Chapter 7
Verification and Validation of Simulation Models

Model Building

- Model building is an iterative process of domain knowledge acquisition and model development.
- The real system and their interactions among various components should be analyzed.
- The domain knowledge can also be acquired from the interaction with concerned people.
- As the model development proceeds, new questions arises and the process of learning system behaviour and structure takes place again.
- Then a conceptual model is constructed with a collection of assumptions and hypotheses and finally developed into a logical model.
- Finally, the logical model is implemented using various simulation software.

Model Verification

- In the context of computer simulation, verification of a model is the process of confirming that it is correctly implemented.
- Verification is concerned with building the model correctly(concerned with building the **model right.).**
- The objective of model verification is to ensure that the implementation of the model is correct.
- Verification answers for Is the developed model performing properly?
- During verification the model is tested to find and fix errors in the implementation of the model.
- Various processes and techniques are used to assure the model matches specifications and assumptions with respect to the model concept.
- If the input parameters and logical structure of the model are **correctly represented,** verification is completed.

Considerations to be used in Verification Process:

1. The operational model should be checked by someone other than the developer, preferably an expert in the simulation software being used.
2. Make a flow diagram that contains all logically possible action a system can perform when an event occurs.
3. Closely examine the model output for reasonableness under variety of input parameters.
4. Have the operational model print input parameters when the simulation ends to check if they are not altered.
5. Make the operational model as self-documenting as possible.
6. Verify animated operational model imitates the actual system.
7. Debugger should be used during simulation model building.
8. Graphical interfaces are recommended.

Model Validation

- Validation checks the accuracy of the model's representation of the real system.
- Validation is the determination that a model is an accurate representation of the real system.
- It attempts to confirm that a model represents the real system accurately.
- Validation is usually achieved through the calibration of the model.
- Calibration is the iterative process of comparing the model with real system, revising the model if necessary, comparing again, until a model is accepted (validated).
- This process is repeated until acceptable accuracy for model is achieved.

Calibration of Model

- Validation is a process of comparing the model and its behavior to the real system and its behavior.
- Calibration is the iterative process of comparing the model with real system, revising the model if necessary, comparing again, until a model is accepted (validated).
- Calibration deals with adjustment of the parameters of the model in order acquire the desired accuracy.
- The comparison of the model to reality is carried out by subjective and objective tests.
- A subjective test involves talking to people, who are knowledgeable about the system, people or experts having idea on making models and forming the judgment.
- Objective tests involve one or more statistical tests to compare some model output with the assumptions in the model.

Naylor and Finger Approach

- Naylor and Finger formulated a three step approach to the validation process.

1. **Build model with high Face Validity**

- Face validity, also called logical validity, is a simple form of validity where you apply a **superficial and subjective assessment** of whether or not your study or test measures what it is supposed to measure.
- A model should appear reasonable on its face to model users and to those who knows about the real system that is being simulated.
- A model should be designed with high degree of realism regarding system structure and behavior through reliable data.
- The potential users should also be involved in the validation process to aid in identification of model deficiencies and optimizing those deficiencies to produce better model. This process is termed as structural walkthrough.

- Sensitivity analysis is also used for face validity of the model. It analyses the effect on output when there is change in input parameters.
- Sensitivity analysis is done through appropriate statistical techniques.

