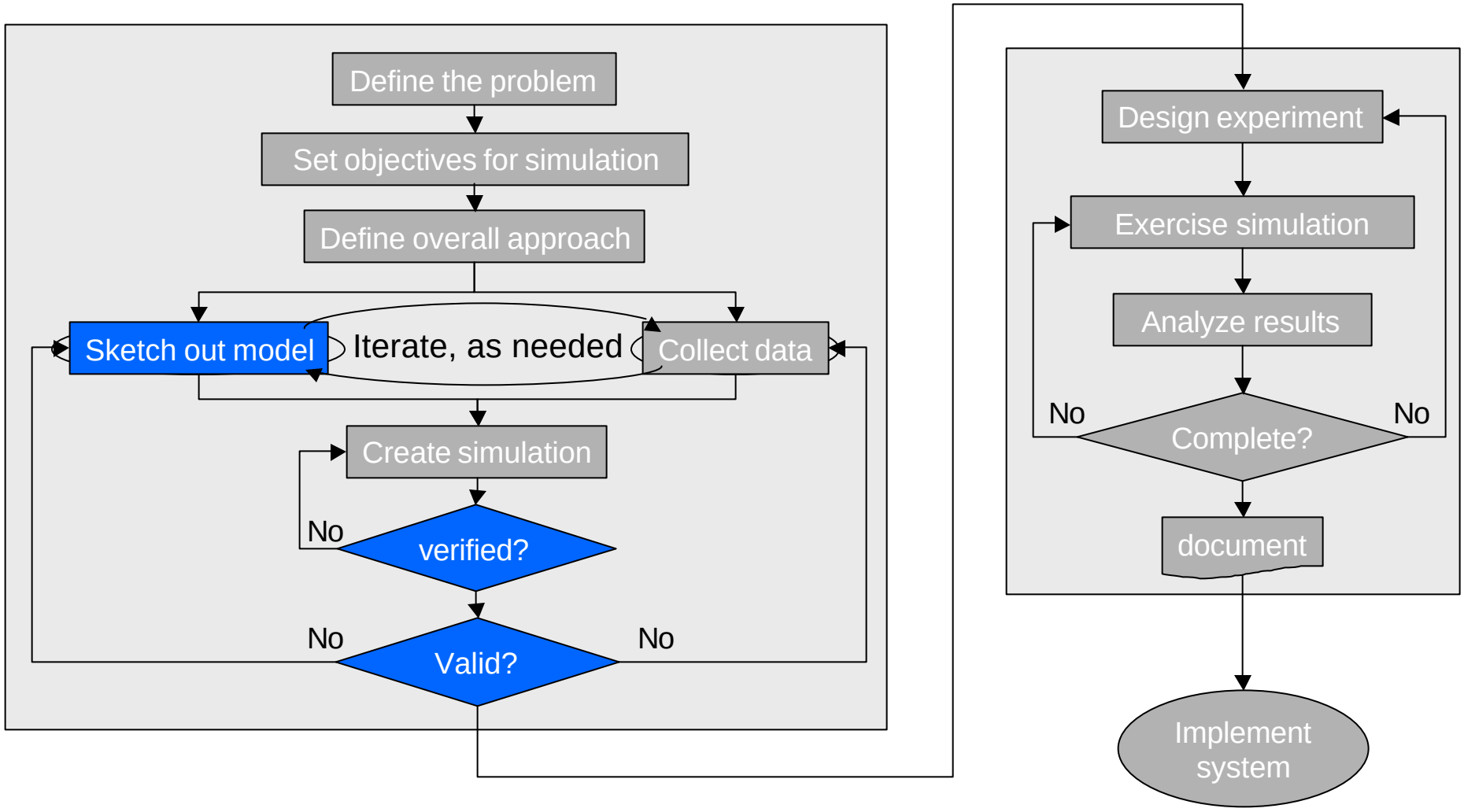
EE/CpE 345

Modeling and Simulation

Fall 2002

Class 11
November 25, 2002

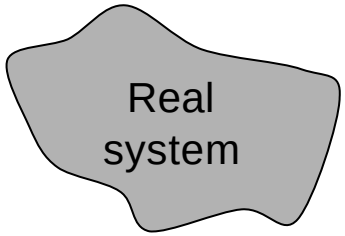
Steps in a simulation study



Verification and Validation of Simulation Models

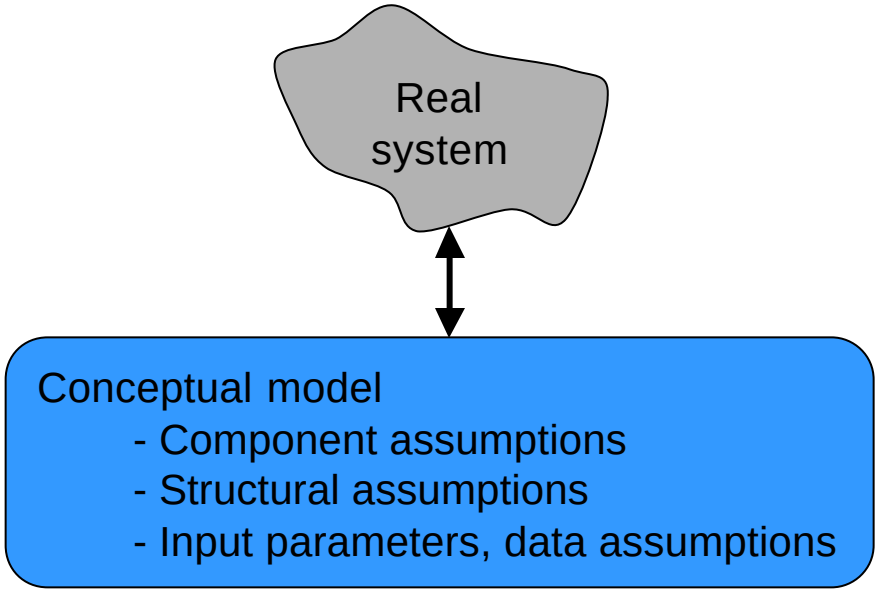
- Model
  - Building the model
  - Verification of the model - is the model built **correctly?**
  - Validation of the model - was the **correct** model built?
    - Face validity
    - Model assumptions
    - Input-output transformation
    - Is the model a reliable and credible representation of the real system?
