IE 373: Facility & Simulation Overview

J. MacGregor Smith
- Sara Gately-Cayatte (Lab Assistant)

Department of Mechanical and Industrial Engineering
- University of Massachusetts Amherst, Massachusetts
- Fall 2004

Fundamental Modelling Problems

- Manufacturing & Service Systems Flow Analysis
  - Step 1.0: Representation of Systems
  - Step 2.0: Analysis of Systems
  - Step 3.0: Synthesis

Step 1.0: Representation of Systems

- Topology of Production/Service System
- Number of nodes
- Number of links
- Customer/Product Types
- Routing vectors
- Service/Workstation rates
- Arrivals of Products/Customers

Facility Planning

- Facility Planning
- Map of Facility
- Diagram of Facility
Step 2.0: Analysis of Systems

Performance Measures
- Throughput
- Work-in-Process (WIP)
- Utilization of Resources

Statistical Analysis
- Confidence Intervals
- Simulation Run Length
- Verification of Model
- Validation of Simulation
- Design of Experiments

Step 3.0: Synthesis

Optimization of Topology/Layout
- Series, Split, Merge Topologies

Optimal Routing and Scheduling of Jobs
- % to certain routes
- Queue Discipline: FCFS, LCFS, Priority, etc.

Optimal Resource Utilization
- number of servers
- number of buffers
- location and arrangement of buffers and servers

Specific Problems and Benefits

Machine/Cell Configuration
- Layout and Location

Resource Allocation Problem
- Optimal Number of Personnel
- Optimal Number of Machines

Scheduling and Inventory Modelling
- Static vs. Real Time
- Forecasting
- Cost Analysis

What is Simulation

Very broad term, set of problems/approaches which involves the construction of a model, normally a mathematical model, in order to represent the dynamic responses of one system by the behavior of another system

The model is comprised of equations that duplicate the functional relationships within the real system.

Generally, imitation of a system via computer

Involves a model—validity?

Many Application Areas

Manufacturing—scheduling, inventory
Staffing personal-service operations
- Banks, fast food, theme parks, Post Office, ...

Distribution and logistics
- Health care—emergency, operating rooms
- Computer systems
- Telecommunications
- Military
- Public policy
- Emergency planning
- Courts, prisons, probation/parole

Don't even aspire to analytic solution
- Don't get exact results (bad)
- Allows for complex, realistic models (good)

Approximate answer to exact problem is better than exact answer to approximate problem

Consistently ranked as most useful, powerful of mathematical-modeling approaches
### Systems

Physical facility/process, actual or planned  
Study its performance  
- Measure  
- Improve  
- Design (if it doesn’t exist)  
- Maybe control in real time  
- Sometimes possible to “play” with the system  
- But sometimes impossible to do so  
  - Doesn’t exist  
  - Disruptive, expensive

### Models

Abstraction/simplification of the system used as a proxy for the system itself  
Can try wide-ranging ideas in the model  
- Make your mistakes on the computer where they don’t count, rather than real where they *do* count  
- Issue of model validity  
- Two types of models  
  - Physical (iconic)  
  - Logical/Mathematical -- quantitative and logical assumptions, approximations

### What Do You Do with a Logical Model?

If model is simple enough, use traditional mathematics (queueing theory, differential equations, linear programming) to get “answers”  
- Nice in the sense that you get “exact” answers to the model  
- But might involve many simplifying assumptions to make the model analytically tractable -- validity??  
- Many complex systems require complex models for validity—simulation needed

### Computer Simulation

Methods for studying a wide variety of models of real-world systems  
- Use numerical evaluation on computer  
- Use software to imitate the system’s operations and characteristics, often over time  
- In practice, is the process of designing and creating computerized model of system and doing numerical computer-based experiments  
- Real power—application to complex systems  
- Simulation can tolerate complex models

### Popularity

M.S. grads, CWRU O.R. Department (1978)  
- Asked about value after graduation; rankings:  
- 137 large firms (1979)  
  1. Statistical analysis (93% used it)  
  2. Simulation (84%)  
  - Followed by LP, PERT/CPM, inventory, NLP

