Computational and Mathematical Organization Theory Workshop

May 3 and 4, 1996
Washington, DC

Organized by

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ABSTRACTS

COMPUTATIONAL AND MATHEMATICAL ORGANIZATION THEORY
1996

NEW WAVES IN INDUSTRY

by
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Comparative research tends to support the observation that two clusters of conditions in particular shape the chances of survival and success of individual members of a population of organizations: material resources (the level and mode of munificence) and social resources (the level and mode of institutionalization). Both factors are conceived as attributes of the population as a whole. The state of social resources is overridingly accountable for survival in the early and final stages of a populations life cycle, and material resources are predominantly determining the fate of population members in the phase of maturity and saturation. Ecology theory only recently started to pay attention to the fact that organizations do rarely act in isolation, even in conditions of resource scarcity. Even in the earliest stages they develop interorganizational networks, and - in most European countries - establish corporatist bonds and peak organizations, capable of collective action. Our empirical study of the rise and development of the contract-catering industry in the Netherlands shows that collective action by the dominant actors of a population is a major determinant of individual survival and success. Collective action performs at least three critical functions, in particular in the early stages: (a) augmentation of its common strenght vis-a-vis other populations vying for some of the same vital resources; (b) mobilization of political support required to establish and improve its legal and contractual working conditions; (c) legitimation of the specific rules of competion between members of the population. Our case study shows that organized populations are perfectly capable of developing collective stands and strategies; can become very active and dynamic in shaping and improving its conditions for its collective survival. The concept of population strategy (dynamics in an active sense) complements individual inertia. It is suggested that population strategies tend to be offensive in the early stages and defensive in the final stages of a populations life cycle. And in between, there's competion. Comparative analysis of population life cycles should include these dimensions and test the prediction that specific form collective action at the population level will increase (or prolong) survival and success of its members.

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earliest stages they develop interorganizational networks, and - in most European countries - establish corporatist bonds and peak organizations, capable of collective action. Our empirical study of the rise and development of the contract-catering industry in the Netherlands shows that collective action by the dominant actors of a population is a major determinant of individual survival and success. Collective action performs at least three critical functions, in particular in the early stages: (a) augmentation of its common strenght vis-a-vis other populations vying for some of the same vital resources; (b) mobilization of political support required to establish and improve its legal and contractual working conditions; (c) legitimation of the specific rules of competion between members of the population. Our case study shows that organized populations are perfectly capable of developing collective stands and strategies; can become very active and dynamic in shaping and improving its conditions for its collective survival. The concept of population strategy (dynamics in an active sense) complements individual inertia. It is suggested that population strategies tend to be offensive in the early stages and defensive in the final stages of a populations life cycle. And in between, there's competion. Comparative analysis of population life cycles should include these dimensions and test the prediction that specific form collective action at the population level will increase (or prolong) survival and success of its members.

COOPERATIVE EFFORTS IN ELECTRONIC CONTEXT: THE RELEVANCE OF PRIOR FACE TO FACE INTERACTIONS

by
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University of Trento, Italy

The paper presents an experiment on the impact of computer mediated communication (CMC) on social dilemmas. Many experimental studies have found powerful effects on social dilemma outcomes attributable to face to face communication (F2F). A former experiment verified this finding holds, but waves of "electronic opportunism" emerge when subjects engage in CMC discussions. A new experiment now investigates whether prior face-to-face interactions affect the emergence of cooperation in a CMC social dilemma. Despite an initial collapse of cooperation, individuals succeed in defining and respecting an agreement until the end of the game. The introduction of prior face-to-face interactions seems to reduce the social distance among individuals, producing group formation ingredients such as group identity and trust. These elements survive after individuals move to a CMC context and provide the "backdrop" for the emergence of cooperation. Insights about transferability of trust from a face-to-face to an electronic context provide important recommendations for the networked, dispersed organization.

Introduction

Turbulent environment, international competition and economic pressures force the modern organization to rapidly adapt to changing conditions. As response, networked, adhocratic and dispersed organizational architectures emerge (Malone, Yates and Benjamin 1987). Uncertain market conditions and needs of high efforts in R&D lead to a variety of inter-organizational relationships, such as alliances, partnerships, joint-venture and research consortia (Ring and Van de Ven, 1994). Both tendencies emphasize a shift toward horizontal mechanisms of coordination, where communication and cooperation takes precedence over vertical lines of authority or discrete market transactions.

Information Technology is regarded as a critical enabler of new ways of organizing (DeSanctis and Jackson, 1994). Despite the supporting role of IT and CMC, cooperation and mutual adjustment still rely on basic aspects of social behavior which include trust, commitment and group identity (Turner, 1987). These aspects should not be taken for granted in electronic contexts (Greif, 1988). As Malone and Crowston (1994) point out, "... issues of incentives, motivations and emotions are usually of much more concern in human systems than in other kinds of systems. Understanding them is an important part of coordination".

Communication lies at the heart of cooperation in several ways: it supports the understanding of collective tasks and provides the feedback necessary for their execution. Moreover, communication provides a framework for social interactions and projects positive personal characteristics on fellow in-group members: They are acknowledged to be "friendlier, more trustworthy, and more honest" (Caporael et al. 1989).

The literature on CMC reveals positive and negative effects on group performance. CMC eliminates inhibitors to spread and fluid communication such as status differences () and influence of the first intervention (Sproull and Kiesler, 1991). Conversely, CMC may be deeply destructive due to de-individuation problems (Diener, 1980), lack of contextual and non-verbal cues (Brennan, 1991), message overloading. Besides, CMC changes the traditional rules of communication, coherence in the conversational thread and alternance in turn taking (Suchman, 1987), the timing with which it happens allowing asynchronous discussions, and the content of communication filtering it in text-form. Whether or not CMC will improve organizational performance may depend on the particular social circumstances under which these electronic media are employed (Fulk and Boyd, 1991).

