, if the flow of messages in aggregate over the channel we of importance, modeling the system via. Continuous simulation could be more appropriate. The models considered in this text are discrete, dynamic, and stochastic.

4.1 Model Building



4.1 Model Building

1. The first step in model building consists of observing the real system and the interactions among its various components and collecting data on its behavior.

   Operators, technicians, repair and maintenancepersonnel, engineers, supervisors, and managers understand certain aspects of the system which may be unfamiliar to others.

   As model development proceeds, new questions may arise and the model developers will return, to this step of learning true system structure and behavior.

4.1 Model Building

2. The second step in model building is the construction of a ***conceptual model*** – a collection of assumptions on the components and the structure of the system, plus hypotheses on the values of model input parameters, illustrated by the following figure

3. The third step is the translation of the ***operational model*** into a computer recognizable form- the computerized model.

Verification of Simulation Models

- The purpose of model verification is to assure that the conceptual model is reflected accurately in the computerized representation.
- The conceptual model quite often involves some degree of abstraction about system operations, or some amount of simplification of actual operations.

Verification of Simulation Models

Many common-sense suggestions can be given for use in the verification process:-

1. Have the computerized representation checked by someone other than its developer.
2. Make a flow diagram which includes each logically possible action a system can take when an event occurs, and follow the model logic for each a for each action for each event type
3. Closely examine the model output for reasonableness under a variety of settings of input parameters.

Verification of Simulation Models

4. Have the computerized representation print the input parameters at the end of the simulation to be sure that these parameter values have not been changed inadvertently.
5. Make the computerized representation of self-documenting as possible.
6. If the computerized representation is animated, verify that what is seen in the animation imitates the actual system.

Verification of Simulation Models

7. The interactive run controller (IRC) or debugger is an essential component of successful simulation model building. Even the best of simulation analysts makes mistakes or commits logical errors when building a model. The IRC assists in finding and correcting those errors in the following ways:
   - The simulation can be monitored as it progresses.
   - Attention can be focused on a particular line of logic or multiple lines of logic that constitute a procedure or a particular entity
   - Values of selected model components can be observed. When the simulation has paused, the current value or status of variables, attributes, queues, resources, counters, etc. can be observed.
   - The simulation can be temporarily suspended, or paused, not only to view information but also to reassign values or redirect entities

