Discrete Event Simulation Modeling

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Simulation: What is it? What for?

Simulation is the approximate representation of reality by mathematical models and computer algorithms.

Simulation is technology designed to help lead people, managers and others make better choices when confronted with difficult decisions and when seeking to improve performance.
Simulation Models

**Deterministic**
Model elements behave according to established physical laws

**Stochastic/Probabilistic**
Behavior of model elements is affected by uncertainty
Discrete Event Simulation

A stochastic modeling methodology in which the evolution of the simulated system takes place through a sequence of changes of its state induced by the occurrence of key events which may be subject to statistical variability.
Successful Applications of DES
(see www.wintersim.org)

- Production Analysis
- Operations Management
- Project Management
- Shop Floor Organization
- Scheduling/Planning
- Business Process Improvement
- Customer Relations
- Inventory Control
- Supply Chain Management
- Purchasing and Sales
- Outsourcing Strategy
- Logistics
- Health Care
- Finance and Insurance
- Risk Assessment
- Military Strategy
Discrete Event Simulation: Key Elements

System and Environment
Entities, Attributes and Activities
Events and their Probabilities
Time, Counter and State Variables
System and Environment

- **System**: Portion of the Universe selected for Study
- **Environment**: Anything else not contained inside the System
Example: Production System

- **Entities** = Widgets, Machines, Workers
- **Attributes** = Types, Speed, Capacity, Failure and Repair Rates, Skill Level and Attitude
- **Activities** = Casting, Forging, Machining, Welding, Moving, Monitoring
- **Events** = Breakdown, Arrival
- **State Variables** = WIP, Busy, Idle
Example: Inventory System

- **Entities** = Warehouse, Handling Systems
- **Attributes** = Design, Capacity
- **Activities** = Withdrawing, Storing
- **Events** = New Order Arrival, Order Fulfillment
- **State Variables** = Inventory level, Backlogged Demands
Example: Banking System

- **Entities** = Customers
- **Attributes** = Account balances
- **Activities** = Withdrawals, Deposits
- **Events** = Arrival, Departure
- **State Variables** = Number of customers in systems, Number of busy tellers
Example: Mass Transportation System

- **Entities** = Riders
- **Attributes** = Destination, Origination
- **Activities** = Riding
- **Events** = Boarding, Getting Off
- **State Variables** = Number of riders in system, Number of riders at each stop
Events and their Probabilities

- **Events**: Occurrences or Happenings which cause a Change in the State of the System

- **Deterministic vs Stochastic**: Events can be fully Deterministic or subjected to Stochastic Uncertainty
Modeling Uncertainty

- Uncertainty is represented in DES in terms of the probability distribution functions of the variables involved.
- Replicated runs are used to obtain statistically representative samples.
Probability Distributions of Input Variables
Time Evolution of the Probability Distributions of Output Variables
Steps in a DES Study

Problem Formulation; Objectives

Model Conceptualization; Data Gathering; Model Translation

Verification; Validation

Document; Report

Production Runs

Implement
DES Software

- Simscript/ModSim
- ProModel
- Witness
- Arena
- FlexSim

- Automod
- Simul8
- Micro Saint Sharp
- OO-SML
- Supply Chain Builder
DES: Elementary Examples

- Queueing Systems
- Inventory Systems
- Machine Repair Systems
- Insurance Systems
Queueing Systems

- Customer Arrival Rate \((\lambda)\)
- Service Rate \((\mu)\)
- Waiting Time of Customers in the System
  \(W = 1/(\mu - \lambda)\) for steady-state MM1 queue
- Number of Customers in the System
  \(L = \lambda/(\mu - \lambda)\) for steady state MM1 queue
Inventory Systems

- New Order Arrival Rate ($\lambda$)
- Stored Product Unit Sale Price ($p$)
- Cost of Storing a Unit of Product ($h$)
- Cost of Restocking a Unit of Product ($c$)
- Time Delay in replenishing Stock ($L$)
- Maximum Inventory Size ($S$)
- Minimum Inventory Size ($s$)
Machine Repair Systems

• Minimum Number of Operational Machines \((n)\)
• Number of Spare Machines Ready to Work \((s)\)
• Number of Machines Waiting for Repair \((w)\)
• Failure Rate of Machines \((\alpha)\)
• Repair Rate of Machines \((b)\)
Insurance Systems

• Arrival Rate of New Insurance Claims ($\lambda$)
• Amount of Individual Claim ($C$)
• Number of Policyholders ($n$)
• Signup Rate of New Customers ($v$)
• Amount Paid by Policyholders ($p$)
• Length of Duration of Insurance Policy ($\mu$)
DES: Advanced Examples - Students at Rensselaer
(see http://www.rh.edu/~ernesto/C_F2002/DES)

- Jet Engine Component Repair
- Fitness Center
- Jet Engine Assembly
- Doctor’s Office
- Jobshop Simulation
- Baseball Strategy
Conclusion

• Simulation Modeling is Technology designed to assist Decision Makers

• Discrete Event Simulation is the Computer based Representation of Systems in terms of the Changes in their States produced by Stochastic Events

• DES is mature and ready for application in many diverse fields