Simulation Studies

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Why Simulation

- Simulations
  - analyze the behavior of complex processes
- Useful in SE Process Research
  - Static models even with data are still hard to anticipate
  - Software processes contain iterations and rework loops
    - leading to delays ranging from minutes to years

Why Simulation

- Static process descriptions (i.e., flow charts)
  - Do not shed much light on the behavior of a process over time
- The usual process analysis method is a case study
  - requires actual engineers
  - extremely costly
  - does not generalize to other contexts

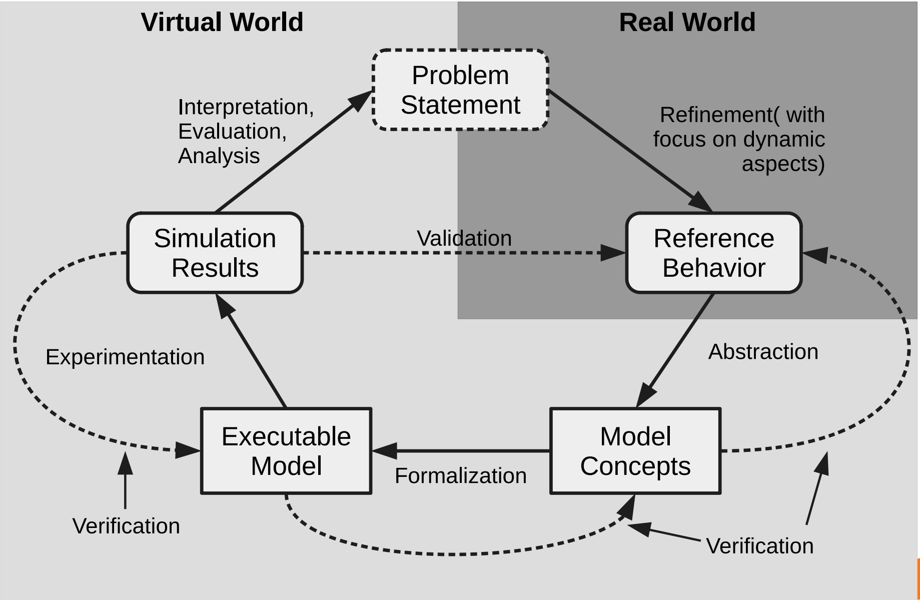
Simulation

- Simulation provides
  - means to clarify assumptions/mental models
  - visualize the implicit mental models that govern observed process behavior
  - support understanding, analysis, prediction, and decision-support
- Simulations act like virtual laboratories
  - hypotheses about problems may be tested
  - corrective policies experimented with
  - provides significant benefits to management decision support
  - can be integrated with systematic experimentation and other empirical research
  - supports project planning and estimation

Effective Simulation

- Simulation is only effective
  - model reflects real world
  - data used to drive the model reflects real world
- Quantitative output requires
  - quantitative expert estimates, or
  - measurement data
- To minimize data collection effort
  - focus on key variables
  - leads to identifying relevant factors for measurement program

Simulation Modeling Process



Problem Statement

- Defines the modeling goal and focuses the modeling activities
- Defines model purpose and scope (Kellner 1999):
  - Purpose
    - strategic management
    - planning, control and operational management
    - process improvement and technology adoption
    - understanding
    - training and learning
  - Scope
    - a portion of the life cycle
    - a development project
    - multiple, concurrent projects
    - long-term product evolution
    - long-term organization

Reference Behavior

- Ensures that the problem statement is sutable for simulation-based problem-solving
- **Reference Behavior**
  - captures dynamic variation of key attributes of real-world entities
  - can be both:
    - observed problematic behavior to be analyzed and improved
    - desired behavior to be achieved
  - Importance:
    - identifies important model (output) parameters
    - focuses subsequent modeling steps
    - input to model validation for comparing simulation results to observed (or desired) behavior

Defining Model Concepts

1. Existing process, quality, and resource models
2. Implicit or explicit decision rules
3. Typical observed behavior patterns
4. Organizational information flows
5. Policies

Model Concepts

- Either quantitative or qualitative models
  - abstractions of behaviors observed in reality
  - captures implicit and tacit expert knowledge as rules
- Domain Experts
  - have knowledge not found in documents/databases alone
  - help distinguish relevant and irrelevant real-world data