      - Reliability -> user issue
      - Credibility -> manager issue
- Simulation
  - Verification of the simulation model - is the simulation a correct implementation of the model intended?

Model Building, Verification, and Validation



1. Observe and understand the real system's operation and behavior

Model Building, Verification, and Validation



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2. Create a conceptual model

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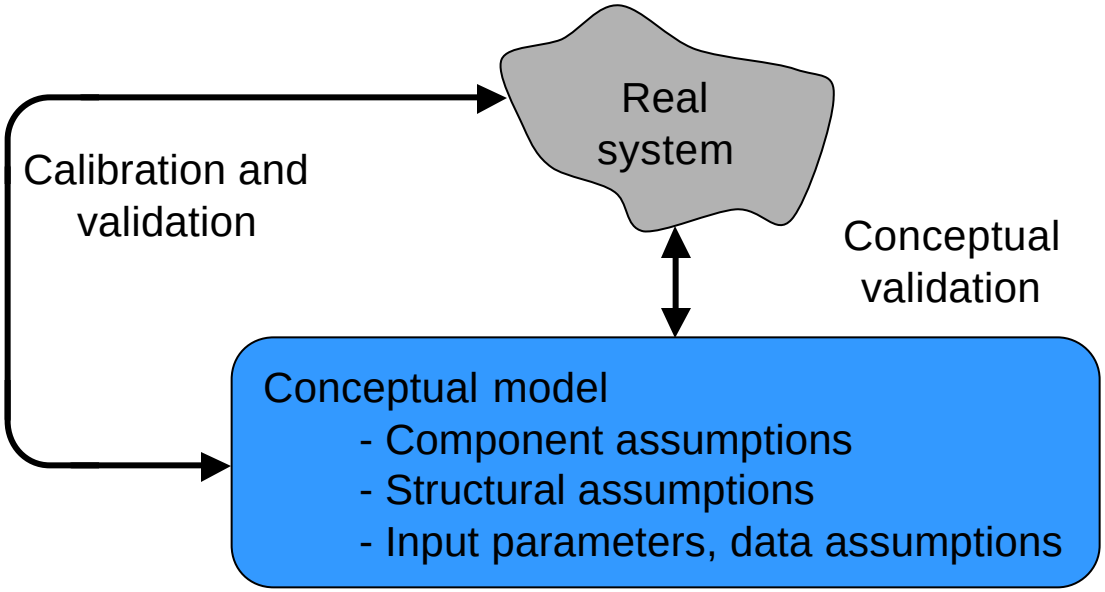