The research question addressed here concerns the extent to which CMC can support a spontaneous mechanism of mutual adjustment and trust building, essential for the development of a stable group cooperation. The experiment provides an exploratory analysis of the impact of context and communication medium on the early stages of group formation with and without prior face-to-face interactions. Additionally, group behavior is observed in subsequent stages of goal clarification, commitment and implementation in the electronic context. A social dilemma characterizes the experiment. This situation represents a highly sensitive context for the analysis of spontaneous cooperation, as the collective benefit deriving from group cooperation is potentially disrupted by the higher individual payoff deriving from a free riding behavior.

Group Formation: a theoretical perspective

At the individual level, the process of socialization takes place through the modeling and learning of roles among group members (Schein, 1978). Additionally, the adoption of the group role has profound effects on how the individual see the world. Once within a role, the person is more likely to see in terms of "us vs. them," with a favored in-group of similar role-holders (us) and an out-group of different roles holders(them).

On the other hand, attention must be given to context and employed media when this process takes place. As Drexler and Sibbet indicate in their 7-stage model (Johnson, 1991), face-to-face meetings are irreplaceable in the earliest stages of orientation and trust building by IT, while audio and video-conferences, voice-mail and electronic-mail become helpful tools in the following stages of goal/role clarification, commitment, implementation, high performance.

Methodology

The experiment consists of a repeated, complete information, 6-person game (Ostrom, Walker and Gardner, 1992). During each round of the game participants decide the individual amount of investment in a market. The group should limit the global investment because a parabolic function characterizes the group payoff. However, the higher the individual investment, the higher the individual share of the group payoff the individual earns. After the 10th, 15th and 20th round subjects engage in a communication phase. Three different communication contexts have been compared: F2F communication (3 experiments), CMC (6 experiments), and CMC with prior F2F interaction (3 experiments). CMC is performed by a mailing list. Subjects are chosen in order to minimize existing friendship or acquaintance relations within each group.

CMC vs. F2F: an hypothesis on transferability of trust

A former investigation compared CMC versus F2F communication. The results showed opposite trends regarding to decision making and cooperation performance. CMC decision making was better off in terms of more homogeneous participation to the discussion, higher number of generated solutions, speed in the individuation of the social optimum. But cooperation didn't hold. Subjects showed great difficulties in converging toward an agreement and, despite their awareness of not performing well (emphasized by flaming exclamations and threats), increasing waves of defection characterized the game progressed. In F2F context decision making was poorer and no group solved optimally the collective action problem during the first communication phase. However, many cues (leadership, division of labor, establishment of behavioral rules) indicated that group formation emerged in the first communication phase. Cooperation held throughout the game. The results emphasized the importance of the context of group formation and led to the following hypothesis: HYP.: Face-to-face interactions enable group formation, providing elements such as group identity, values, history which are essential to the emergence of mutual trust. Once established, trust supports cooperative efforts even if the group meeting place is a purely electronic context.

To test the hypothesis, three groups were invited to meet and work on a face-to-face task a day before the CMC social dilemma experiment.

Results

Interesting and homogeneous results emerge from the experiments. During the first communication phase subjects show a strong desire to come to an agreement. However, CMC causes coordination problems while they are comparing alternative strategies of investment. These problems explain the collapse of cooperation after the first communication phase, although no drastic opportunism emerges. During the second and third communication phases subjects succeed in defining the agreement, without threats, flaming exclamations, and complaints about the message flow. The content analysis of messages shows the group recognizes a social identity. Cues, such as answering each others' questions, frequent use of the pronoun "us" rather than "anyone" or "you", emphasis on the concept of "our interest" characterize the flow of messages. Moreover, like in the previous experiments, decision making is better off by CMC. Hence the complementary of face-to-face and CMC optimizes the groups' performance on cooperation and decision making processes.

Conclusion

Despite the limited number of experiments, theoretical and practical insights emerge from the analysis. The results confirm that the ways in which CSCW systems restructure social relationships at work depend on preexisting pattern of authority, obligation, and cooperation (Kling, 1991). Thus, face-to-face communication might acquire a symbolic role in the emerging virtual organization, sustaining important elements to interaction patterns like history, routine, norms, social relationships, and deeply shared behavioral and interpretative context (McKenney et al, 1992). The entrepreneurial recommendation consists of the recognition of the importance of face-to-face episodes of interaction to optimize the use of CMC technologies. These episodes should constitute precise organizational measures related to a careful observation of the timing of group's life, including its formation and renewal.

References

1. Brennan, S. E. (1991). Conversation With and Through Computers. User Modeling and User-Adapted Interaction, 1:67-86.

2. Caporael, L. R., Dawes, R. M., Orbell, J. M., and Van De Kragt, J. C. (1989). Selfishness Examined: Cooperation in the Absence of Egoistic incentives. Behavioral and Brain Sciences, 12:683-99.

3. DeSanctis, G., Jackson, B. M. (1994). Coordination of information technology management: Team-based structures and computer-based communication systems. Journal of Management Information Systems, 10(4):85-110.

4. Diener, E. (1980). De-Individuation: The Absence of Self-Awareness and Self-Regulation in Group Members. In Paulus, P. The Psychology of Group Influence, Erlbaum, Hillsdale, New York, 1980.

5. Fulk, J. and Boyd (1991). Emerging Theories of Communication in Organizations. Journal of Management, 17:407-446.

6. Johnson, Virginia (1991) Teamwork: Different Kinds of Meetings for Each Stage of Group Development. Successful Meetings v40, n6, Part 1:92-96.

7. Kling, R. (1991). "Cooperation, Coordination and Control in CSCW". Communication of the ACM, 34(12):83-88.

8. Malone, T. and Crowston, K. (1994). The Interdisciplinary Study of Coordination. In "ACM Computer Surveys, 26(1):87-119.

9. McKenney, J. L., Zack, M. H., Doherty, V. S. (1992). Complementary Communication Media: a Comparison of E-mail and Face-to-face Communication in a Programming Team". In Nohria N. and Eccles R. (Eds.) Networks and Organizations, Cambridge, MA: HBS Press:262-287.

10. Ostrom, E., Walker, J. and Gardner, R, (1992). Covenants with and without a Sword: Self-Governance is Possible. American political Science Review, 86:404-417.

