Modeling Decision Making

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References:

1. Sterman, John D. (2000). *Business Dynamics: Systems Thinking and Modeling for a Complex World*. McGraw-Hills. Chapter 3: The Modeling Processes.

A model for simulating dynamic system behaviour requires formal policy descriptions to specify how individual decisions are to be made. Flows of information are continuously converted into decisions and actions. No plea about the inadequacy of our understanding of the decision-making processes can excuse us from estimating decision-making criteria. To omit a decision point is to deny its presence- a mistake of far greater magnitude than any errors in our best estimate of the process.

Jay W. Forrester , 1992

Principles for Modeling Decision Making (1 of 2)

- All model structures consist of two parts:
  - Assumptions about **the physical and institutional environment**.
    - The physical and institutional structure of a model includes <u>the model boundary</u> and <u>stock</u> and <u>flow</u> structures of people, material, money, information, and so forth that characterize the system.
  - Assumptions about **the decision processes of the agents** who operate in those structures.
    - The decision processes of the agents refer to <u>the decision rules</u> that determine the behavior of the actors in the system.

Principles for Modeling Decision Making (2 of 2)

- Accurately portraying the physical and institutional structure of a system is relatively straightforward. In contrast, discovering and representing the decision rules of the actors is subtle and challenging.

- To be useful, simulation models must mimic the behavior of the real decision makers so that they respond appropriately, not only for conditions observed in the past but also for circumstances never yet en- countered.

- You must specify a robust, realistic decision rule at every decision point in the model.

Decision and Decision Rules

- **Decision rules** are the policies and protocols specifying how the decision maker processes available information
- **Decisions** are the outcome of this process
- Example
  - In the department store example, the decision rule is the procedure for marking up wholesale costs and adjusting the markup based on inventory turnover, competitor prices, and so on. The decision rule leads to decisions such as pricing a particular item at, say, $9.95.

Five Formulation Fundamentals (1 of 2)

1. **The Baker Criterion: The inputs to all decision rules in models must be restricted to information actually available to the real decision makers.**
    - The future is not known to anyone. All expectations and beliefs about the future are based on historical information. Expectations and beliefs may therefore be incorrect.
    - Actual conditions and perceived conditions differ due to measurement and reporting delays, and beliefs are not updated immediately on receipt of new information. Perceptions often differ from the actual situation.
    - The outcomes of untried contingencies are not known. Expectations about "what if" situations that have never been experienced are based on situations that are known and may be wrong.
2. **The decision rules of a model should conform to managerial practice.**
    - All variables and relationships should have real world counterparts and meaning.
    - The units of measure in all equations must balance without the use of arbitrary scaling factors.
    - Decision making should not be assumed to conform to any prior theory but should be investigated firsthand.

Five Formulation Fundamentals (2 of 2)

3. **Desired and actual conditions should be distinguished. Physical constraints to the realization of desired outcomes must be represented.**
    - Desired and actual states should be distinguished.
    - Desired and actual rates of change should be distinguished.
4. **Decision rules should be robust under extreme conditions.**
5. **Equilibrium should not be assumed. Equilibrium and stability may (or may not) emerge from the interaction of the elements of the system.**

Formulating Rate Equations

1. Fractional Increase Rate
2. Fractional Decrease Rate
3. Adjustment to a Goal
4. The Stock Management Structure:
   Rate = Normal Rate + Adjustment
5. Flow = Resource * Productivity
6. $Y = Y^{*}$ * (Effect of X_1 on Y) * (Effect of X_2 on Y) * (…) * (Effect of X_n on Y)
7. Fuzzy MIN Function
8. Fuzzy MAX Function
9. Floating Goals
10. Non Linear Weighted Average
11. Modeling Search: Hill-Climbing Optimization

1. Fractional Increase Rate

- Consider a stock **S** with inflow rate R_I. Often the inflow is proportional to the size of the stock. The stock grows at a fractional increase rate g (<1), which may be constant or variable:

$$R_I = gS$$

- Examples:

Birth Rate = Fractional Birth Rate * Population

Interest Due = Interest Rate * Debt Outstanding

2. Fractional Decrease Rate

- Consider a stock **S** with outflow rate R_O. The outflow is often proportional to the size of the stock. The outflow can be formulated either as depending on the fractional decrease rate d (<1) or equivalently as the stock divided by the average lifetime L for the items in the stock:

$$R_O = dS = S/L$$

- Examples:

Death Rate = Fractional Death Rate * Population
= Population / Average Lifetime

Defaults on Account Receivable(AR) = Fractional Default Rate * (AR)
= AR / Average Time to Default

These examples all form linear, first-order negative loops and generate exponential decay with a time constant of L = 1/d. They are equivalent to a first-order material delay. The fractional rates or average residence times can be variables.

3. Adjustment To Goal

- Managers often seek to adjust the state of the system until it equals a goal or de- sired state. The simplest formulation for this negative feedback is:

$$R_I = \text{Discrepancy}/AT = (S^*-S)/AT$$

- Discrepancy is the gap between the desired state of the system **S***and the actual state S. The adjustment time AT is the average time required to close the gap.

- Examples:

Change in Price = (Competitor Price - Price) / Price Adjustment Time

Net Hiring Rate = (Desired Labor - Labor) / Hiring Delay

“Desired minus actual over adjustment time” is the classic linear negative feedback system, and, in the absence of other rates, generates exponential adjustment to the goal

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