MFS605/EE605
Systems for Factory Information and Control

Lecture 6 (half lecture)
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Discrete-Event Simulation

Simulation: running model of system on a computer
Simulation allows specific questions and models

- **How is behavior during startup? During steady-state?**
- **What if we have a new inventory management policy?**
- **What if we have different kinds of parts circulating?**
- **What is the effect of a new piece of equipment?**
- **What kind of manpower do we need?**
- **What size buffers? Where?**
- **What about location and type of carts, conveyors, etc.?**
- **What is our predicted "performance"?**
  - Throughput time
  - Return on investment
  - WIP
  - Scrap

Advantages of Simulation

- **Cheaper and faster than prototype**
- **Less restrictive than deterministic or queueing models**
- **Can answer steady-state and transient questions.**

- **Disadvantages:**
  - **more detailed model --> more model-building time**
  - **no analytical relationships --> "try this and see"**
  - **potential pitfalls (to cover later)**

Review

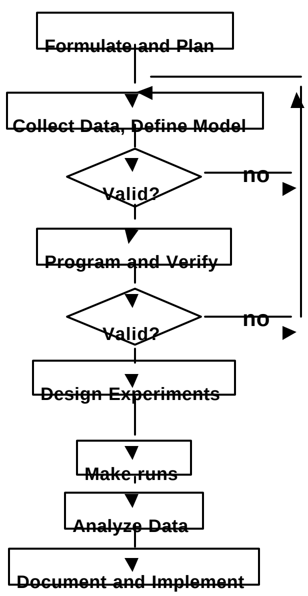
- **Discrete Event Simulation**
  - **run computer model of system instead of prototype**
  - **"Discrete-Event" because state changes at event occurrences, not every time step**

  - **Key idea: since events occur only infrequently, we can skip clock forward in time to next event**
    - maintain event list
    - maintain state variables
    - maintain clock
    - etc.

Classes of simulation tools

- **general purpose computer languages (write it yourself in C, etc.)**
- **simulation languages (SLAM, SIMAN, GPSS, …)**
- **graphical simulation modeling tools (Promodel, Arena, …)**

Steps of Successful Simulation Study



- **Formulate the problem and plan the study**
- **Collect data and model**

Issues in Modeling

- How detailed?
- What is the scope of the model?
- What assumptions will be made?
- What random variables to be modeled?

How complex a model?

- ***<u>Start simple, then add complexity only as needed</u>***
- **Complex models:**
  - **harder to understand, debug, validate, modify, document, explain, etc.**
  - **may be less accurate due to difficulty to debug and find errors**
- **Smaller models allow more replications and longer runs**
- **Judge simplifications in terms of impact on our performance measure: "will they increase or decrease it"?**

Common Modeling Problems

- Selection of inappropriate distributions

Common Modeling Problems (cont.)

- Removing Randomness by using mean instead of distribution

How do we choose distributions?

- Use collected data directly as input to the simulation
  - Problems:

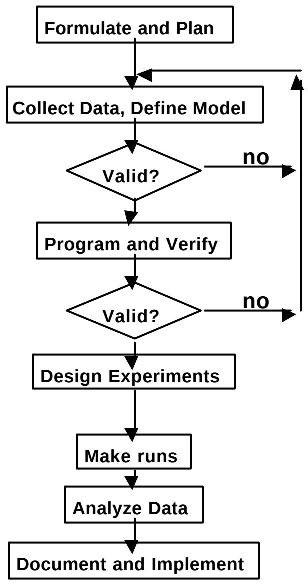
- Use data to define empirical distribution

- Fit a theoretical distribution form to the data
  - may smooth out irregularities in an empirical model
  - able to generate extremes that may not be in original samples
  - sometimes physical reason to assume distribution

Example: dangers in modeling

- Single machine, broken 10% of time
  - Model 1: machine breaks on avg of 540 min., then down for 60 minutes
  - Model 2: machine breaks down avg. of 54 minutes, then down for avg. of 6 min.
  - Model 3: Production rate is just decreased by 10% (thus machine breaks down constantly)

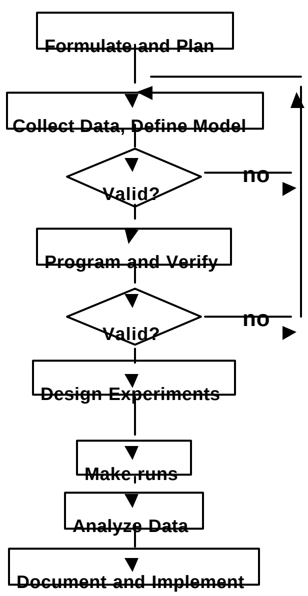
Steps of Successful Simulation Study



- **<u>Validating:</u>**
  - **Does the model appropriately represent reality??**

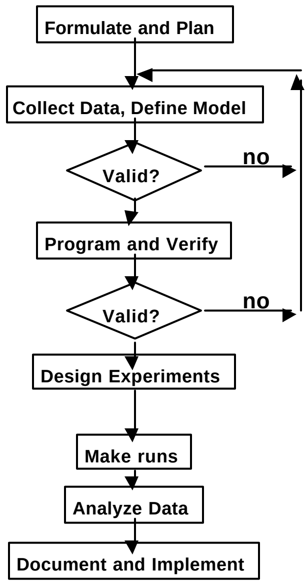
- **<u>Verifying:</u>**
  - **Is the program faithful to the model??**

Steps of Successful Simulation Study



- **Program and Verify**
  - ***Programming should only be 30-40% of time for study!***

Steps of Successful Simulation Study



- Design Experiments
  - How long a run?
  - Initial Conditions?
  - # of runs?

- Keys:
  - Don't consider a single run valid
  - Don't neglect warmup period

Model methods

- Event Model view
- Process model view

Event Models

- **Event graph:**
  - **Identifies events and shows interrelationships**

  - **Nodes = events**
  - **Arcs indicate how one event schedules others**
- **Example: single machine from last time:**
  - **Arrival event schedules:**
    - next arrival
    - start service event (if idle)
  - **Start service event schedules completion event**
  - **Completion event (if queue not empty) schedules next start service.**

Process Models

- **Simulation model divided into:**
  - **Resources**
    - Machines, operators, etc.
    - May have states: such as idle, busy, down, etc.
  - **Transactions (entities)**
    - Properties are “Attributes”
  - **Queues**
    - May include speeds, capacity, etc.

- ***Process model* view: Consider sequence of steps taken by a transaction in the system. Sequence of steps called *process*.**
- **Model may have multiple processes interacting together.**

Process model example

- Part arrives to system
- Part enters buffer
- Part starts service
- Part completes service

Pitfalls to avoid…

1. Failure to have well defined objectives
2. Inappropriate level of model detail
3. Failure to interact with management on a regular basis
4. Insufficient simulation and statistics training
5. Inappropriate simulation software
6. Misuse of animation
7. Replacing a distribution by its mean
8. Using the wrong probability distribution
9. Incorrect modeling of machine down times
10. Misinterpretation of simulation results