Verification and validation of simulation models

By

Prof. S. Shakya

Verifications

- Verification pertains to the computer program prepared for the simulation model.
- Is the computer program performing properly?
- If the input parameters and logical structure of the model are correctly represented in the computer, verification has been completed.

Validation

- Validation is the determination that a model is an accurate representation of the real system.
- Validation is usually achieved through the calibration of the model, an iterative process of comparing the model to actual system behavior and using the discrepancies
- between the two, and the insights gained to improve the model.
- This process is repeated until model accuracy is judged acceptable.

Calibration and Validation of Models

- Validation is the overall process of comparing the model and its behavior to the real system and its behavior.
- Calibration is the iterative process of comparing the model to the real system.
- Making adjustment or changes to the model, comparing the revised model to reality and so on.
- 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 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.

Calibration and Validation of Models

- For a given program, while common sense verification is possible, strict verification of a model is intractable, very much similar to the proof of correctness of a program.
- 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).

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

1. Build a model that has high face validity.
2. Validate model assumptions
3. Compare the model input-output transformations to corresponding input-output transformation for the real system.

Calibration and Validation of Models

Face Validity

- Build a ``reasonable model'' on its face to model users who are knowledgeable about the real system being simulated.

Calibration and Validation of Models

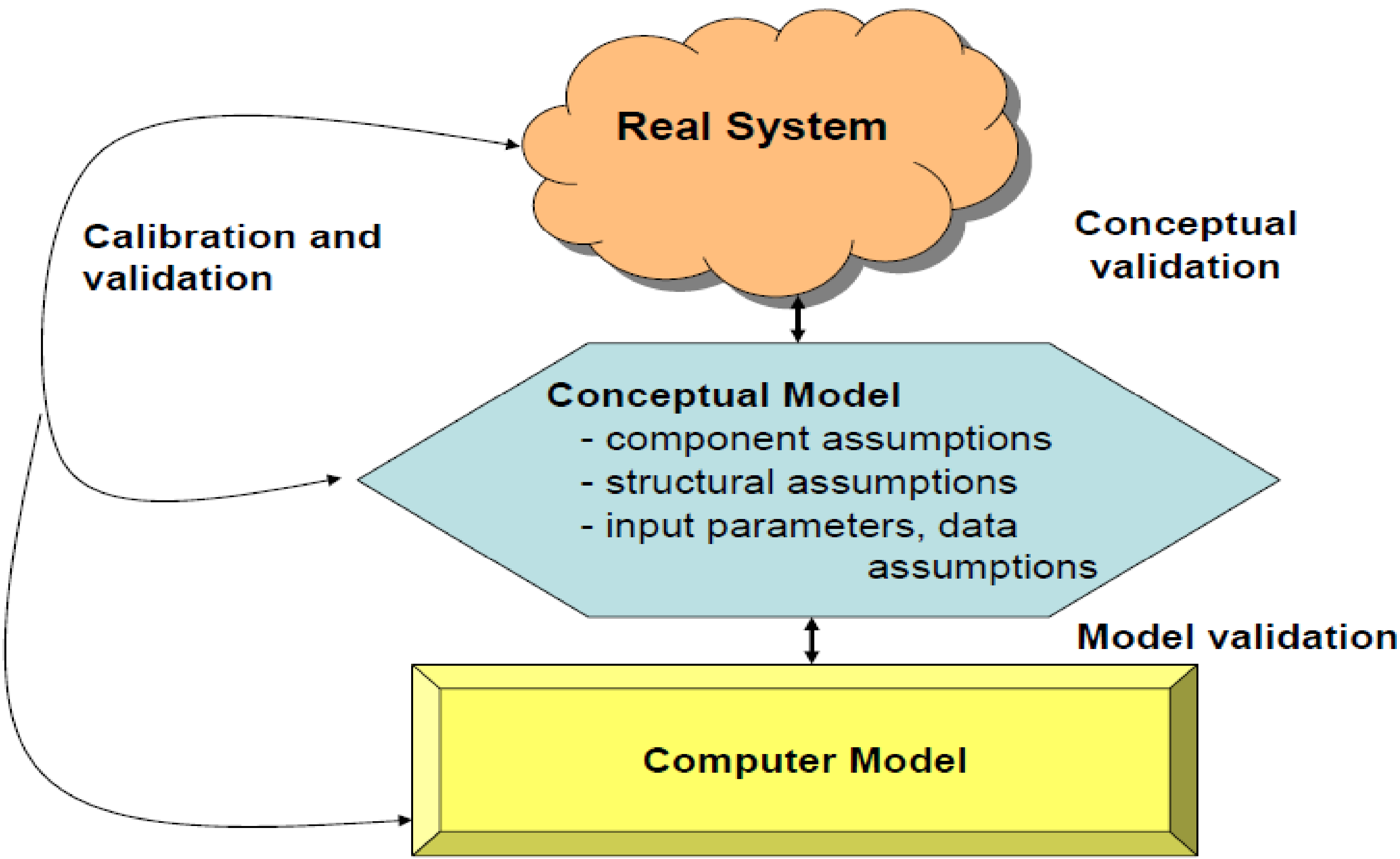
Validation of Model Assumptions

- Model assumptions fall into two categories: structural assumptions and data assumptions.
- 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: what kind of input data model is? What are the parameter values to the input data model?

Validating Input-Output Transformations

- View the model as a black box
- 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
- Otherwise, something is wrong

From modeling to simulation: model building, verification and validation

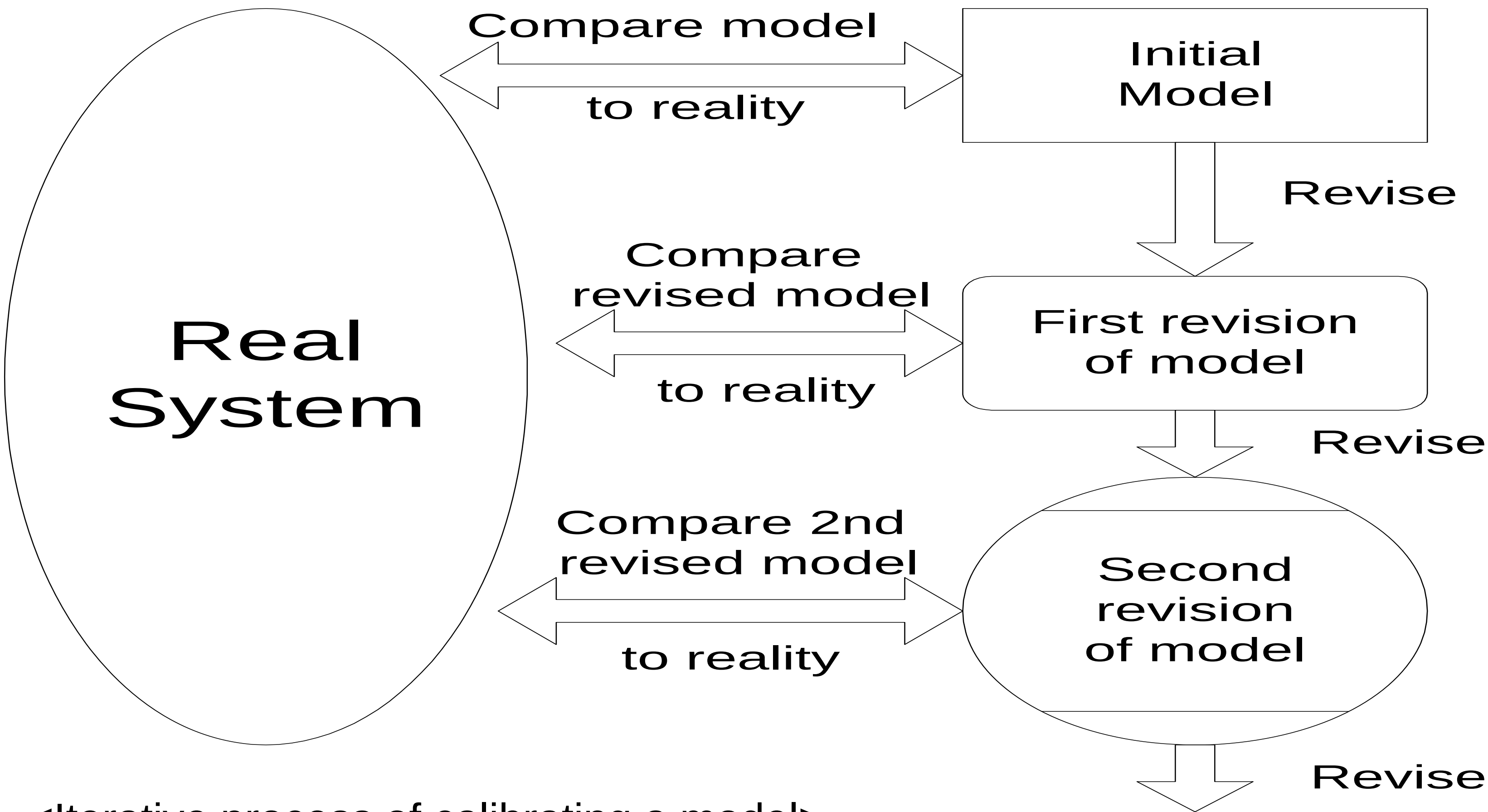


Model Calibration and Validation

- When a model is used to analyze a system, it is crucial for the user to understand how it represents the biological, physical and chemical processes relevant for the system under study.