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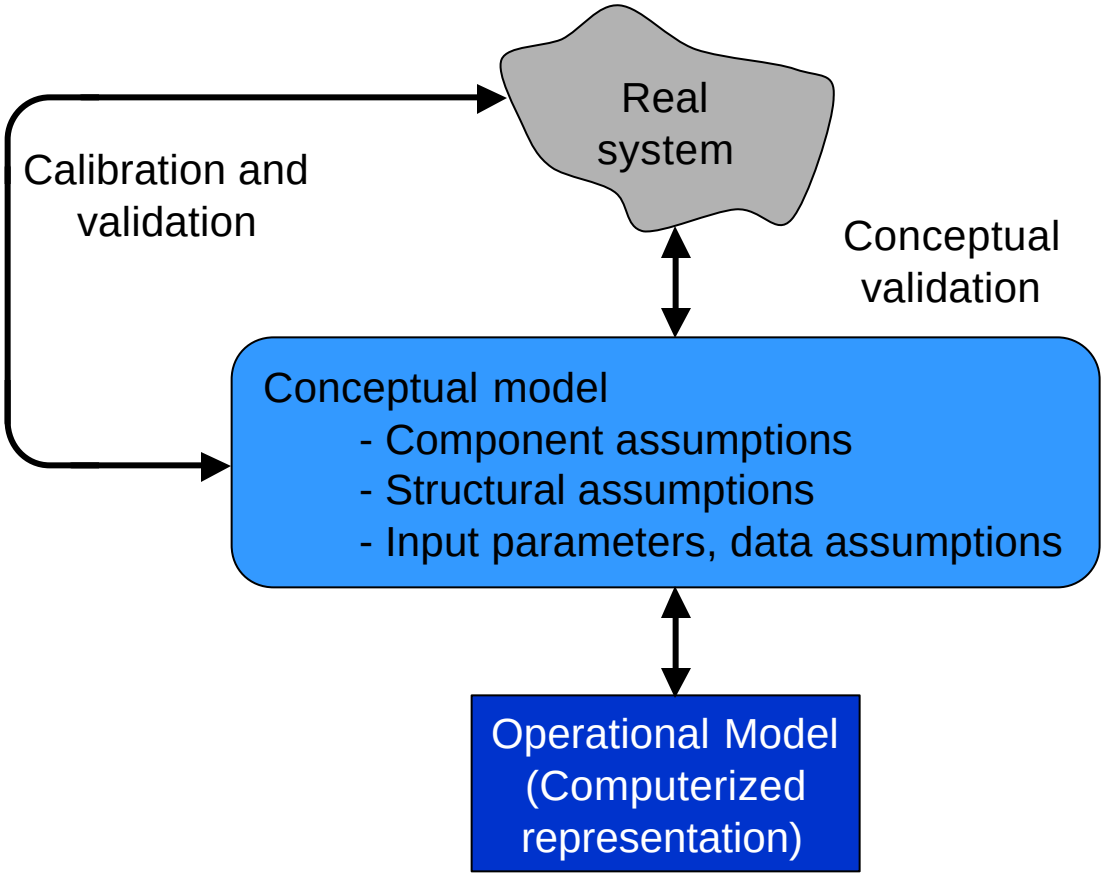

