USING SIMULATION TO STUDY, DESIGN, AND INVENT ORGANIZATIONS

RAYMOND E. LEVITT

Abstract: Over the past 50 years, computational modeling and simulation have had enormous impact on the advancement of knowledge in fields such as physics, chemistry, and subsequently, biology. After simulation models had been validated in these fields, they were rapidly adopted as powerful new tools to enhance and extend engineering practice. Might social science and management practice be following a similar trajectory? This article argues that progressively validated, calibrated, and refined computational simulation models of organizations are rapidly evolving into: (a) powerful new kinds of organizational analysis tools to support organization design by predicting the performance of specific organizational configurations for a given task and environment; (b) flexible new kinds of organizational theorem provers for validating extant organization theory and developing new theory; and (c) organizational test benches that can be used to explore the efficacy of hypothetical organizational configurations that can address the unprecedented demands of new and emerging work processes in the presence of high levels of uncertainty and ambiguity.

Keywords: Simulation; agent-based; organization design; research methods

Agent-based simulation has advanced the predictive power of the physical sciences and engineering immensely since the late 1960s. Computational simulation models of bridges, buildings, and airplanes can often predict their stress-strain-deflection behavior to finer tolerances than they can be built. Similarly, chemical reactions, groundwater flow, and many other engineering phenomena are being ever more accurately simulated. Could social science and management practice—specifically, the science and practice of organization theory, which began to explore the use of computational modeling in earnest starting around the 1980s—be following a similar trajectory? This article argues that the spectacular success of simulation in advancing engineering science and practice over the past 50 years provides a template for the potential impact of agent-based simulation on organizational science and organizational design.

AGENT-BASED SIMULATION IN ORGANIZATION SCIENCE AND DESIGN

Similar to their colleagues in the physical sciences and engineering, organizational scientists have generally used a "three-legged stool" research approach. They have:

1. Gathered empirical data from real-world observations to motivate, test, and refine organization theories;
2. Designed and executed experiments, typically using paid student subjects, in much the same way as engineering researchers used physical scale models; and
3. Developed theories based on these observations and experiments, sometimes formalized in mathematics (especially in economics) but more commonly expressed in words and diagrams.

Journal of Organization Design
JOD, 1(3): 58-63 (2012)
DOI: 10.7146/jod.7016

Arguably, the most serious shortcoming of traditional social science research has been the paucity of unified, multi-level theories. Micro behavioral theories and empirical findings from cognitive and social psychology have been developed in relative isolation from macro theories and empirical findings in sociology, political science, and economics. The result—until some recent work in behavioral economics and political science—has been a series of unconnected, single-level, discipline-based “islands of theorizing” in the social sciences.

Agent-based computational simulation addresses this deficiency in traditional social science research. Mature, validated, micro social science findings can be embedded in computational agents as sets of “canonical” micro behaviors. The designer of a simulation experiment can then model the way in which these canonical agents interact with other computational agents and aspects of the task and/or environment to generate emergent meso- and macro-level organizational predictions, which can then be validated against meso- and macro-empirical data. This is the approach that was used so successfully by physical scientists and engineers in developing their “finite element” models of structural and other engineered systems: Embed well-validated micro physical behaviors in thousands of small “finite elements” and then simulate the elements’ collective behaviors and their interactions with connected elements to generate emergent meso- and macro-level predictions that can be tested against real-world macro data.

Starting with the pioneering work of Cyert and March (1963) and Cohen and Cyert (1965), and encouraged by the widely cited “garbage can model” of organizational choice (Cohen, March, & Olsen, 1972), computational modeling and simulation have now provided a fourth modality for social science research. Social science research based on computational modeling and simulation has not yet come close to replacing synthetic experiments in the same way that computational modeling in the physical sciences has almost totally replaced physical scale models, but it is beginning to augment traditional synthetic and natural empirical experiments in psychology, sociology, economics, and political science for developing and testing theories, and some mature computational modeling tools have begun to be used by management consultants for organizational diagnosis and design.