11. Schein, E. H. (1978). Career dynamics: Matching individual and organizational needs. Reading, MA: Addison-Wesley.

12. Sproull, L. and Kiesler, S. (1991). Connections. New Ways of Working in the Networked Organization. The MIT Press, Cambridge.

13. Suchman, L. A. (1987). Plans and Situated Action. The problem of human machine communication. Cambridge University Press. New York.

14. Turner, J. C. (1987). Rediscovering the social group: a self-categorization Theory. London: Basil Blackwell.

NEW EMAIL LIST ON SCIENCE STUDIES AND COMPUTER SIMULATION

by
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Since the 1950s, various computer simulation techniques have become increasingly important research tools across a wide range of natural (and social) sciences. Software packages based on these techniques are also widely used in more applied fields such as engineering, finance, or environmental management, often in connection with computerised databases and electronic data gathering devices.

We are trying to get in touch with other people working in the broad area of Science Studies / ST&S / HPS, who are interested in the issues raised by these modelling techniques, and who would like to join a special interest email list. Our intention is that by having a relatively narrow focus to the list, there will be a good chance of having lively debate of interest to most subscribers.

The list will be useful for:

- exchange of ideas about computer simulation
- passing on details of books and articles.
- announcements of relevant conferences etc.

To join the list, please send email containing only the words: subscribe simulist to the address majordomo@lists.lancs.ac.uk (No subject line necessary)

Please pass on this message to anyone who may be interested.

A HAND-CALCULATED VIRTUAL DESIGN TEAM MODEL, USING QUEUES WITH STATE TRANSITIONS

by
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Previous research in the Virtual Design Team project at Stanford University has focused on simulating information flow in an organization at an atomic level. Although the communication content is abstracted out, every single instance of communication (memo, phone call, 'corridor' meeting, scheduled meeting etc.) is modeled as a separate entity. The phrase "Wind Tunnel Simulation" has been semi- humorously coined to characterize this type of modeling, where the behavior that is being sought only emerges from an aggregation of many hundreds of events.

This paper discusses research whose aim is arrive at similar results and conclusions using a more high-level model, one in which the only variables are the actors' processing times and the inter-arrival times of the different communications that they handle. The basic VDT assumptions are used as a foundation for further abstraction that makes possible a traditional queuing theory formulation of the system. These assumptions include:

1) Galbraith's 'exception handling' theory of work, where a supervising manager is kept busy mostly responding to subordinates' demands for decisions on how to proceed at critical junctures (exceptions)
2) A view of task-level failure interdependence, where failure to carry out appropriate remedial work (e.g. when the supervisor's decision is delayed) increases the number of exceptions in a whole set of dependent tasks.

3) A required amount of coordination between reciprocal activities, which needs to be attended to in a timely manner to reduce the frequency of exceptions in all activities.

The Hand-calculated model has as inputs various types of dependencies necessary to depict these assumptions. The list of activities, actors and their various interdependencies is invariant in each model instance. All other variables, such as skill match, communication media, and workload as a function of time, are abstracted up to the level of determinants of the two crucial measures, processing time and inter-arrival time of communications. The values of these two variables for each actor summarize the state of an organization at any given point in time. A Stochastic Activity Network or Petri Net is then used to illustrate transitions from states of "normal" work flow to states of critical information overload for each actor. This means that standard analytic methods can be used to calculate the predicted performance of a certain organization assigned to a certain project.

The formulation described above is used to mimic the behaviour of a VDT simulation of a medium-sized project model. This enables a concluding comparison to be made between the two models in terms of output quality, result accessibility, input effort and computing costs.

REFLECTIONS ON THE VIRTUAL DESIGN TEAM RESEARCH PROGRAM

by
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The Virtual Design Team research program was launched in the late 1980s to develop computational tools for analyzing organizations engaged in concurrent engineering, software development and similar, complex, but relatively routine, project-oriented tasks. Two Ph.D. and Two Engineer Degree students have completed their dissertations on the project by now, and several more are in progress and approaching completion. The "Virtual Design Team" has progressed from the idea that real organization structures could be analyzed to lend rigor to organizational (re)engineering efforts, through research prototypes, to a relatively well validated system that is now being used in teaching graduate and undergraduate courses in several countries, and will be commercialized starting in late 1996. This presentation reflects on the path taken by the VDT research program since 1989 and tries to extract some lessons learned about this style of computational organizational modeling.

PURPOSES FOR SIMULATION

Rich Burton and Borge Obel's [95] insightful JCMOT paper sets out a list of purposes for computational simulation of organizations--descriptive simulation, intellective simulation, normative simulation and business games and proposes appropriate experimental designs and data analysis procedures for each. However, the they do not discuss whether new kinds of organizational simulation approaches should address these purposes in any given sequence. As a set of conceptual ideas and software implementations of those ideas mature over time, we will argue that purpose should adapt. And we advance a sequence of purposes that worked well to help us achieve our ultimate purpose: normative simulation.

PURPOSES OF VDT PROGRAM

The high level goals of the VDT research have always been:

1. Normative: To develop modeling methodologies and software tools that can be used by managers to analyze the performance of organizations engaged in complex project tasks; and

2. Intellective: To develop a micro-contingency theory of organizations that can predict the impact of low level changes in tasks, actors and organization structure (including tools to support information processing and communication) on the performance of project teams.

To address these goals, it might appear that intellective simulation--modeling quasi realistic organizations and tasks to test the impacts of extreme values of independent variables on simulation results -- would be the logical first step. However, we decided to follow the tradition of Cyert and March and begin with descriptive simulation, in order to develop a language and framework with sufficient expressiveness to support normative analysis of real organizations later.

The kinds of work processes and organizations that we intended to model are "information-bounded." By this we mean that the organizations we are interested to model, unlike the kinds of "organized anarchies" that Cohen, March and Olson model, have relatively well understood and agreed upon goals and means. The limits to effectiveness and efficiency are thus set by the organization's capacity to process and communicate information.