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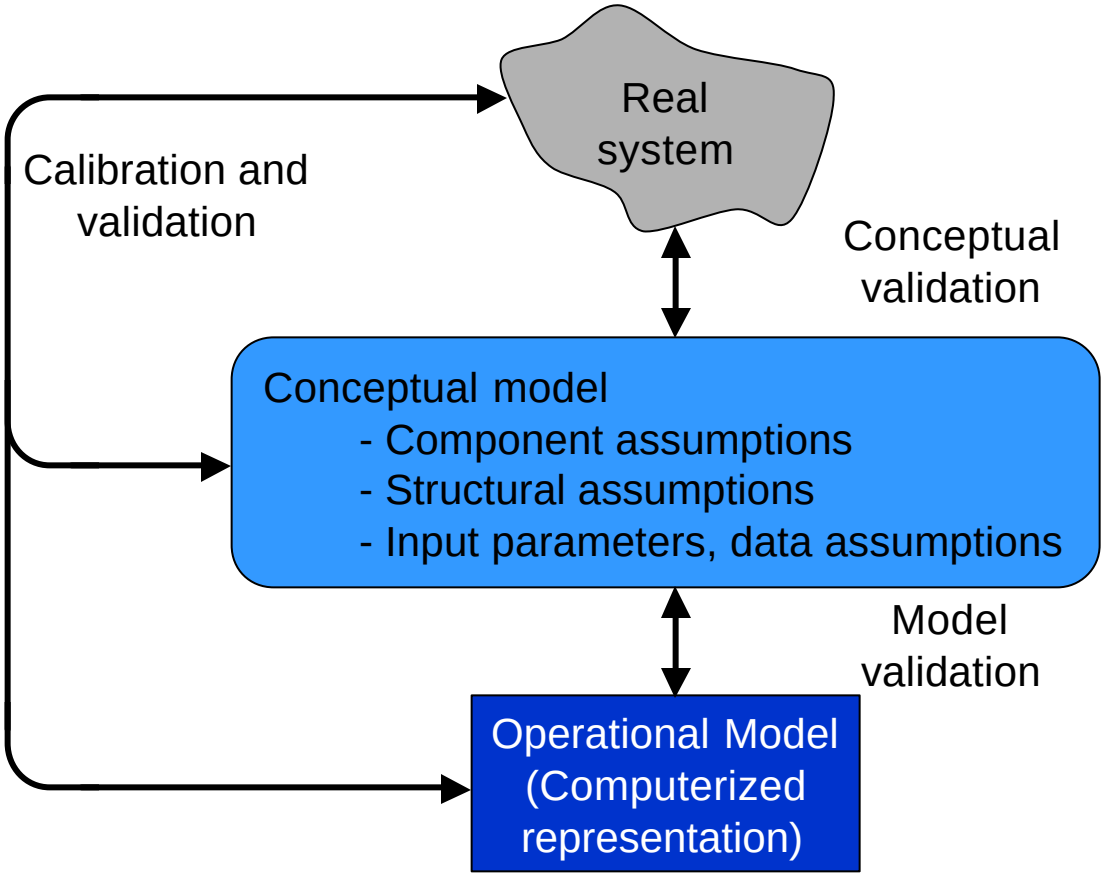

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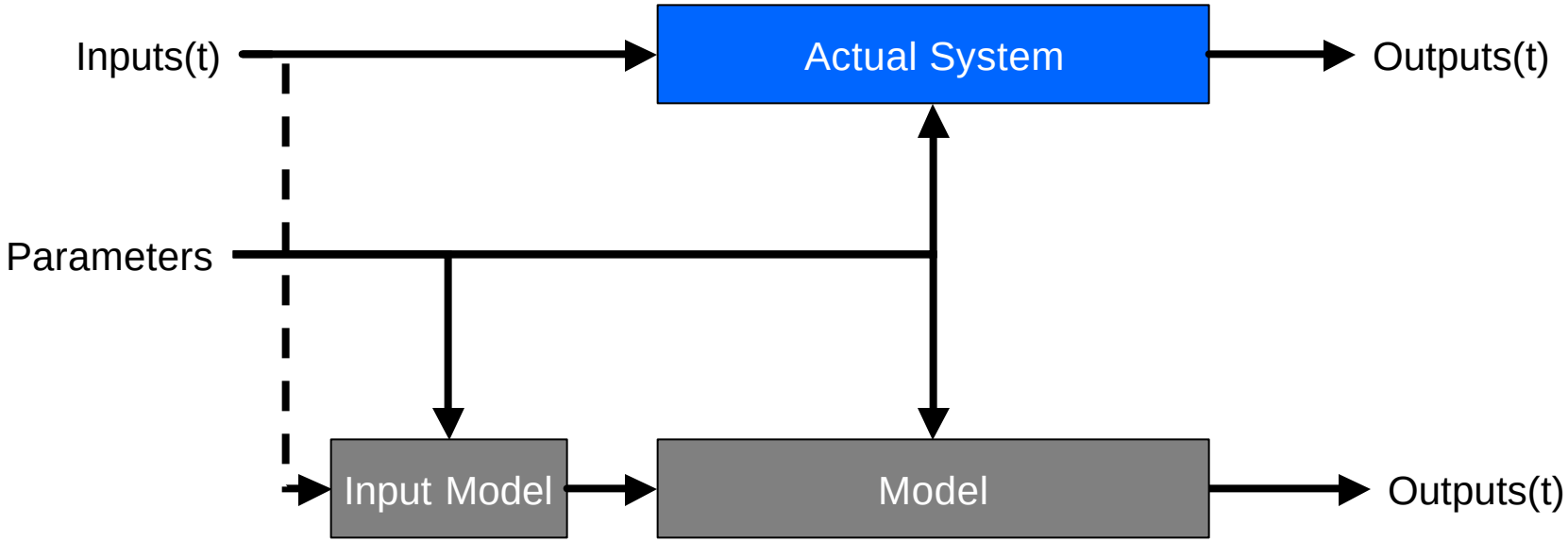
Verification of Simulation Models