THE POWER OF “SERIOUS PLAY”

Michael Schrage (2000) describes how validated simulation tools with intuitive visual inputs and outputs allow multidisciplinary groups of people to engage in new kinds of collaborative work. He termed the process in which group members can propose alternatives and rapidly simulate and visualize their predicted outcomes “serious play.” Working as an organizational design consultant in some highly charged corporate situations, the author has experienced the serious play phenomenon firsthand with organizational simulations. Competing ideas about how a work process and organization should be configured are imbued with the ego of each alternative’s proponent and are impossible to test without simulation except by trial and error *in vivo*. They are thus not easily resolved. However, when provided with intuitive and credible real-time simulation outputs that reveal and display the implications of alternative proposed solutions, participants immediately shift their focus from debating the ego-bound, proposed alternatives to a much more objective discussion about the implications of the competing alternatives. A far more rational and constructive dialogue develops that becomes focused on which set of outcomes is more or less desirable, rather than on the beauty—or lack thereof—of each proponent’s ideas. The following section presents two software tools with strong grounding in organization science research that enable this kind of serious play in the process of organization design.

CAPABILITIES AND LIMITATIONS OF TWO ORGANIZATIONAL SIMULATION TOOLS

A small number of computational modeling and simulation tools for organizational diagnosis and design have undergone extensive validation and can be used confidently both for organization design and organizational research. We describe two examples here. Various others are currently being developed.

Burton and Obel’s (2004) Organizational Consultant® uses sets of rules based on meticulously integrated findings from decades of empirical organizational research to analyze the degree of fit among an organization's environment, technology, management style, and multiple dimensions of its structural configuration. Organizational Consultant has been validated against more than one hundred enterprises in multiple countries and can thus be used confidently at the level of a business unit or an enterprise to diagnose structural misfits as well as to explore the fit of alternative organizational configurations and to make predictions about the fitness of innovative organizational designs proposed to address hypothetical future technological, environmental, and managerial contexts.

SimVision®, based on Stanford's 20-year "Virtual Design Team"[1] research program, is an agent-based model that simulates the information processing demand vs. information processing capacity of project organizations engaged in complex and fast-paced, semi-routine, project-based work. SimVision makes specific quantitative predictions about schedule, cost, and quality outcomes of alternative organizational configurations, including task assignments; reporting relationships; managers' spans of control; workers' and managers' skill levels; levels of centralization, formalization, and matrix strength; and team experience (Jin & Levitt, 1996; Levitt, Thomsen, Christiansen, Kunz, Jin, & Nass, 1999). It has been validated over more than a decade on hundreds of projects in construction, aerospace, consumer products, software development, semiconductors, and pharmaceuticals and is now in routine commercial use to design organizations for complex, fast-track engineering projects worldwide. It has been extended to model the contention for scarce human resources in an organization posed by a portfolio of ongoing projects or programs, so that it can provide business unit or enterprise-level simulation of project-based organizations like engineering firms, management consulting firms, or large IT departments. Moreover, SimVision® has increasingly been used by researchers since 2000 as an organizational test bench to answer organizational questions and explore innovative organizational configurations (e.g., Cardinal, Turner, Fern, & Burton, 2011; Carroll & Burton, 2000; Carroll, Gormley, Bilardo, Burton, & Woodman, 2006; Jensen, Håkonsson, Burton, & Obel, 2010; Kim & Burton, 2002; Nissen & Burton, 2011; Wong & Burton, 2000).

CAUTIONS ABOUT ORGANIZATIONAL SIMULATION

With rapid advances in object-oriented computer languages, it is now relatively easy to embed multiple complex behaviors into computational agents, assemble the agents into different organizational configurations in different contexts, assign tasks to the agents, and generate emergent organizational outcomes. Predictably, the ease of building new simulation models has led to simulation research of varied quality. Good science builds on previous science, but many of the simulation models developed during the last decade have not built on previous research. This section offers some cautions in developing organizational simulations to avoid the pitfalls of poor science and ineffective management consulting.