8. Graphical interfaces are recommended for accomplishing verification & validation .

Calibration and Validation of Models

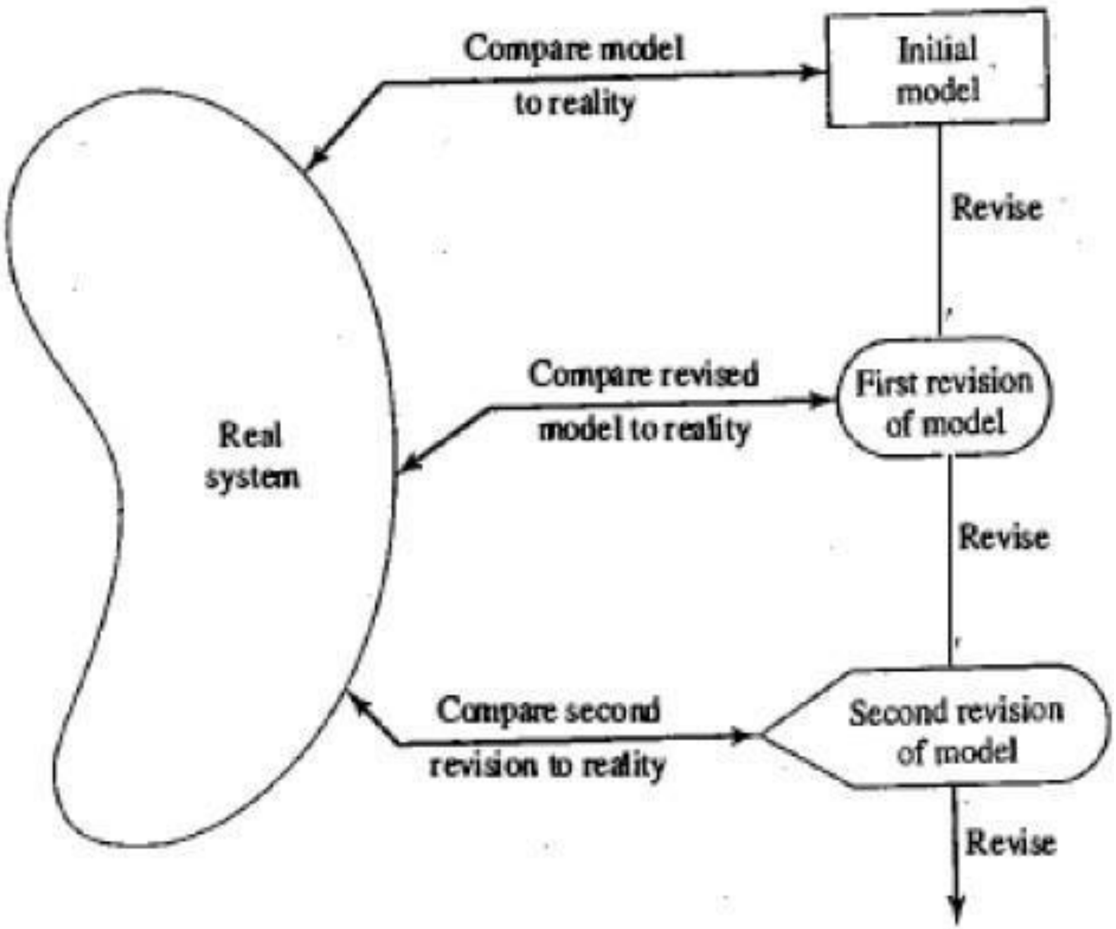


Fig: Iterative process of calibrating a model.

Calibration

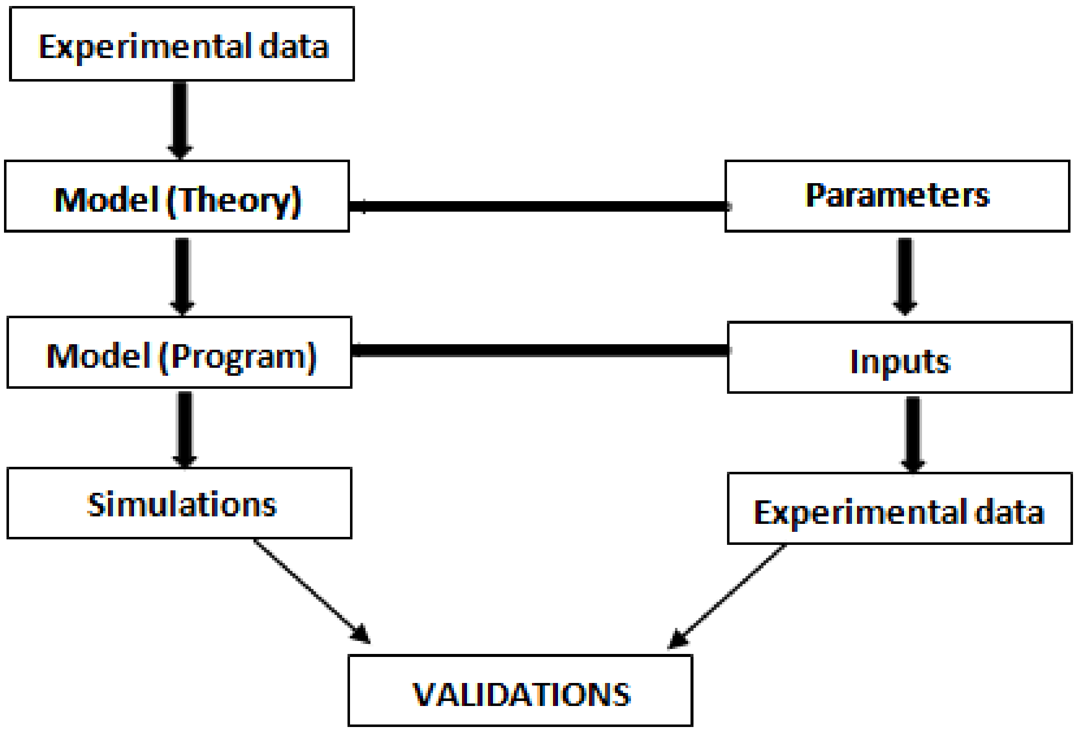
- Calibration is the iterative process of comparing the model to the real system, making adjustments to the model, comparing again and so on.
- The figure shows the relationship of the model calibration to the overall validation process.
- The comparison of the model to reality is carried out by variety of test
- Test are subjective and objective.
- Subjective test usually involve people, who are knowledgeable about one or more aspects of the system, making judgments about the model and its output.
- Objective tests always require data on the system's behavior plus the corresponding data produced by the model.