2. Validate Model Assumptions

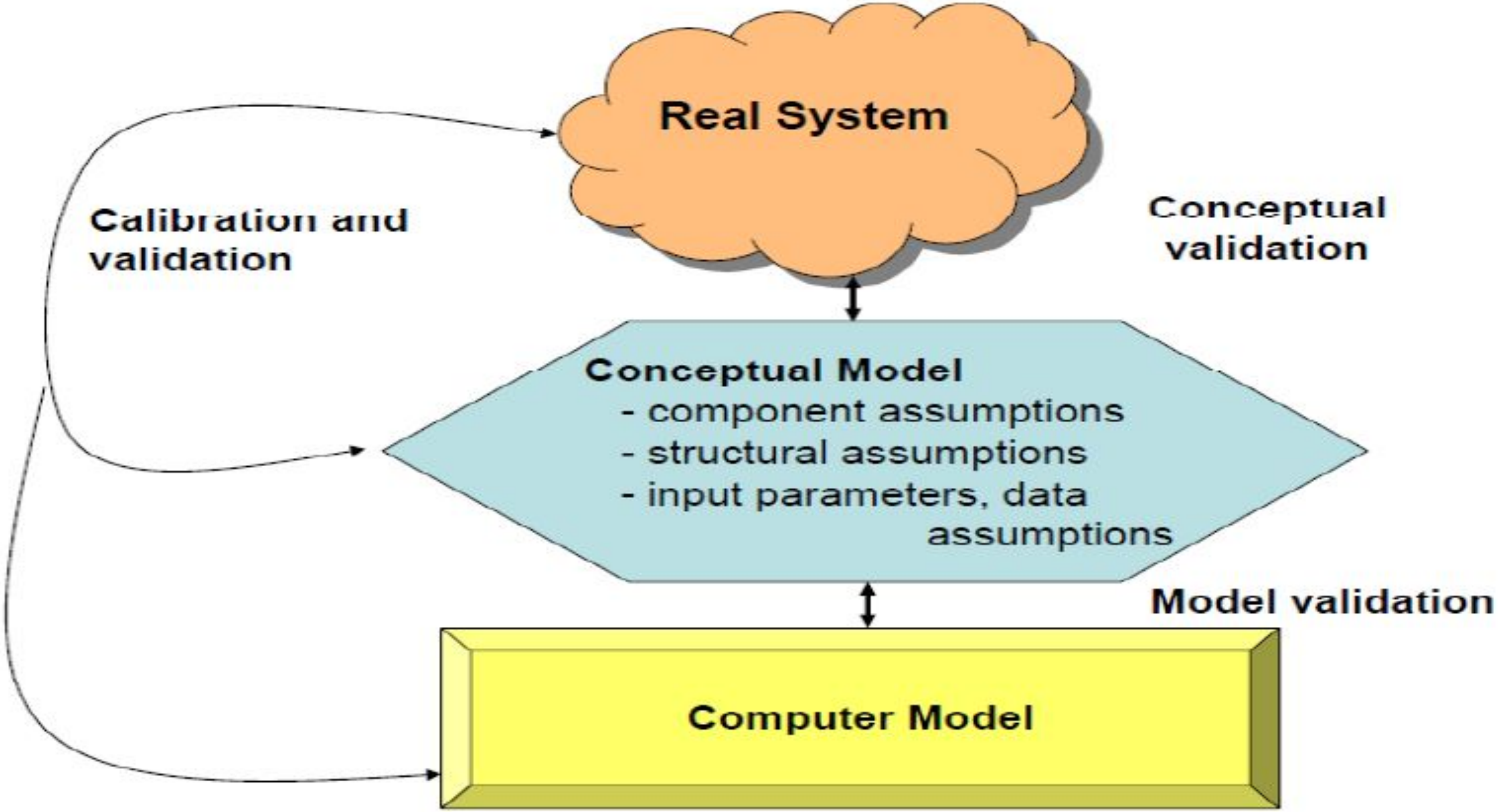
- Sensitivity analysis is done through appropriate statistical techniques. These assumptions are of two types: **structural assumption** and **data assumption**.
- Structural assumptions involves simplification and abstraction of reality.
- Structural assumptions deal with such questions as how the system operates, what kind of model should be used, queueing, inventory, reliability, and others.
- Data assumptions should be done based on collection of reliable data.
- Data assumptions deal with such questions as : what kind of input data model is? What are the parameter values to the input data model?

- For example - Consider a bank system in which customer are queued before providing service.
- The structural assumptions may be - Customers form a single queue which is served by multiple tellers - Customers form one line for each teller - The number of teller should be fixed or variable.
- These structural assumptions should be validated by actual observation during appropriate time periods and also by discussions with the managers and tellers.
- The data assumptions may be - interarrival times of customers during peak hour - interarrival times of customers during slack period - service time for personal accounts and so on.
- These data assumptions should be validated by consultation with bank managers. The validation is done by using goodness-of-fits tests such as chi-square test or Kolmogorov-Smirnov tests.