- Is the computer simulation an accurate representation of the conceptual model?

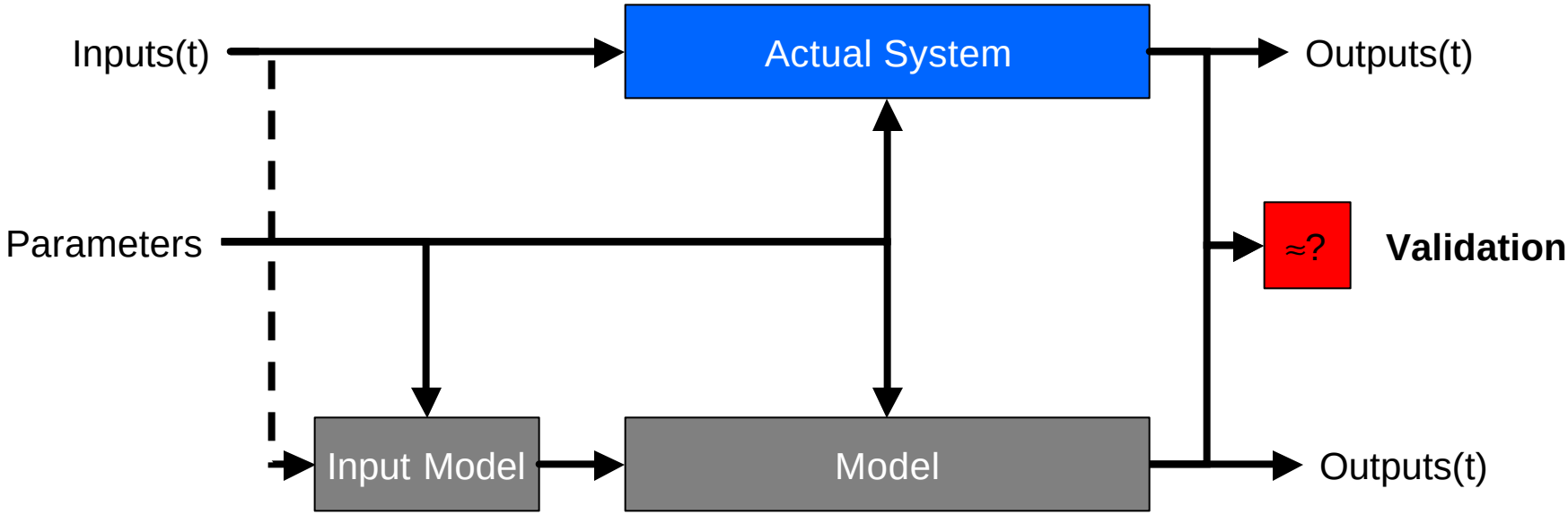
- Common sense approach to verification:
  - **VERIFY INITIAL CONDITIONS!**
  - Use graphical representation whenever possible - you can scan a 2 dimensional (graphical) view faster than a 1 dimensional (textual) view
    - Flow charts
    - Graphs of output behavior
    - Graphs of internal operation of model
    - Animations
  - Where possible, create internal model partitions that correspond to partitions in the real system - i.e., a top-down hierarchical view of model
  - **Test the simulation model for reasonableness under extreme value conditions**.
  - Test the simulation model for reasonableness under *variation* in parameters. Does the response follow the *direction* of the change?
  - Examine inputs and outputs of subsystems - too few or too many events may indicate errors elsewhere
  - Whenever possible, compare selected test conditions to analytical results