Calibration is needed for two main reasons:

- It allows users to describe the system under study. This is referred at times as calibration but it is just selecting correct inputs to properly characterize the system under study.
- To account for the empiricism which is often at the base of the relations used in the model.
  - The difference between mechanistic model and statistical models resides in the level where the empiricism is placed.
  - Mechanistic model have empiricism one or two levels below the level at which prediction is made.
  - Statistical models have the empiricism at the same level of prediction.
  - A possible criticism of the calibration phase, were it to stop at point, ie., the model has been validated only for the one data set used; that is,the model has been "fit" to one data set.
  - Validation is not an either/or proposition—no model is ever totally representative of the system under study. In addition, each revision of the model, as in the Figure above involves some cost, time, and effort.

Validation Process (Model Validation)

- Model validation is a necessary requirement for model application. To do a reliable validation several steps must be taken and each of them may be a source of errors which will influence the final result.



The goal of the validation process is twofold:

- ***To produce a model that represents true system behavior*** closely enough for the model to be used as a substitute for the actual system for the purpose of experimenting with the system.
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Three steps approach in the validation process:

1. Build a model that has high face validity:

- Build a reasonable model on its face to model users who are knowledgeable about the real system being simulated.
- Do some "sanity check".

2. Validate model assumptions:

- Model assumptions fall into two categories:

  i) Structural Assumptions

  ii) Data Assumptions

i) Structural Assumptions deal with such questions as how the system operates; what kind of model should be used, queuing, inventory, reliability etc.

ii) Data Assumptions deal with what kind of input data model is? What are the parameter values to the input data model?

Three steps approach in the validation process:

3. Compare the model input-output transformations to corresponding input-output transformation for the real system:

- View the model as a black box
- Feed input at one end and examine output at other
- Use the same input for a real system, compare the output with the model input
- If they fit closely, the black box seems working fine, otherwise something is wrong

1. Face Validity

- The first goal of the simulation modeler is to construct a model that appears reasonable on its face to model users and others who are knowledgeable about the real system being simulated.
- The users of a model should be involved in model construction from its conceptualization to its implementation to ensure that a high degree of realism is built into the model throughreasonable assumptions regarding system structure, and reliable data.
- Another advantage of user involvement is the increase in the models perceived validity or credibility without which manager will not be willing to trust simulation results as the basis for decision making.
- Sensitivity analysis can also be used to check model's face validity.

1. Face Validity

- The model user is asked if the model behaves in the expected way when one or more input variables are changed.
- Based on experience and observations on the real system the model user and model builder would probably have some notion at least of the direction of change in model output when an input variable is increased or decreased.
- The model builder must attempt to choose the most critical input variables for testing if it is too expensive or time consuming to: vary all input variables.

2. Validation of Model Assumptions

Model assumptions fall into two general classes: structural assumptions and data assumptions.

a) Structural assumptions involve questions of how the system operates and usually involve simplification and abstractions of reality.

