Computational Modeling: Opportunities for the Information and Management Sciences*

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Context: Malaise and Opportunity

- Dotcom bust; poor job market
- Ambient hype
- Wolfram's *A New Kind of Science*
- Opportunity: rethink role of computing
- Opportunity: explore certain naggingly elusive, emerging ideas

The Suggestion

Computational modeling and explanation is a valid and vigorously emerging mode of conducting science. Especially social science. This development presents opportunities to computing researchers in the management fields. The opportunities come with qualifications and nuances.

Goal here: expand upon and clarify this suggestion; frame and interpret.

- New concepts and methods; exciting
- History of and comment on ideas
- Aim to prompt discussion, dialog

Science and Explanation

- Science $\approx$ (explain, predict, intervene)
- Works via theories, laws and models
- Models: terse, abstractions, behavior corresponding (more or less) to target system
- Explanation with models: identify observed behavior with modeled behavior

  Often: affords prediction and intervention

Science and Explanation (con't.)

- Roughly, laws are entrenched models, theories are explanations of laws
- Laws and models usually expressed as algebraic equations, especially differential equations.
- Laws and models sometimes built upon axiom systems, especially utility theory and in game theory and in economics.
- Is there any other way?

Yes. Consider Darwin.

- Standard story: it's not the evolution, it's the natural selection.

- Agree, but, more generally, Darwin explained a lot of really complicated stuff with a very simple procedure.

  1. Profusion of progeny
  2. Progeny vary with traits that affect survival and reproduction
  3. These traits are to some degree heritable

  Inevitably, then, "descent with modification by natural selection".

- Where are the equations? Where are the axioms?

Refining procedures

- Three levels of kindred explanation:
  1. procedural
  2. constructive
  3. interpreted
- By merging Darwinism and Mendelism we get a constructive (more than barely procedural) explanation.
- With modern understanding, we see that the process is also a computational one.
  Roughly (another topic): we have an empirical theory on how to interpret the elements in the process. Very roughly: in biological evolution, fitness is being maximized; DNA sequences carry information about the world. Wolfram's mistake (one of very many) in *A New Kind of Science.* But that's another story.

Remarks on the Levels

- procedural. Think: the model is a flowchart. (Darwin)
- constructive. Think: we can specify how to execute the steps in the flowchart. (Mendel + chromosome theory)
- interpreted. Think: the representations posited in the flowchart are there (causally) *because* of the information they carry. (DNA; genes are for carrying information about the world)

Fully computational model/explanation: a model with all three levels present.

Related: Marr in *Vision*, 1982, page 25

- Computational theory

  What is the goal of the computation, why is it appropriate, and what is the logic of the strategy by which it can be carried out?

- Representation and algorithm

  How can this computational theory be implemented? In particular, what is the representation for the input and output, and what is the algorithm for the transformation?

- Hardware implementation

  How can the representation and algorithm be realized physically?

Comments

- Strong impulse towards constructivism in social science modeling; favors computational modeling.

  See examples: Schelling, ZI-traders, attack on Walrasian equilibrium models, etc.

- Interpreted criterion: Often muted or not addressed in models.

  Fundamentally important, but can be finessed for present purposes. Basic idea: any definite procedure can be interpreted as a computation. Actually, infinitely interpreted so. A genuine computational model must have a natural interpretation for its procedure. This is where Wolfram goes wrong; one of many places.

In Sum: Computational Explanation Explains with a Process

- Algorithms and machines, yes; equations, usually not.

- My claims:

  1. These kinds of explanations (models, etc.) are on the wax and proving to be successful
  2. There is good reason for this; these are good kinds of explanations
  3. This presents nice new opportunities in Management Science and Information Systems: contribute by helping to expand the realm of the computationally explained and modelled.

Selected Examples

. . . what counts as an explanation has become more and more difficult to distinguish from what counts as a recipe for construction.

–*Making Sense of Life* by Robin Fox Keller, 2002

- Traditional discrete event simulation: a special case. What might we do to extract more information from such models?
- Cyert & March, *A Behavioral Theory of the Firm*
- Molecular biology and embryology, e.g., Yuh et al., "Genomic cis-regulatory logic: Experimental and computational analysis of a sea urchin gene," *Science*, 279(5358): 1896–1902, 1998.