Calibration and Validation of Model



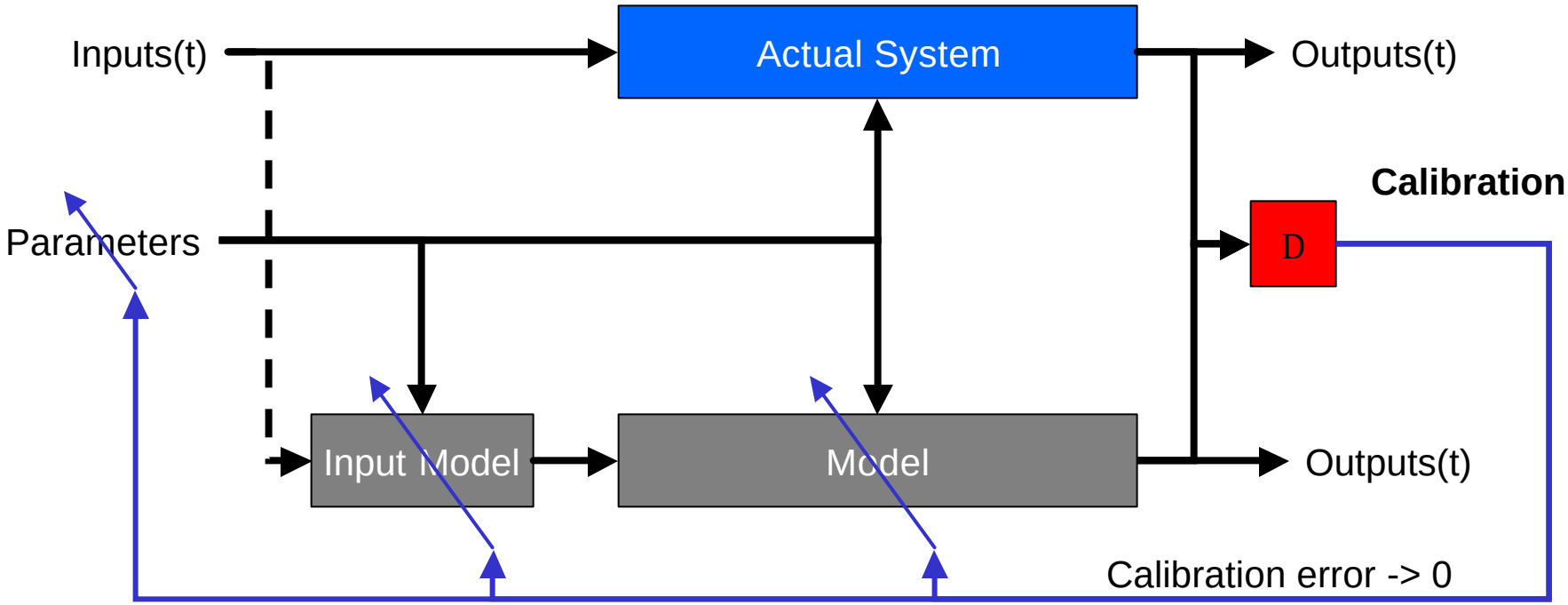
- Calibration and validation processes are distinct processes, normally performed simultaneously and interactively

Calibration and Validation of Model



- Validation - does the behavior of the simulated system match that of the real system?

Calibration and Validation of Model



- Calibration - adjust or alter models and parameters to best fit real system behavior
- Consider the calibration process as a feedback control system, adjusting model to minimize the error (difference between model and reality)
- Calibration/Validation stops when error is less than some threshold, often cost-based

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- Is the model reasonable on its face, i.e., without deep inspection or analysis
- Does behavior of model change in expected ways with modification of parameters?