For example, consider the customer queuing and service facility in a bank. Customers may form one line, or there may be an individual line for each teller. If there are many lines, customers may be served strictly on a first-come, first-served basis, or some customers may change lines if one is moving faster. The number of tellers may be fixed or variable. These structural assumptions should be verified by actual observation during appropriate time periods together with discussions with managers and tellers regarding bank policies and actual implementation of these policies.

2. Validation of Model Assumptions

b) Data assumptions should be based on the collection of reliable data and correct statistical analysis of the data. Datawere collected on.

- Inter arrival times of customers during several 2-hour periods of peak loading ("rush-hour" traffic)
- Inter arrival times during a slack period.
- Service times for commercial accounts.
- Service times for personal accounts.

The procedure for analyzing input data consist of three steps:-

1: Identifying the appropriate probability distribution.

2: Estimating the parameters of the hypothesized distribution.

3: Validating the assumed statistical model by goodness – of – fit test such as the chi-square test, K-S test and by graphical methods.

3. Validating Input-Output Transformation:-

- In this phase of validation process the model is viewed as input – output transformation.
- That is, the model accepts the values of input parameters and transforms these inputs into output measure of performance. It is this correspondence that is being validated.
- Instead of validating the model input-outputtransformation by predicting the future, the modeler may use past historical data which has been served for validation purposes that is, if one set has been used to develop calibrate the model, its recommended that a separate data test be used as final validation test.

3. Validating Input-Output Transformation:-

- Thus accurate ¯prediction of the past‖ may replace prediction of the future for purpose of validating the future.
- A necessary condition for input-output transformation is that some version of the system under study exists so that the system data under at least one set of input condition can be collected to compare to model prediction.
- If the system is in planning stage and no system operating data can be collected, complete input-output validation is not possible.
- Validation increases modeler’s confidence that the model of existing system is accurate.

3. Validating Input-Output Transformation:-

- Changes in the computerized representation of the system, ranging from relatively minor to relatively major include:
  1. Minor changes of single numerical parameters such as speed of the machine, arrival rate of the customer etc.
  2. Minor changes of the form of a statistical distribution such as distribution of service time or a time to failure of a machine.
  3. Major changes in the logical structure of a subsystem such as change in queue discipline for waiting-line model, or a change in the scheduling rule for a job shop model.
  4. Major changes involving a different design for the new system such as computerized inventory control system replacing a non computerized system.
     - If the change to the computerized representation of the system is minor such as in items one or two these change can be carefully verified and output from new model can be accepted with considerable confidence. Partial validation of substantial model changes in item three and four may be possible.

Errors in validation

As a general rule, if there are discrepancies between observed and simulated data, the technical structure of a model should be the last factor to suspect.

- Model Inadequate(Poor)
- Lack of Calibration
- Errors in the code
- Errors in the input
- Errors in the use
- Errors in the experimental data

Model Adequacy (Competence)

- ✓ Are all the important processes for a given environment included?
- ✓ Are the processes modeled correctly?
- ✓ Was the range of data used to develop model components for process simulation wide enough to include our conditions?

Errors in the code

- ✓ Following steps can be under taken to check a code:
  - ➢ Do calculations using for instance a spreadsheet and compare with model results.
  - ➢ Verify that simulation results are within the known physical and biological reality.
  - ➢ Run simulation with highly contrasting inputs.
- ✓ The effect of an error in the inputs used to run a simulation is proportional to the sensitivity that the model has for that input.
- ✓ A model is an interpretation of a system i.e. elements interrelated in the real world. If correctly structured, a model contains sub-models to simulate the most important processes in a given environment.
- ✓ All models have limitations in their use given by their structure, using the model in conditions where non-simulated processes are important causes wrong estimates for most of the simulated processes.

Errors in the experimental data

- The experimental data used to test model predictive capabilities are affected by experimental error, which can be large.
- Only a large number of experimental data allows a meaningful evaluation of model performance in statistical terms.