Build organizational simulation models on firm ground. For a model's predictions to be credible and repeatable, its agent micro behaviors must be grounded in the findings of the best available research. Before they could be used for the design of buildings or airplanes, finite element engineering models had to undergo extensive evaluation of their micro behavior, their interaction algorithms, and their outputs at multiple levels. Similarly, before simulation models can be used with confidence to design real-world organizations, their micro behavior, interaction algorithms, and outputs need extensive validation.[2] When no prior empirical micro social science research exists to specify the agent behaviors of interest, organizational researchers—or their cognitive and social psychology collaborators—must study and understand the micro behaviors of interest through meticulous new ethnographic research rather than simply assuming them.

1 The name Virtual Design Team was intended to denote a computer simulation of a real design team not the current colloquial meaning of a "virtual" team as a geographically distributed or temporary, multi-organizational team.

2 This kind of validation is very time-consuming, extending way beyond the duration of a typical Ph.D. dissertation, and so has often not been done as well as it should be. Thomsen, Levitt, Kunz, Nass, and Fridsma (1999) propose the stages of validation through which a computational model of organizations should be developed.

Use just enough detail. It is now easy to build agent-based models with sets of behaviors that are far more complex, and that interact in many more ways, than can be done intelligibly using verbal models or, more formally, in tractable mathematical models. This has led many early computational modelers to build models with agent behaviors and interactions that are so complex that the causality of their emergent behavior is as opaque as that of the real-world organizations they aspire to inform. As Burton and Obel (2011) state, overly complex models do not serve to advance organizational science. And, because they cannot be scientifically validated, their predictions are unlikely to hold up in real-world settings. So the second caution for aspiring computational modelers is to keep models as simple as possible for their intended purpose.

Use natural workplace idioms not organizational jargon. Model terminology must be focused on its intended audience. Early versions of VDT that we developed for academic audiences use terms like “actors” and “activities” to describe what managers call “workers” and “tasks”. We learned very quickly, however, that tools being used to support organization design in managerial settings must use natural idioms from the workplace to be effective.

Find the future at the edges of the present. When the author was looking to simulate examples of radically decentralized organizations that could be models for new kinds of “power to the edge” construction projects, the most relevant examples were found in open-source software development, Internet video production, and other emerging workplaces, not on the construction sites of even the most progressive construction firms. The future of organizational forms is being invented by Web 2.0 millennials in their highly interactive and creative work and play, not in the R&D departments of Fortune 100 companies or the laboratories of on-campus social scientists.

CONCLUSIONS

This article began by asking whether computational simulation of organizations might follow the same trajectory that proved so successful in advancing the physical sciences and engineering. We conclude that this is indeed the case, albeit lagging the physical sciences by about two decades. Computational experiments and computer-aided organization design consulting are already becoming routine. Organizational Consultant currently provides valuable, albeit qualitative, suggestions for improving structural and contextual fit at the level of an enterprise or business unit, and SimVision provides quantitative predictions for project organizations engaged in semi-routine work processes. The limitations of these simulations, although significant, still allow both of these models to be used to design a wide range of real-world enterprise and project-level organizations. Moreover, these kinds of computational models are also now being used to teach organization design at dozens of universities around the world. And they are being used to explore designs for new, more agile, and decentralized forms of organizations that can cope with the rapid change and the democratic and interactive work styles of the “Web 2.0” world and the new millennial workers (Alberts & Hayes, 2003; Cardinal et al., 2011; Levitt, 2011).

The increasing availability of “Big Data” (Galbraith, 2012; McKinsey Global Institute, 2011) about social behavior contained in the myriad online traces that users of enterprise computing systems, supply chain management tools, and social networking sites leave behind them offers a treasure trove of data to refine and extend micro theories of human behavior. These data are already being used extensively by marketing researchers and being applied to design ever more finely targeted advertising and political campaigns. Organizational researchers can use the same kinds of big data, under appropriate privacy protocols, to extend and refine our theories of micro behavior in a working world that is increasingly communicating online and becoming more socially networked.

There is exciting and important work to be done, and powerful and accessible tools and data sources to do it with. Go forth and simulate!