3. Validating Input-Output Transformation

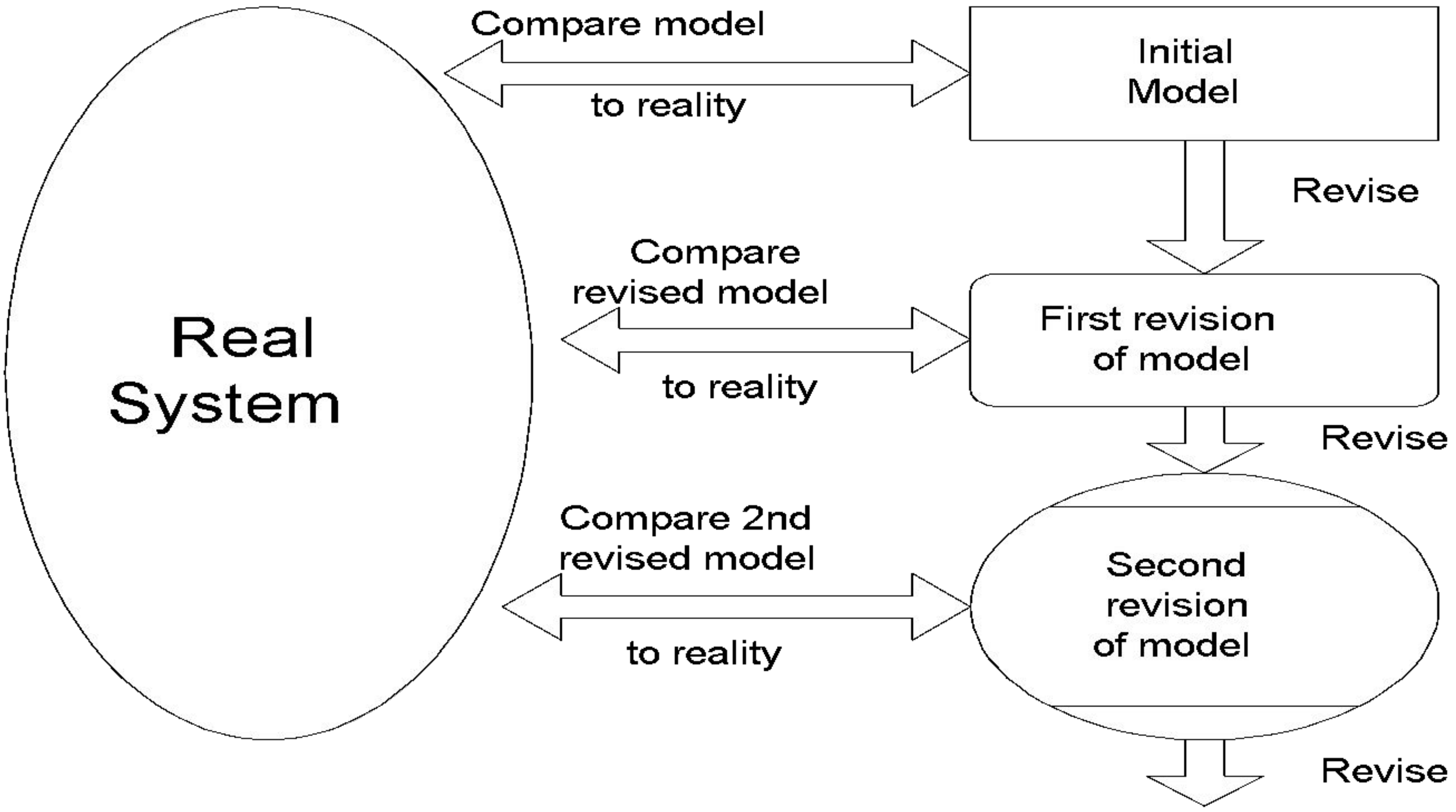
- It involves validating whether the model can predict the future behavior of the real system when the model input data match the real inputs and when a policy implemented in the model is implemented at some point in the system.
- Here the model is viewed as a black box.
- We feed the input at one end and examine the output at the other end.
- Use the same input for a real system, compare the output with the model output. If they fit closely, the black box seems working fine. Else something is wrong.
- If in future, the model is used for different purpose, it should be revalidated in terms of new response of interest.