We needed a modeling language and framework for describing interdependencies between subtasks, and for predicting the information processing load on each actor in the organization associated with performing direct work in each subtask, and coordinating with actors responsible for interdependent subtasks. Jay Galbraith [77], Tushman and Nadler and others developed information processing models of organizations during the 1970s and 1980s. However, they modeled the organization as a whole, in a qualitative way, so these models needed to be significantly extended for our purposes. Nevertheless, they provided a good enough starting point for our work that we felt we could go directly to descriptive simulation.

DEVELOPING A LANGUAGE AND FRAMEWORK

Geoff Cohen, our first Ph.D. student in the VDT program, observed design teams closely for many weeks, and then used these observations plus his own considerable design experience to develop a modeling language and actor micro-behaviors for multi-disciplinary engineering design projects.

INITIAL DESCRIPTIVE SIMULATION EXPERIMENTS

Cohen[92] validated his VDT model (for construct validity) by applying it to a 100-person project team engaged in designing an oil refinery in two offices on opposite coasts of the US. He made some simple predictions from the theory about impacts of raising centralization and adding voice mail on project duration and compared these to managers' predictions and to VDT results. This was a crucial first step in demonstrating that the approach could be used to model real teams and that the simulation model produced results with some degree of face validity.

EXTENDING THE LANGUAGE AND FRAMEWORK

Tore Christiansen, our second Ph.D. student, was interested in extending VDT-1 to reason about process quality. He made two key contributions to Cohen's framework. First, he developed a structured methodology for modeling the coordination load placed on individual actors in an organization by the inherent complexity and uncertainty of the subtasks for which each actor is responsible and by the interdependencies between their subtasks and others'. Second, to model process quality, he added explicit task failures, and actor behaviors for exception referral and handling. Overloaded actors fail to process exceptions or respond to requests for coordination, leading to uncorrected exceptions and reduced process quality.

ADDITIONAL DESCRIPTIVE SIMULATION EXPERIMENTS

Christiansen [93] used his extended VDT model, which we dubbed "VDT 2.0," to model two real project teams: a utility company team designing an electric substation; and a team designing a subsea oil production module for the North Sea. Both of these projects had already been completed. Tore compared managers' predictions about the global impacts of changes in centralization and formalization on cost, duration and two measures of process quality. This more extensive set of experiments was analyzed with ANOVA techniques and yielded statistically significant findings, which further validated the VDT methodology and framework in terms of both construct and content validity.

TOWARDS NORMATIVE SIMULATION

These experiments provided us with some confidence that VDT could model many important features of real project teams. Since we calibrated the model to actual past data and then used managers' predictions to validate "What if?" scenarios, the validation experiments described above did not demonstrate that VDT was calibrated well enough to predict the performance of project teams proactively -- our long term goal.

SIMULTANEOUS VALIDATION

A third set of structured validation experiments is currently being run by Jan Thomsen and Yul Kwon, current Ph.D and undergraduate students respectively in the

VDT program. They are modeling a less routine task: design of the commercial version of a missile system to be used for launching telecommunication satellites. (Thomsen's work also involves extending VDT to represent and reason about goal incongruencies between members of a project team. Thomsen and Kwon hope to present their approach and results separately at the CMOT workshop.) The key difference in this validation experiment is that we modeled an organization in the early stages of a project and predicted the team's performance, including the locus of bottlenecks in information processing, a priori. Results to date have been excellent; a key bottleneck predicted by VDT has turned out to be a major headache for the project manager as the subteam in question became overloaded by the need to coordinate its work with other subteams in the face of multiple design changes.

PROACTIVE VALIDATION IN NEAR-REAL-WORLD EXPERIMENTS

Proactive validation will require that we use VDT to make predictions of project team performance for multiple project teams with different values for independent variables before work commences, and then compare these predictions to actual results. This is obviously a difficult experiment to set up and run in the real world, so we will go half way to the real world of design teams--to student design teams.

In collaboration with Professor Poul Hansen, we plan to model multiple groups of small student teams (with 7-10 participants) attempting to solve realistic design problems in mechanical engineering design classes at the University of Aalborg in Denmark (a pioneer in the development of "project-based learning" engineering curricula). We hope to describe the results of this experiment at a future CMOT workshop.

INTELLECTIVE SIMULATION

Starting about now, we are launching a series of "intellective simulations" to test the full parameter space of VDT with quasi-realistic organizational models. The goals of this set of experiments are twofold:

1) Perform extensive sensitivity analyses of parameters in VDT in order to understand which have the greatest influence on team performance. This will hopefully allow us to better understand the model dynamics so we can simplify the representation and reasoning in VDT. If we are successful at this, we can simplify the coordination load modeling methodology (i.e., the way that we currently describe a project task and team in VDT) as well as the VDT simulation system itself.

2) Develop a characterization of organizational information flow regimes. We hope to discover non-dimensional parameters to characterize information flow through organizations -- analogously to the way that Reynolds Numbers are used to characterize fluid flow regimes as laminar or turbulent flow. We believe that insights from this style of "coordination science" would represent significant contributions to organization theory [Christiansen 93].

INTELLECTIVE SIMULATION SECOND, NOT FIRST, WHY?

We started with descriptive simulation. As we gained confidence in the predictive accuracy of our methodology and tools, we initiated some normative simulations. And only now are we starting to perform intellective simulations. In reflecting about why we followed this path, we feel that our culture as engineering scientists led us to work this way. We always had the goal of developing new kinds of organizational analysis tools that could be used to support organizational design -- one might call this kind of tool an "organizational wind tunnel." We felt that enough of the basic science to characterize the problem had already been done by Thompson, Galbraith and others for us to build prototype simulation systems directly and then test them against empirical data.

Engineering scientists who developed computational models of the behavior of complex structural or thermal systems since the 1960s have followed this same path. The benefit of building "computational wind tunnels" to model realistic problems is that one can then perform three-way comparisons, testing the predictions from theory and computational models against each other, and against real world data. As we have found increasing empirical validation for our VDT analysis framework, we are beginning to deploy VDT as an "organizational theorem prover" to try to discover fundamental laws and new theory.