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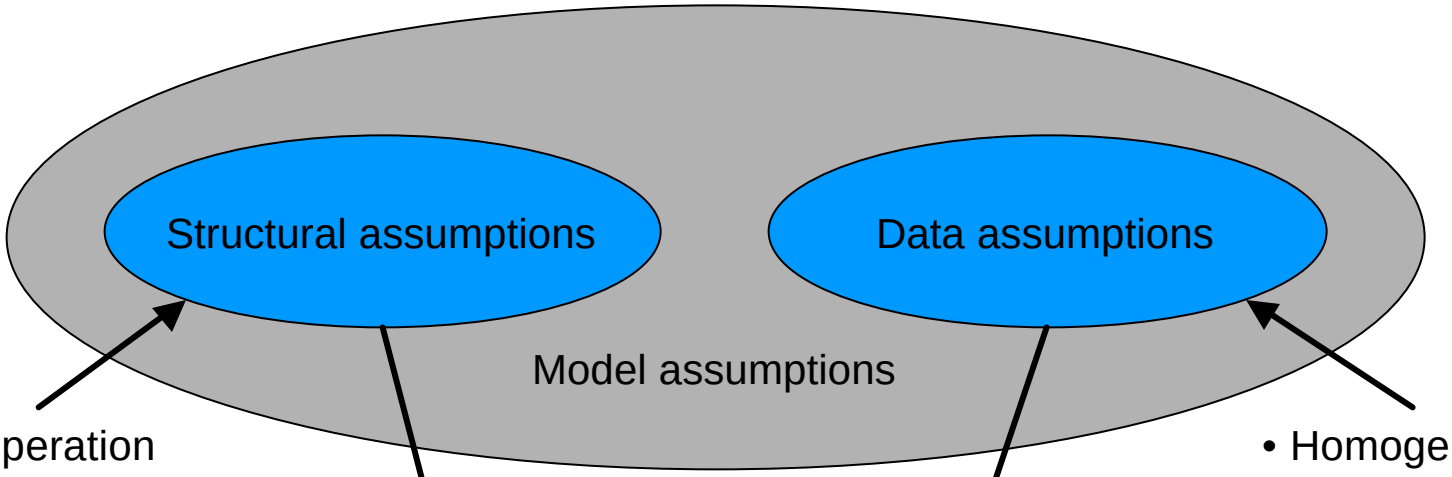
  - What happens to server utilization as the arrival rate, l, or service rate, m, increase, or as we change the number of servers, c?
  - r increases with increasing m, and decreases with increasing m, which is obviously incorrect. The change with changing c is appropriate.
  - This model is invalid on its face.

Validation of Model Assumptions



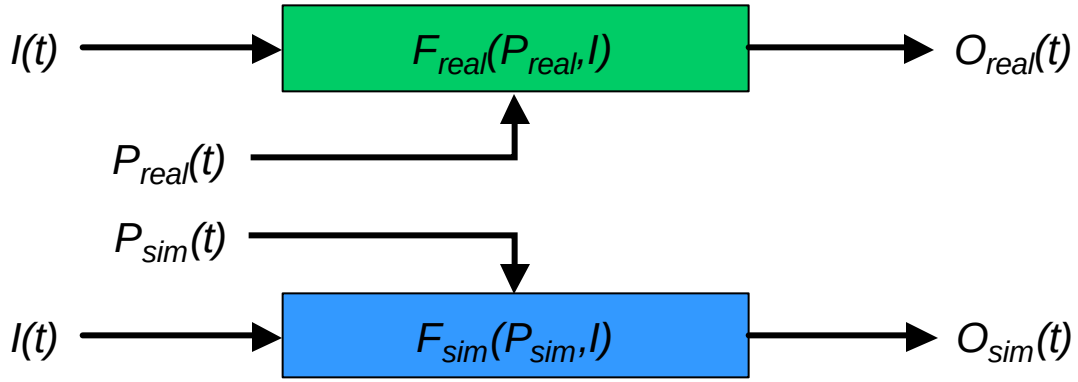
- System operation
- Simplifying assumptions
- Abstractions of reality

