Simulation

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What is Simulation?

Chapter 1
Simulation Is …

- *Simulation* – very broad term – methods and applications to imitate or mimic real systems, usually via computer
- Applies in many fields and industries
- Very popular and powerful method
- Book covers simulation in general and the *Arena* simulation software in particular
- This chapter – general ideas, terminology, examples of applications, good/bad things, kinds of simulation, software options, how/when simulation is used
• **System** – facility or process, actual or planned
  
  ▪ Examples abound …
    – Manufacturing facility
    – Bank operation
    – Airport operations (passengers, security, planes, crews, baggage)
    – Transportation/logistics/distribution operation
    – Hospital facilities (emergency room, operating room, admissions)
    – Computer network
    – Freeway system
    – Business process (insurance office)
    – Criminal justice system
    – Chemical plant
    – Fast-food restaurant
    – Supermarket
    – Theme park
    – Emergency-response system
Work With the System?

• Study the system – measure, improve, design, control
  ▪ Maybe just play with the actual system
    – Advantage — unquestionably looking at the right thing
  ▪ But it’s often impossible to do so in reality with the actual system
    – System doesn’t exist
    – Would be disruptive, expensive, or dangerous
Models

- **Model** – set of assumptions/approximations about how the system works
  - Study the model instead of the real system … usually much easier, faster, cheaper, safer
  - Can try wide-ranging ideas with the model
    - Make your mistakes on the computer where they *don’t* count, rather than for real where they *do* count
  - Often, just *building* the model is instructive – regardless of results
  - Model *validity* (any kind of model … not just simulation)
    - Care in building to mimic reality faithfully
    - Level of detail
    - Get same conclusions from the model as you would from system
    - More in Chapter 13
Types of Models

• **Physical (iconic) models**
  - Tabletop material-handling models
  - Mock-ups of fast-food restaurants
  - Flight simulators

• **Logical (mathematical) models**
  - Approximations and assumptions about a system’s operation
  - Often represented via computer program in appropriate software
  - Exercise the program to try things, get results, learn about model behavior
• If model is simple enough, use traditional mathematical analysis … get exact results, lots of insight into model
  - Queueing theory
  - Differential equations
  - Linear programming

• But complex systems can seldom be validly represented by a simple analytic model
  - Danger of over-simplifying assumptions … model validity?
  - Type III error – working on the wrong problem

• Often, a complex system requires a complex model, and analytical methods don’t apply … what to do?
Computer Simulation

- Broadly interpreted, computer simulation refers to methods for studying a wide variety of models of systems
  - Numerically evaluate on a computer
  - Use software to imitate the system’s operations and characteristics, often over time
- Can be used to study simple models but should not use it if an analytical solution is available
- Real power of simulation is in studying complex models
- Simulation can tolerate complex models since we don’t even aspire to an analytical solution
• Consistently ranked as the most useful, popular tool in the broader area of operations research / management science
  
  1978: M.S. graduates of CWRU O.R. Department … after graduation
  1. Statistical analysis
  2. Forecasting
  3. Systems Analysis
  4. Information systems
  5. Simulation

  1979: Survey 137 large firms, which methods used?
  1. Statistical analysis (93% used it)
  2. Simulation (84%)
  3. Followed by LP, PERT/CPM, inventory theory, NLP, …
Popularity of Simulation (cont’d.)

- **1980:** (A)IIE O.R. division members
  - First in utility and interest — simulation
  - First in familiarity — LP (simulation was second)

- **1983, 1989, 1993:** Longitudinal study of corporate practice
  1. Statistical analysis
  2. Simulation

- **1989:** Survey of surveys
  - Heavy use of simulation consistently reported
Advantages of Simulation

- **Flexibility to model things as they are (even if messy and complicated)**
  - Avoid *looking where the light is* (a morality play):
    You’re walking along in the dark and see someone on hands and knees searching the ground under a street light.
    You: “What’s wrong? Can I help you?”
    Other person: “I dropped my car keys and can’t find them.”
    You: “Oh, so you dropped them around here, huh?”
    Other person: “No, I dropped them over there.” (Points into the darkness.)
    You: “Then why are you looking here?”
    Other person: “Because this is where the light is.”

- **Allows uncertainty, nonstationarity in modeling**
  - The only thing that’s for 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*
    - Though Chapter 11 discusses continuous and combined discrete-continuous models
Simulation by Hand: The Buffon Needle Problem

- Estimate $\pi$ (George Louis Leclerc, c. 1733)
- Toss needle of length $l$ onto table with stripes $d$ ($>l$) apart
- $P$ (needle crosses a line) = $\frac{2l}{\pi d}$
- Repeat; tally $\hat{p}$ = proportion of times a line is crossed
- Estimate $\pi$ by $\frac{2l}{\hat{p}d}$
Why Toss Needles?

- Buffon needle problem seems silly now, but it has important simulation features:
  - Experiment to *estimate* something hard to compute exactly (in 1733)
  - *Randomness*, so estimate will not be exact; estimate the error in the estimate
  - *Replication* (the more the better) to reduce error
  - *Sequential sampling* to control error — keep tossing until probable error in estimate is “small enough”
  - *Variance reduction* (*Buffon Cross*)
Using Computers to Simulate

- **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 (on which Arena is based, and is included in Arena)
  - Popular, still in use
  - Learning curve for features, effective use, syntax

• High-level simulators
  - Very easy, graphical interface
  - Domain-restricted (manufacturing, communications)
  - Limited flexibility — model validity?
Where Arena Fits In

- **Hierarchical structure**
  - Multiple levels of modeling
  - Can mix different modeling levels together in the same model
  - Often, start high then go lower as needed

- **Get ease-of-use advantage of simulators without sacrificing modeling flexibility**

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Higher

User-Created Templates
- Commonly used constructs
- Company-specific processes
- Company-specific templates
  etc.

Application Solution Templates
- Contact centers
- Packaging lines
  etc.

Basic Process Panel
- Many common modeling constructs
- Very accessible, easy to use
- Reasonable flexibility

Advanced Process, Advanced Transfer Panels
- Access to more detailed modeling for greater flexibility

Blocks, Elements Panels
- All the flexibility of the SIMAN simulation language

Lower

User-Written Visual Basic, C/C++ Code
- The ultimate in flexibility
- VBA is built in
- C/C++ requires compiler
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• 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
• 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
• The recent past (late 1980s-1990s)
  ▪ Microcomputer power
  ▪ Software expanded into GUls, 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
  ▪ Networked sharing of data in real time
  ▪ Integration with other applications
  ▪ Distributed model building, execution