Sociologists, political scientists and other researchers, whose goals are first and foremost to develop new descriptive theories for their own sake, might more naturally begin with intellective simulations, test them against predictions from the underlying theory and defer attempts at rigorous empirical validation until later. The latter approach has been used successfully by many of our colleagues to develop and refine organization theory.

SIMULATION TOOLS AS "MANAGEMENT GAMES"

We have been using VDT in classes since 1993. Aside from the insights that a tool such as VDT can provide in teaching students about computational organizational models (initial Ph.D class), managing design teams (MS level design project class) and advanced project management (current class for MS and upper division undergraduates), we have found that introducing computational organizational models into classes is a powerful forcing function for the research team to focus on simplifying and "bulletproofing" not only the software tools, but the modeling methodologies as well.

Computational organizational models provide excellent vehicles for developing management simulation exercises in which students can learn organization theory inductively by simulating cause and effect in realistic "games." The systems dynamics researchers have been prolific developers of such management games. We see this kind of simulation as a logical outgrowth of our current work with VDT. Modern workstations provide rich possibilities for graphical display of actor micro-behaviors in response to changes in independent variables. Grapical displays of inputs and outputs facilitates rapid development of "model-based management judgement" by users of these kinds of simulation exercises. We will attempt to develop such simulation exercises using VDT, as a logical outgrowth of our descriptive, normative and intellective simulation experiments to date.

COMMERCIALIZING VDT

Although using tools like VDT in classes represents a powerful form of technology transfer, the more challenging technology transfer stage in the evolution of a simulation model like VDT is when it is commercialized as a tool to be used widely in industry.

We have been distributing VDT through Stanford's Office of Technology Licensing (free to Universities, and at a modest cost to companies) since 1994. As the number of licenses starts to rise, it has become very difficult and distracting for us to support the community of users from the university. We are, therefore, forming a company later this year, with Stanford University as a partner, to commercialize and distribute VDT.

In conjuction with extending VDT to model less routine kinds of work, with adaptive actors, our research focus will then shift to the "management of technology" perspective. What changes in attitudes, behavior and performance occur when organizations attempt to design their structures systematically?

REFERENCES

Burton, R. M., and B. Obel, "The Validity of Computational Models in Organization Science: From Model Realism to Purpose of the Model," Computational and Mathematical Organization Theory, 1 (1), 1995, pp 57-71

Christiansen, T. R., Modeling Efficiency and Effectiveness of Coordination in Engineering Design Teams. Ph.D. Thesis, Dept. of Civil Engineering, Stanford University, September 1993.

Cohen, G. P., The Virtual Design Team: An Information Processing Model of Design Team Management, Ph.D. Thesis, Dept. of Civil Engineering, Stanford University, December 1992.

Galbraith, J.R., Organization Design, Addison-Wesley, Reading,

MODELING ORGANIZATIONAL LEARNING IN RESPONSE TO NEW TECHNOLOGY

by
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This talk will describe a computational model for studying individual and group learning in organizational settings. The main motivation in building the model has been to study the response (primarily in terms of structural changes and short and long term organizational performance) of different organizational structures to a sudden disturbance (e.g., a new technology). The model is based on four assumptions: (1) The type of organizational change that we are studying comes from routine incremental adaptations in response to the environment usually with a short term focus. (2) These incremental adaptations are constrained by and in time reflected in individual preferences and competencies for the organization's technologies and resources, individual beliefs in organizational rules and routines, and individual and group aspirations. (3) The main experiential learning mechanisms are preference adaptation, rule-following and experimentation. (4) Learning takes place in response to an individual's own experience as well as in response to other comparable individuals' experiences.

The second part of the talk will focus on the computational model's application to two specific technology problems. The first problem involves two competing technologies that have both advantages and disadvantages in terms of two organizational goals. This conflicting goals case is used to study the effect of initial goal aspirations, aspiration adaptation rates and learning rates on individuals' tendency to specialize in a technology when learning involves one of pure preference adaptation, experimentation and rule-following. The second problem depicts an emergent technology case in which an old technology's capabilities are gradually surpassed by an emerging technology. The model simulations reveal the effect of different amounts and types of experimentation together with different preference and aspiration adaptation rates on the adoption of the new technology and on optimum old to new technology transition performances. The emerging technology is defined in terms of two dimensions: (1) Maturation time that is the time it takes for the technology to fully develop and surpass the capabilities of the old technology; and (2) Technology learning speed that is the rate at which the emerging technology can be mastered.

Finally the talk will describe a set of potential areas that the computational model can be applied to involving multiple agents and/or organizations.

ORGANIZATIONAL DESIGN THROUGH DATA MINING: THE IMPACT OF SUBUNIT INTERDEPENDENCIES

by
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Organizations act as information processing systems in an attempt to cope with uncertainty within their environments [Galbraith, 1973]. This uncertainty stems from three primary sources: unstable subunit task environments, subunit task complexity, and interdependence among subunits [Tushman and Nadler,1978]. The current research effort is focused on the impact of interdependencies on the way a simulated organization learns, and ultimately on the way it must be structured to improve its overall decision m aking performance. We begin with Carley's basic model [Carley, 1990], which we extend to capture more complex and interdependent tasks. In particular, we show that our extension of the basic model expresses the power of weighted propositional logic between tasks. We illustrate several applications to demonstrate that interdependencies expressed in this model are quite common and natural in real life. Once introduced into the model, task interdependencies can be manipulated in such as way as to test the effect of subunit interdependency on organizational learning across different organization structures. We discuss the general implications for the model, and report our simulation results on the implications of levels of interdependency and task complexity and on the implications of types of interdependencies.