From Model Building to Validation



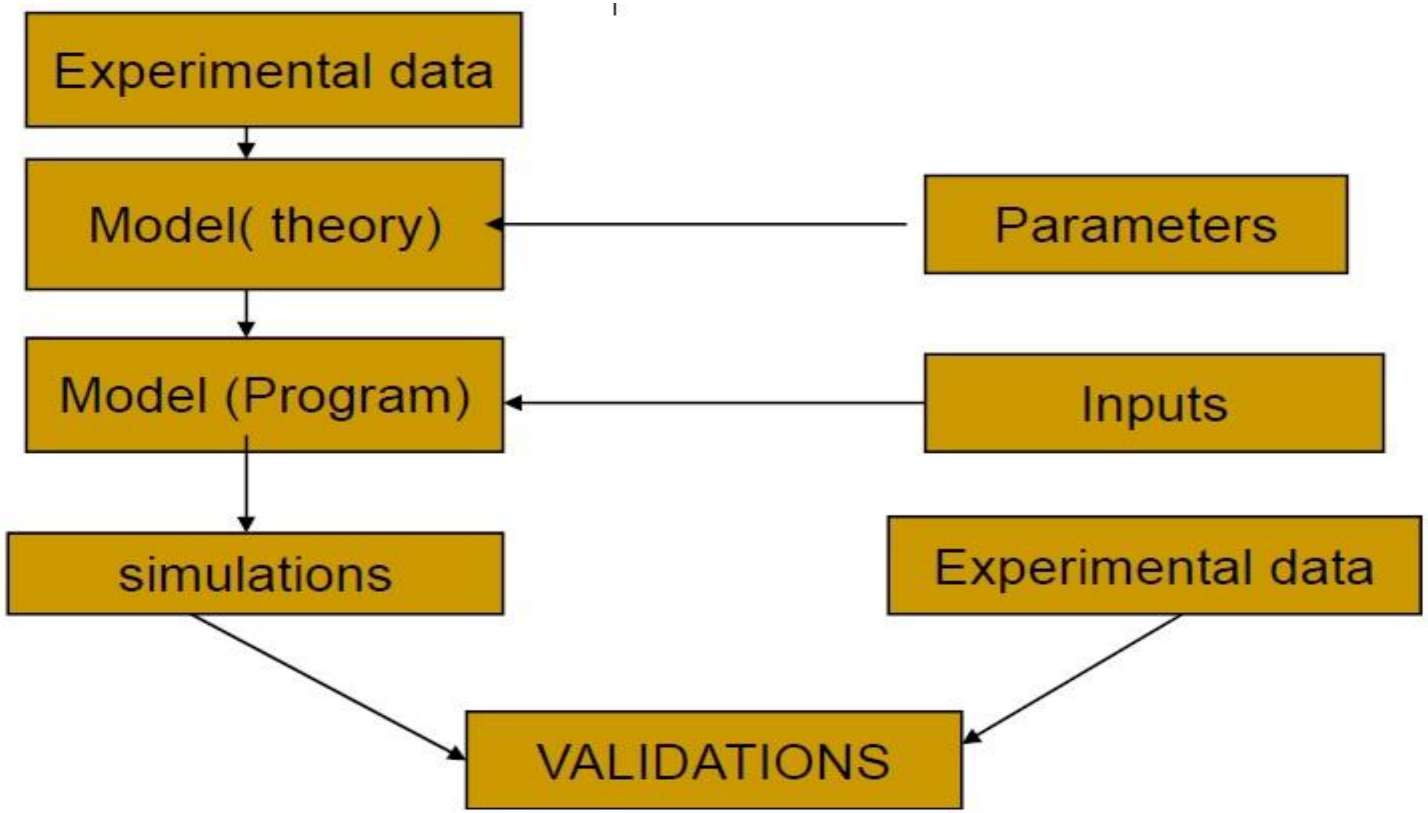
Iterative Process of Calibrating a Model

- Iterative calibration means to validate the model with the real system, look out for the places for betterment of the models and revising the model to form next better model repeatedly until a satisfiable model is not achieved.
- The initial model is developed and is calibrated using Naylor-Finger calibration steps with the real system. It is then revised and a first revision model is generated.
- The first revision model is then calibrated with the real system. It is revised to form a second revision model.
- This process is continued until the model becomes acceptable.


Real System
Compare model
to reality
Initial Model
Revise
Compare revised model
to reality
First revision of model
Revise
Compare 2nd revised model
to reality
Second revision of model
Revise

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.



Validation Errors

- During the validation phase, errors might be present.
- 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.
- Following may be some reasons for errors:

1. **Model inadequate:** Model Adequacy deals with the following questions:
    - 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?

2. **Lack of calibration:** Calibration should be done in order to adjust the parameters of the model so as to acquire the desired accuracy.

3. Errors in the code

 Errors might be present on the code that we write.

 Following steps can be taken to check a code:

a. Do manual calculations for instance using a spreadsheet and compare with model results.

b. Verify that simulation results are within the known physical and biological reality.

c. Run simulations with highly contrasting inputs.

4. Errors in the inputs

 There might be error while providing the input data or parameters.

5. Errors in the use

 There might be error while using the model.

6. Errors in Experimental Data

- Experimental data are used to test the predictive capabilities of model.
- These experimental data 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.