Acknowledgements: The research that underlies this article was supported by the Center for Integrated Facility Engineering and Collaboratory for Research on Global Projects at Stanford University, the National Science Foundation, and the Center for Edge Power of the

Naval Postgraduate School. The support of these organizations for this research is gratefully acknowledged. However, the author is solely responsible for the opinions expressed in the article.

REFERENCES

Alberts D, Hayes R. 2003. *Power to the Edge: Command… Control… in the Information Age*. Center for Advanced Concepts and Technology, Command and Control Research Program, US Department of Defense. http://www.dodccrp.org/files/Alberts_Power.pdf

Burton RM, Obel B. 2004. *Strategic Organizational Diagnosis and Design: The Dynamics of Fit,* 3rd edition (with OrgConSoftware). Kluwer Academic Publishers, Boston, MA.

Burton R, Obel B. 2011. What-is, what-might-be, what-should-be studies—and triangulation? *Organization Science* 22(5): 1195–1202.

Cardinal LB, Turner SF, Fern MJ, Burton RM. 2011. Organizing for product development across technological environments. *Organization Science* 22(4): 1000–1025.

Carroll T, Burton RM. 2000. Exploring "complex" organizational designs. *Computational and Mathematical Organization Theory* 6(4): 319–337.

Carroll TN, Gormley TJ, Bilardo VJ, Burton RM, Woodman KL. 2006. Designing a new organization at NASA: An organization design process using simulation. *Organization Science—Special Issue on Organizational Design* 17(2): 202–214.

Cohen KJ, Cyert RM. 1965. Simulation of organizational behavior. In J.G. March (Ed.), *Handbook of Organizations*, 305–334. Rand McNally, Chicago, IL.

Cohen MD, March JG, Olsen JP. 1972. A garbage can model of organizational choice. *Administrative Science Quarterly* 17(1): 1–25.

Cyert RM, March JG. 1963. *A Behavioral Theory of the Firm*. Prentice-Hall, Englewood Cliffs, NJ.

Galbraith JR. 2012. The evolution of enterprise organization designs. *Journal of Organization Design* 1(2): 1-13.

Jensen KW, Håkonsson DD, Burton RM, Obel B. 2010. The effect of virtuality on the functioning of centralized versus decentralized structures—an information processing perspective. *Computational and Mathematical Organization Theory* 16(2): 144–170.

Jin Y, Levitt RE. 1996. The virtual design team: A computational model of project organizations. *Journal of Computational and Mathematical Organization Theory* 2(3): 171–195.

Kim J, Burton RM. 2002. The effect of task uncertainty and decentralization on project team performance. *Computational and Mathematical Organization Theory* 8(4): 365–384.

Levitt RE, Thomsen J, Christiansen TR, Kunz JC, Jin Y, Nass C. 1999. Simulating project work processes and organizations: Toward a micro-contingency theory of organizational design. *Management Science* 45(11): 1479–1495.

Levitt RE. 2011. Toward project management 2.0. *Engineering Project Organization Journal* 1(3): 197–210.

McKinsey Global Institute. 2011. Big data: The next frontier for innovation, competition, and productivity.

Nissen M, Burton RM. 2011. Designing organizations for dynamic fit: System stability, maneuverability, and opportunity loss. *IEEE Transactions on Systems, Man, and Cybernetics—Part A: Systems and Humans* 41(3): 418–433.

Schrage M. 2000. S*erious Play: How the World's Best Companies Simulate to Innovate*. Harvard Business Press, Boston, MA.

Thomsen J, Levitt RE, Kunz JC, Nass CI, Fridsma DB. 1999. A trajectory for validating computational emulation models of organizations. *Journal of Computational and Mathematical Organization Theory* 5(4): 385–401.

Wong S, Burton RM. 2000. Virtual teams: What are their characteristics and impact on team performance? *Computational and Mathematical Organization Theory* 6(4): 339–360.

RAYMOND E. LEVITT

Kumagai Professor of Engineering
Stanford University
E-mail: ray.levitt@stanford.edu