SIMULATING TECHNOLOGY'S IMPACT ON COOPERATIVE WORK: MODELING AND TESTING

by
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Information technologies, both individually and in new and uniquecombinations, are playing an increasingly important role in theday-to-day business of most organizations. Extant research focuses ondesigning, building, and delivering these technologies to users, yetlittle research focuses on their evaluation. Information technologyevaluation research has been restricted to either retrospective fieldstudies or narrowly focused experiments. Limitations of this workinclude either a focus on few information technologies or many factorschanging at the same time. Providing a computational framework wouldallow researchers to simultaneously examine changes in types oftechnologies while providing greater control over what is beingexamined. A computational framework for cooperative work, theCommunicating and Information Technology (COMIT) model and simulation,allows researchers to examine the impacts of various informationtechnologies on an organization~s performance. COMIT is capable ofsimulating maintenance tasks in both solo and collaborative environmentsutilizing a variety of information technology. Output from COMITincludes aggregate and detailed statistics on the number and duration ofactions (e.g., communication, information lookup, and task tries), atask~s quality, and a detailed trace of action execution and timing.Though COMIT may be useful to test interactions of technologies andtask, it may be equally useful making predictions about the use oftechnology in differing situations. Making specific predictionsrequires calibration from the results of experiments (involving humansubjects, not computer agents). COMIT calibrates well to thefrequencies of actions, and predicts ordering of actions at asignificant level. For predicting, COMIT is well suited to predictingthose actions that occur with high frequency.

LINKING THEORY CONSTRUCTION AND THEORY TESTING TO EMPIRICAL DATA VIA EMPIRICALLY DRIVEN COMPUTER SIMULATION: THE APPLICATION OF A COMPLETE METHODOLOGY TO ORGANIZATION THEORY

by
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Continuous-time, continuous-state computer simulation has been used to construct theories (Richardson, 1987; Hanneman, 1988; Patrick, 1996), test theories for internal validity(Patrick, 1997) and link theories to empirical data (Patrick, 1991, 1993, Bronson & Jacobson,1989). This paper proposes a consolidation of these trends. A process of theory construction and testing will be outlined from the formalization of theory with computer simulation, to the testing of the formalized theory with data from a specific organization. This method of theory construction and testing follows four general steps: 1) Theory formalization, 2) Theory testing for internal validity, 3) Theory testing with empirical data from secondary data, and 4) Theory testing with data from specific organizations
.

Steps One and Two

The first two steps generally operate together. Traditionally, social theories are expressedin natural language. Theories of this type usually are formalized only in the form of isolated propositions. Computer simulation allows the researcher to continue the formalization process toa level of semi-mathematical language. Computer simulation operates between the cumbersome level of natural language and the extremely abstract level of mathematical language. Operating between these two extremes allows the user the best of both. Highly complex theories can beformalized in explicit terms without losing subtleties of natural language. Pioneers in continuous-time, continuous-state computer simulation have outlined the processes of both theory construction and theory translation (Richardson & Pugh, 1988; Hanneman, 1989). This methodhas been used extensively to understand complex and dynamic relationships present in organizational control processes (Patrick, 1991).

In this example a theory of organizational control taken from Collins (1988) will be used to illustrate the process. The complete theory is highly complex and dynamic containing over 44 formalized concepts. In this paper the process of coordinating the activities of members will beused for illustration.

Step Three

The first two steps in this methodology are purely theoretical. The theory is formalized and tested for internal validity. Step three begins the process of empirical parameterization. Once a theory has be formalized and adjusted to operate well internally, linkages to empirical reality can be made with secondary data. While there are several methods of linking simulations to empirical data (Bronson & Jacobson, 1987; Patrick, 1993, 1996, 1997), the method advanced here is the use of a meta-analysis of secondary data sources. Correlation coefficients obtained from published sources are used to parameterize simulation equations. This first link to empirical data allows the researcher to continue the testing and adjustment process with relative ease.

For this paper the results of the theoretical simulation of coordination of membersactivities will be compared the the same concept parameterized with secondary empirical data. This comparison has been done before (Patrick, 1993) but will serve to illustrate the overall methodological process.

Step Four

The forth and final step in the methodology is the testing of formalized theory with empirical data taken from a specific organization expressly for the purpose of parameterizing the model. In step three the data used was composite data from existing literature but in step four the data is taken from a specific organization. Computer simulation may work well at a theoretical level and even at a meta-analytic level but the true test of any theory is its application to specific situations. This step is new to this methodology. For the purposes of this paper data taken from a medium security prison will be used to parameterize a model of organizational control. In this case the organization in question can be seen as a coercive organization (Collins, 1988). As in the previous three steps, the coordination of members activities, in this case the coordination of inmates activities, will serve as the illustrative example. Results of the theoretical, meta-analytic,and empirical simulations will be compared and the overall theory will be evaluated.

Conclusions

The goal of this paper is to offer one possible method of theory construction and testing that can be used by anyone studying organizational phenomenon. One goal of theory is to understand the empirical world at an abstract level but theory becomes its most useful when itmakes possible the understanding or prediction of specific phenomenon. The methodology outlined here allows the researcher to move from the abstract level of verbal theory down to the empirical level of a specific organization in a systematic, controlled fashion.

ORGANIZATION ADAPTATION AND EVOLUTION THROUGH BUSINESS PROCESS REENGINEERING: CHOOSING WHAT TO REENGINEER--A KNOWLEDGE-BASED APPROACH

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Business Process Reengineering (BPR) has become a major vehicle for organizations to change their structure and processes. Many firms are using BPR to make radical changes in a wide range of processes. Since firms are making these large changes, there is interest in the process of how organizations choose what processes to engineer.

This research presents a model of that choice based on empirical data. The model is represented computationally as a knowledge-based system. In particular, a prototype system was built using M.4 to model the choice process. The preliminary version of the model has about one hundred knowledge base entries.

The key drivers "forcing" reengineering appear to be drawn from both external (e.g., competitors, regulation and new technology) and internal (e.g., costs and profitability) sources. These key drivers influence firms from different geographical locations (e.g., European and North American) and industry (e.g., Automotive, Pharmaceuticals, etc.) differentially. For example, North American firms are more likely to reengineer because of foreign competition than European firms.

The cause of the need to reengineer influences quite strongly "what" processes need to be reengineered. If regulation caused reengineering, then the processes most immediately subject to regulation get the attention of BPR. If foreign competition is the cause, then the manner that foreign competition is competing influences the choice of the BPR effort.