Endo16

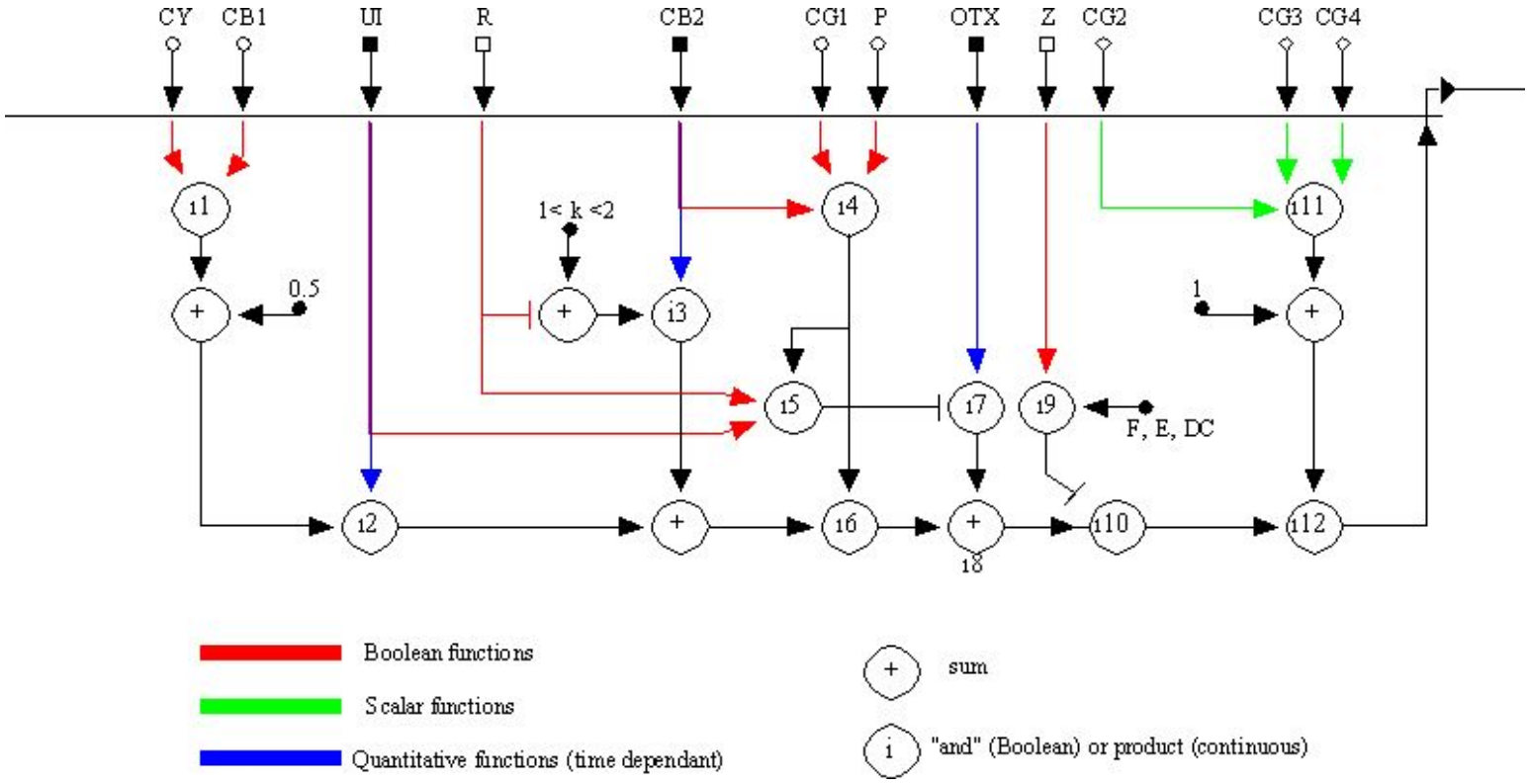

Figure 1: The Endo16 model of cis-regulatory control

Examples: Evolution, economics and game theory

Theme: constructivism; "from the bottom up". Not interpretation free, but with minimal semantic content.

- Schelling's segregation model

  Natural interpretation of blue and red: my kind or not.

- Axelrod and IPD

  Tournaments with surprising results. Natural interpretation of C and D.

Examples: Evolution, economics and game theory

- Epstein and Axtell: Sugarscape and Walras

  Walrasian auctioneer: procedural, but not constructive. E&A offer a fully computational, "bottom up", procedural, constructive, and interpreted alternative model. Arguably: promises of superior validity.

- Gode and Sunder: Zero-intelligence traders

  Even more radical computational model.

- Roth and Erev: reinforcement learning models human behavior in games

Other Examples

- Management science. See "Exploring a Two-Market Genetic Algorithm" (Kimbrough et al.) GECCO, 2002.

  Using the two-population version to explain results.

  Also, applications to logistics and supply chain design. Distributed computation via agents, etc.

- Agent-based modeling, agent-based simulation in other social sciences

  Political science. Sociology, see Michael W. Macy and Robert Willer, "From Factors to Actors: Computational Sociology and Agent-Based Modeling", *Annual Review of Sociology*, 2002.

Community Recognition: New Journal

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Computational Management Science

Editors: Berc Rustem, Istvan Maros, Panos Pardalos, Hans Amman, Aims and Scope

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Interpretive Remarks

Computational modeling and explanation is a natural and opportune extension of the community's wonted research areas:

- Problems of designing, building, and maintaining business IT applications
- Computational problem solving in OR/MS (INFORMS)
- IS and organizational behavior
- IS and economics

Problem: Gotta know the territory

- Social scientists avidly do computational modeling. Is there an apt role for computational modelers doing social science?

- Lesson from MS/OR modeling: Gotta know the territory

  But it can be done successfully. Same point for simulation studies.

- Challenge: Can computational modeling develop as its own legitimate (mini)field, with its own special research problems and expertise?

  Compare: mathematicians and differential equations, statisticians and statistical models.

  What does the history of OR/MS tell us?

Finally, connection with exciting ideas

- Complex adaptive systems

  Seem to be inherently computational, calling for computational modeling and explanation.

- Emergence

  Of surprising phenomena from. . . simple elementary processes

Connection with exciting ideas

- Distributed problem solving

  Found and found useful, increasingly so

- Social and economic phenomena

  Such as trust, cooperation, commitment, coalition formation, bargaining, market behavior, norms, and meaning in signaling systems

Happy Prospect

By including computational modeling and explanation in our core research activities, we stand to make better progress on many of the problems that motivate the field.

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