- Without a knowledge of both the system under study and the model used to simulate it, it is not possible to correctly interpret the discrepancies between measured data and simulation outputs.

Calibration and Validation of Models

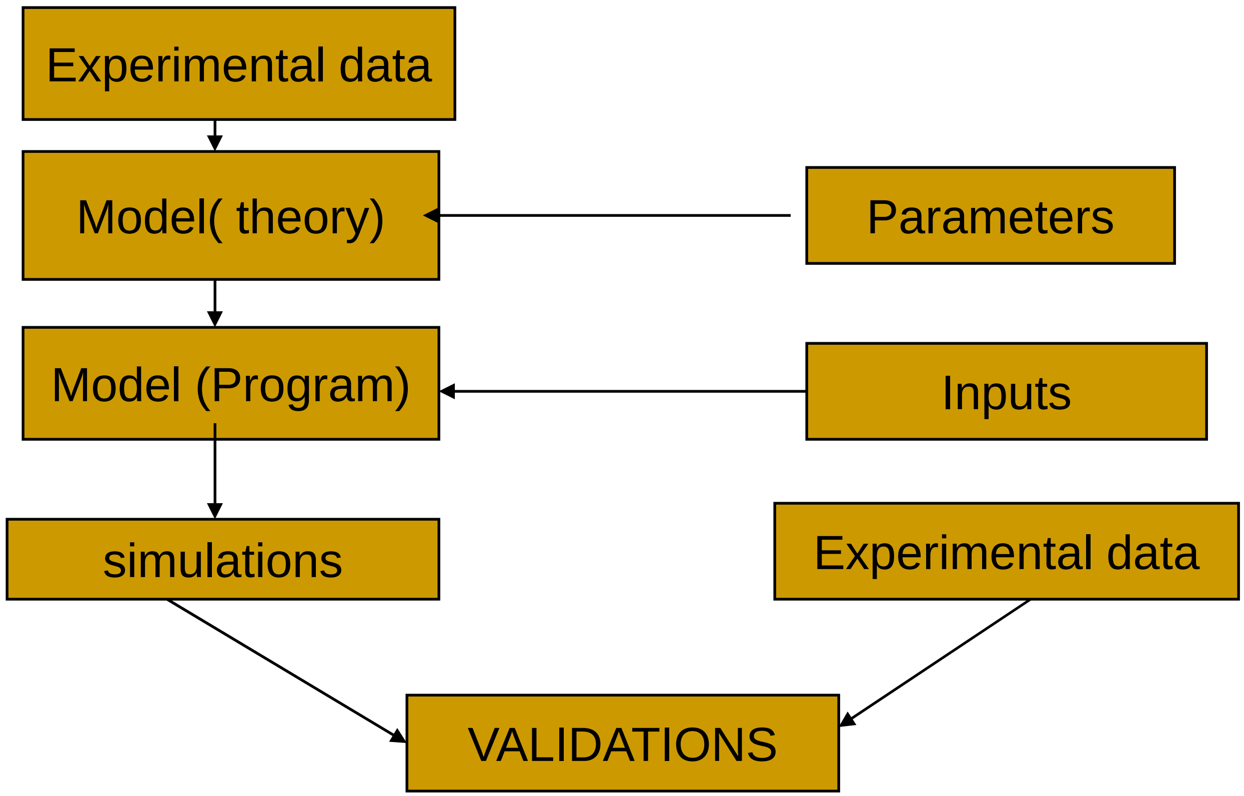


<Iterative process of calibrating a model>

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


Experimental data
Model(theory)
Parameters
Model (Program)
Inputs
simulations
Experimental data
VALIDATIONS

Validation: Errors

- 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.

1. Model inadequate
2. Lack of calibration
3. Errors in the code
4. Errors in the inputs
5. Errors in the use
6. Errors in the experimental data

Model Adequacy

- 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 undertaken to check a code:

1. Do calculations using for instance a spreadsheet and compare with model results
2. Verify that simulation results are within the known physical and biological reality
3. Run simulations with highly contrasting inputs

Errors in the Code

- 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 word.
- If correctly structured, a model contains the submodels 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.