For those firms where the key factors don't immediately determine what needs reengineering, a number of decision approaches (benchmarking, activity-based costing, etc.) have been used, where their choice is also based on key drivers. For example, where competition is the key driver, "competitive analysis" is used to isolate specific processes facing competition; where costs are the key factor, activity based costing is used to isolate the primary costs forcing a need for reengineering.

All these factors are summarized in a computational model of how firms choose whether or not to reengineer. Such a model could be useful, since around two-thirds of all firms that do reengineering, do some search and analysis trying to decide what to reengineer.

MAKING GENERIC PROTOCOLS SITE-SPECIFIC

by
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Modern medical care is a collaborative activity among physicians, nurses, and other health care providers working within large, complex organizations. Managed care and market pressures are driving medical organizations to increase productivity and to reduce costs, all without adversely affecting patient care. One method that has been used to achieve these goals is to adopt standard protocols or protocols for patient care and there has been significant effort at both national and institutional levels to create standard care plans, critical pathways, and protocols. When properly followed, protocols do have the desired effect of improving patient care while reducing patient care costs.

Because of the substantial time and effort needed to create good protocols, there is an incentive to make these protocols general enough to be shared among different institutions. Site-independent protocols are difficult to use, however, without modifications to reflect the way in which medical care is delivered within a particular organization. As a result, most protocols must undergo significant change to make them acceptable to health care providers within a particular setting. At present, these modifications are made by committees of health care professionals in an ad-hoc fashion, and until a protocol is actually used in an organization, it is not known whether the protocol will have the desired effect on patient care. In some cases, site-specific protocols, intended to reduce cost, have had the opposite effect when actually used in a particular organization.

We are developing a methodology to take generic protocols and make them site-specific in a more principled way, and are motivated by a desire for a computational model of both the protocol and the organization. Generic protocols are poorly accepted by health care providers until they have been modified to reflect site-specific information, and there is no computer-based support for these modifications. Second, generic protocols are not detailed enough for implementation in computer-based information systems or for organization simulations, without additional site-specific information. It is necessary to separate the site-specific information from the sharable, generic protocols, and provide a link between the site-specific information and the generic protocol descriptions.

In our framework, to make a generic protocol site-specific, a medical director needs three components: (1) A generic protocol that has been annotated with additional information to make explicit assumptions the authors of the generic protocol in constructing their protocol, (2) a model of activities in the site, with indications of the resources, policies and preferences, and (3) rules that define legal transformations that make a generic protocol site-specific. CAMINO provides tool support for this process

Generic protocols are not always explicit about the protocol's intentions, about how each of the activities in the protocol assist in achieving an intention, or about the relative importance of a particular activity versus other activities. Do the protocol authors intend to save money by preventing unnecessary testing or treatment? To achieve the protocol's intentions, is it necessary to follow the protocol exactly, or are some activities more important than others? Does this protocol emphasize cost containment over timely diagnosis? To answer these questions, site-independent protocols must make explicit:

-the intentions of the protocol authors in specifying the activities that the protocol comprises
-a measure of the value or utility of the activities that support the protocol's intention (since not all activities within a protocol provide equivalent support for the protocol's intentions).
-a measure of cost assumed for the activities in the protocol-constraints on the temporal ordering of the protocol activities.

With this information, site-specific protocols can be created that follow the intentions of the protocol, but that may substitute different ways of achieving those intentions. For example, one hospital may find it better to use an intravenous pyelogram than to refer the patient to a distant hospital for an ultrasound in the diagnosis of kidney stones. At another site, because of local expertise, it may be more desirable to get an ultrasound prior to surgery in a patient with suspected appendicitis than it is to perform surgical exploration based only on clinical parameters. If the site-independent protocol is annotated with information about the assumptions and intentions of the protocol author, it is easier to make changes that remain true to the protocol, while remaining consistent with the characteristics of the organization that is using the protocol.

To create a site-specific protocol, a series of transformations must occur. These include:
Addition In the simplest case, this is the addition of new activities that expand on activities in the generic protocol. For example, a generic protocol might suggest doing a particular test. In a site-specific protocol, additional steps of ordering the test, monitoring the test result, notifying the patient of the result, and providing additional educational resources would be the organizational expansion of the more generic clinical activity.
Deletion In the process of specialization, this would mean the removal of activities that cannot be done in that organization, or that are redundant.
Aggregation The protocol may indicate two different activities that the organization always treats as a unit. For example, a protocol may indicate to check a patient's blood pressure and then his pulse. The clinic may care only that the vital signs are taken, of which the BP and the pulse are a part. In this case, the generic protocol has more detail than is necessary for doing the tasks within the organization.
Substitution Substitution is a combination of addition and deletion. The original activity is deleted, and one or more activities are added to the protocol.
Temporal reordering It should be possible to reorder activities that do not have explicit temporal constraints to be consistent with the organization's procedures. For example, if the protocol indicates that one test should be done and a second done based on the results of the first, it may be more efficient for the organization (and convenient for the patient) to do these tests at the same time and then to evaluate them both simultaneously.

CAMINO

We have created a prototype system, CAMINO, that assists protocol developers in making site-specific protocols from generic protocols and have demonstrated how such a system might integrate into a workflow tool to help manage medical tasks. CAMINO uses a generic protocol that has been annotated with intentions, relative costs and utilities, and matches these activities to site model activities, based on intentions. We are also extending this framework to include patient data, demonstrating how we anticipate integration into a workflow manager or hospital information system might occur.

Our site model contains activities supported by the organization, but at a much finer level of detail than the generic protocol contains. Similar to the generic protocol, the site activities are annotated with the intentions, relative costs, and relative utility, but have additional slots for resources that are required, the clinic providers, their skills, and the activities for which they are responsible.. For each of the activities in the generic protocol, CAMINO is capable of finding the organizational activities that match the intentions of the generic protocol and displays these site activities for review by the user. For example, if the generic protocol activity is "Do excisional biopsy", we see that this activity has the intention of determining whether the breast mass is malignant or benign, with a relatively high cost, and a high utility value. In our site model, there may be three activities that have the same intention, but with different costs and utilities-needle-placement biopsy, core biopsy, and surgical excisional biopsy. These alternatives are similar to the specialization of processes described in the process handbook, but with the addition of preference and cost information and with intention as the organizing concept. With this additional information, we can provide computer-based support to help rank the possible choices for the physician and give the physicians a sense of the value that the organization places on activities that may have the same intention and goals.