(A)IE, O.R. division members (1980)  
- First in utility and interest: Simulation  
- But first in familiarity: LP (simulation was second)  
  1. Statistical analysis  
  2. Simulation  
- Survey of such surveys (1989)  
  - Consistent heavy use of simulation
Advantages of Simulation

Flexibility to model things as they are (even if messy and complicated)
- Avoid "looking where the light is" (a morality play):
  - "It's nothing short in the dark and we can see on hands and knees searching the ground under a street light."
  - "What's wrong? Did I break you?"
  - Other person: "I dropped my coat away and ran find you."
  - You: "Oh, I dropped them over there." (Points into the darkness.)
  - Other person: "Okay, why are you walking here?"
  - You: "Because this is where the light is."
- Allows uncertainty, nonstationary in modeling
  - The only thing that's sure: nothing is for sure
  - Danger of ignoring system variability
  - Model validity

Advantages of Simulation (cont'd.)

Advances in computing/cost ratios
- Estimated that 75% of computing power is used for various kinds of simulations
- Dedicated machines (e.g., real-time shop-floor control)
- Advances in simulation software
- Far easier to use (GUIs)
- No longer as restrictive in modeling constructs (hierarchical, down to C)
- Statistical design & analysis capabilities

The Bad News

Don't get exact answers, only approximations, estimates
- Also true of many other modern methods
- Can bound errors by machine roundoff
- Get random output (RIRO) from stochastic simulations
  - Statistical design, analysis of simulation experiments
  - Exploit: noise control, replicability, sequential sampling, variance-reduction techniques
  - Catch: "standard" statistical methods seldom work

Different Kinds of Simulation

Static vs. Dynamic
- Does time have a role in the model?
- Continuous-change vs. Discrete-change
  - Can the "state" change continuously or only at discrete points in time?
- Deterministic vs. Stochastic
  - Is everything for sure or is there uncertainty?
- Most operational models:
  - Dynamic, Discrete-change, Stochastic

Using Computers to Simulate (cont'd.)

General-purpose languages (FORTRAN)
- Tedious, low-level, error-prone
- But, almost complete flexibility
- Support packages
  - Subroutines for list processing, bookkeeping, time advance
  - Widely distributed, widely modified
- Spreadsheets
  - Usually static models
  - Financial scenarios, distribution sampling, SQC

Simulation languages
- GPSS, SIMSCRIPT, SLAM, SIMAN
- Popular, in wide use today
- Learning curve for features, effective use, syntax
- High-level simulators
  - Very easy, graphical interface
  - Domain-restricted (manufacturing, communications)
  - Limited flexibility—model validity?
When Simulations are Used

Uses of simulation have evolved with hardware, software

The early years (1950s-1960s)
• Very expensive, specialized tool to use
• Required big computers, special training
• Mostly in FORTRAN (or even Assembler)
• Processing cost as high as $1000/hour for a sub-286 level machine

When Simulations are Used (cont’d.)

The formative years (1970s-early 1980s)
• Computers got faster, cheaper
• Value of simulation more widely recognized
• Simulation software improved, but they were still languages to be learned, typed, batch processed
• Often used to clean up “disasters” in auto, aerospace industries
  – Car plant; heavy demand for certain model
  – Line underperforming
  – Simulated, problem identified
  – But demand had dried up—simulation was too late

When Simulations are Used (cont’d.)

The recent past (late 1980s)
• Microcomputer power
• Software expanded into GUIs, animation
• Wider acceptance across more areas
  – Traditional manufacturing applications
  – Services
  – Health care
  – “Business processes”
• Still mostly in large firms
• Often a simulation is part of the “specs”

When Simulations are Used (cont’d.)

The present
• Proliferating into smaller firms
• Becoming a standard tool
• Being used earlier in design phase
• Real-time control

The future
• Exploiting interoperability of operating systems
• Specialized “templates” for industries, firms
• Automated statistical design, analysis