Model Concepts

- Model concepts are implemented into a simulation tool
- Domain knowledge is represented in the simulation
- Result is then an **executable model**

Executable Model

- Last step is **model calibration and experimentation**
  - Experiments are performed to understand the system's behavior
  - Calibration is the adjustment of model parameters until the output corresponds with real-world data
  - Both go hand-in-hand
- Calibration can be done through
  - expert estimation
  - parameter fitting based on historic data

Executable Model

- Calibration helps to build confidence in the model
  - Once calibrated experiments are used to:
    - understand observed behavior
    - evaluate planning alternatives
    - explore improvement opportunities
- Output: **simulation results**

Model V&V

- **Verification** - ensures the model fits its intended purpose
  - check internal correctness/appropriateness
  - requires expert knowledge concerning selected simulation technique
  - partially supported by tools
- **Validation** - ensures the model appropriately reflects the real-world behavior
  - check whether transformation steps defined in the simulation have been conducted correctly
  - checks whether the model represents structural/behavioral properties of the real system
  - partly supported by tools
  - requires expert knowledge about the real-world system
- These activities continue throughout the modeling life-cycle

SE Applications

- Project management
- Risk management
- Product and Requirements Engineering
- Process Engineering
- Strategic Planning
- Quality assurance and management
- Software maintenance and evolution
- Global software development
- Software acquisition management and COTS
- Product-lines
- Training and education

Simulation Techniques

- **Deterministic** vs. **Stochastic**
- **Static** vs. **Dynamic**
- **Continuous** vs. **Event-Driven**
- **Quantitative** vs. **Qualitative**

Deterministic vs Stochastic

- **Stochastic** - has probabilistic components
  - outputs depend on stochastic variation of (due to random sampling of statistical distributions)
    - input parameters
    - internal model variables
- **Deterministic** - non-probabilistic
  - for same inputs will have same outputs
- You need to remember to repeat stochastic simulation runs to see the output distribution
  - number of runs is depends upon
    - computing power limitations
    - confidence required for results

Static vs Dynamic

- **Static** - captures variation at one single point in time
  - Monte Carlo simulations
- **Dynamic** - captures variation over a period of time

Continuous vs ED

- Both are types of Dynamic Simulations
- **Continuous**
  - update variables at equidistant time steps using defined equations
  - based on a set of linear differential equations
  - Best known approach: **System Dynamics** (SD)
- **Event-Driven**
  - updates values of variables as events occur
  - Best known approach: discrete-event (DE) simulation
    - Models are represented as a network of activities
    - Items then flow through the network triggering events
    - Events may occur at any time

Quantitative vs Qualitative

- **Quantitative**
  - Model params are specified as real or integer numbers
    - needs empirical data of sufficient quantity and quality
    - experts to provide estimates
- **Qualitative**
  - approach to understand general behavior patterns of dynamic systems
  - useful when conclusions must be drawn from insufficient data

Hybrid Simulation

- Combining continuous and event-driven
- Combining deterministic with stochastic elements
- Benefit
  - gain advantages of both model types
- Drawback
  - increased complexity

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SD vs. DE

- System Dynamics
  - captures complex process behavior via a small set of core constructs
  - possible to reuse a set of generic model patterns
  - focuses on modeling the average of a system
  - captures cause/effect relationships better
- Discrete Event
  - Complementary perspective to SD
  - Provides a more detailed view of system behavior
  - Utilizes attributes/properties of modeled components which may be refined
  - Easily adaptable to changes
  - Can model distinct real-world entities
  - may capture too many details

ROAR

Practical Aspects

- Simulation is not a “silver bullet”
  - Garbage in = Garbage out
  - Predictive power depends upon model validity
- Often simulation is not practical
  - human actors data gathering is often very costly
  - may not be able to reproduce simulated events for purposes of validation

Practical Aspects

- Simulation is only a simplification of the real-world
  - we cannot prove a priori model correctness
  - more tests and observations leads to more confidence
- Simulation is not:
  - a means unto itself (requires follow-up action)
  - a means to generate ideas

Are there any questions?