Based on:
- Observation

Based on:
- Collection of reliable data
- Correct statistical analysis

- Homogeneity
- Independence
- Distribution

Validating Input-Output Transformations



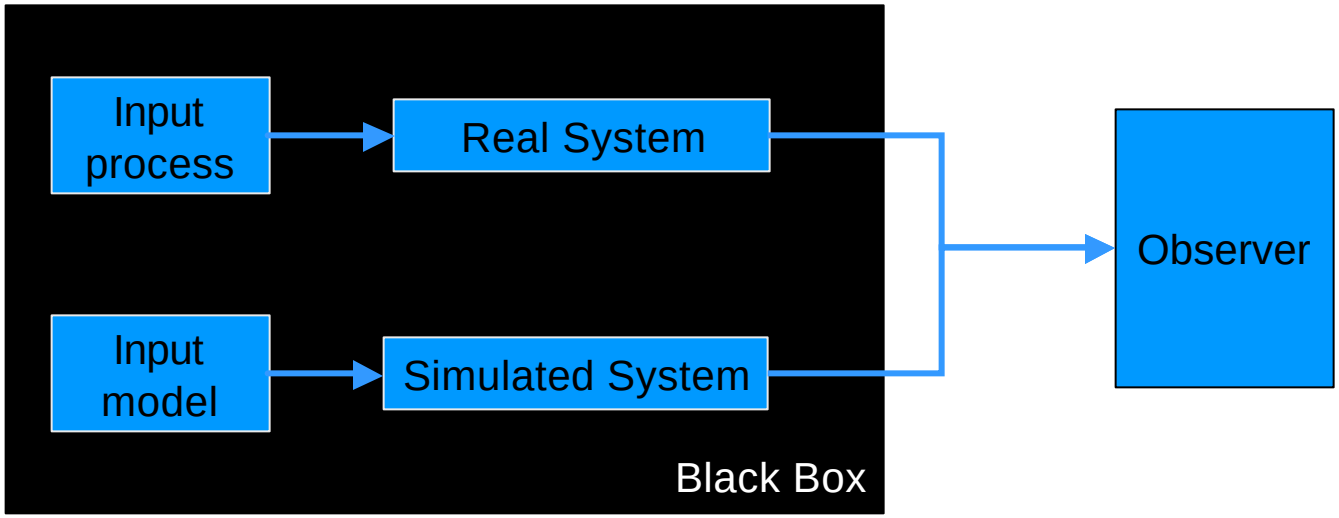
- Consider real system and simulation to be functional transformations of inputs, based on parameter settings

- To what extent does simulation:
  - agree with real system
  - accurately predict future behavior of real system
  - accurately predict behavior of real system under different input conditions or parameters?

- This is the only objective measure of the model as a whole

- Usable for comparison only if there is something to compare to!

The Turing Test

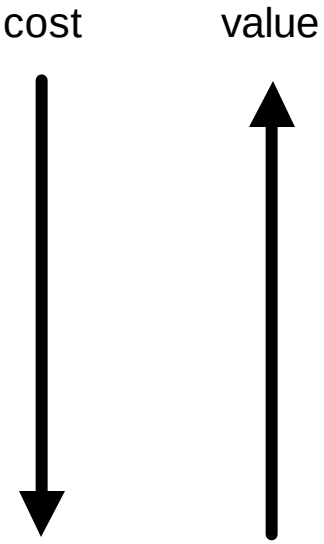


- If expert observer cannot distinguish output from real and simulated system with any consistency, validity of simulation is not refuted by this test
- If observer consistently identifies simulation, their critical observations can be used to improve simulation

Summary

- The quality of decisions made, based on a simulation and its underlying model, are only as good as the validity of the simulation and the model

- Possible validation techniques:
  - Develop models with high face validity, use existing knowledge
  - Conduct statistical tests on input
  - Conduct a Turing test
  - Compare model to real system output with statistical tests
  - Build new system based on simulation, collect data and use to validate model *(a.k.a. a cart-horse ordering problem)*
  - Do little or no validation *(Is this your lucky day?)*



Homework 11

- Complete your project - due for next class (12/2/02)