Discussion

Patient care protocols are not new to medicine, but it has only been recently that interest in protocol-based care has increased, in part due to economic and social factors to improve standardization of care and maintain high quality care. At the most general level, protocols attempt to capture the medical information that is most salient to the care of the patient, without including site-specific details about how the care is carried out.

Protocols are most effective at altering provider behavior when they are customized for the institution that will use them. Unfortunately, this customization makes it difficult to share protocols between different institutions, validate protocol changes or maintain protocols in the face of organizational change. We believe our formalism will help solve some of these problems, by allowing both for site-independent generic protocols, and for a process that builds valid, site-specific protocols from those generic protocols.

It is clear that generic protocols and the activities that support those protocols, must have descriptions that are more detailed and formal than simply indicating the next step in a protocol. Shahar et al. has defined a formal language of intention to describe protocols and their actions. This language should allow administrators flexibility when building site-specific protocols, while remaining faithful to the intentions of the generic protocol. This language has not yet been applied to site-specific protocols, but we believe it can be extended to cover such protocols. Future versions of CAMINO will support this formalism.

In our methodology, we emphasize the importance of a site model as a source of information about the organization in which the protocol is to be used. What features will be important to encode in the site model will, in part, depend on the application for which the protocol will be used. Since the kind of application for which the protocol is to be use is an issue of site-specific implementation, it is appropriate that this information be contained in the site model. For example, if the generic protocol is to be specialized for use in a clinical information system or workflow environment, the site model would need a detailed description of resources and resource constraints that that particular site and application required. A different institution might use the same protocol for education and training, but their site model would contain information about supporting reference material. It is an active research issue to define the features of a site model that would facilitate these customizations.

Finally, we believe the best opportunity to improve the efficiency, the cost and the quality of patient care is by including organizational factors in protocol development. Once we have assured that the site-specific protocols are valid and consistent with respect to the intentions and goals of the protocol authors, we can focus on the process of care and ways in which it might be changed to improve patient care quality. There has been significant effort in the business community to improve organization performance through business process reengineering, computational organization models, and discrete event simulations. We believe we can apply this work to medical care by using site-specific protocols as a model of the organizational processes in health care. Computational models of organizations provide a "wind-tunnel" for testing and simulating organizational processes. Such simulations can be used to gain insight into how organizational makeup hinders or helps patient care. Our framework allows generic protocols to be maintained as site-independent protocols, but provides a mechanism to modify these protocols for use in detailed, organization simulations.

With additional knowledge of what the organization does most efficiently, we can make modifications to the generic protocol in ways that remain true to the intention of the original site-independent protocol, and provide a protocols that reflects accurately the best medical knowledge, the best patient knowledge and the best organizational knowledge relevant to the care of patients.

References

1. Field, MJ, Lohr KN, ed. Clinical Practice Guidelines: Directions for a New Program. IOM report, National Academy Press, Washington, D.C. 1990.

2. Loback DF, Hammond WE. Development and evaluation of a Computer-Assisted Management Protocol. Symp on Comp App in Med Care, 1994:787-91.

3. Ellrodt AG, Conner L, Ridinger M, et al. Measuring and improving physician compliance with clinical practice guidelines: A controlled interventional trial. Annals of Internal Medicine, 1995;122(4):277-82.

4. Brown JB, Shye D, McFarland B, The paradox of guideline implementation: how AHCPR's depression guideline was adapted at Kaiser Permanente Northwest Region., Jt Comm J Qual Improv, 1995;21(1):5-21.

5. Purves I, Computerised Guidelines in Primary Health Care: Reflections and Implications, in Health Telematics for Clinical Guidelines and Protocols ed. Gordon C, Christensen JP 1995; 57-74.
6. Gensensway D. Putting Guidelines to work-lessons from the real world. ACP Observer, 1995 15:(1).
7. Shahar Y, Miksch S, Johnson P. An Intention-Based Language for Sharing Clinical Guidelines, Proc Symp Comp Appl Med Care, 1996; submitted.
8. Shahar Y, Musen MA. Plan recognition and revision in support of guideline-based care. Proc AAAI Spring Symp on Representing Mental States and Mechanisms, 1995; 118-126.
9. Russell S, Norvig P, Artificial Intelligence: A Modern Approach. Prentice-Hall, Englewood NJ,1995; p. 350.
10. Wyner GM, Lee Jintae. Applying Specialization to Process Models, in Conference on Organizational Computing Systems, ed Comstock N. King R, Mylopoulos J, Kaplan S 1995; 290-301.
11. Levitt RE, Cohen GP, Kunz JC et al. The "Virtual Design Team": Simulating How Organization Structure and Information Processing Tools Affect Team Performance, in Computational Organization Theory, ed. Carley KM, Prietula MJ, 1994.
12. Malone , Crwoston, K, Lee, J et al. Tools for inventing organizations: Toward a handbook of organizational processes, In Proceedings of the 2nd IEEE Workshop on Enabling Technologies Infrastructure for Collaborative Enterprises, Morgantown, WV, April 20-22, 1993.

GETTING COMMITMENTS FROM DELINQUENT CARDMEMBERS - MODELING HOW CREDIT COLLECTORS LEARN ON-LINE FROM OUTCOME FEEDBACK

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At the workshop, I will propose an approach for modeling how credit collectors at a major U.S. bank (the bank) learn on-line from outcome feedback. The approach builds on the formulation of goal-directed learning in dynamic decision tasks I presented at last year's workshop. This formulation hypothesizes that decision-maker's in dynamic environments learn two types of knowledge on-line from outcome feedback: (1) Which actions to take to achieve desired outcomes; and (2) The effects of their actions on the environment. To date, my collaborators and I have compared the formulation's predictions against human data in the Sugar Production Factory, a simple dynamic decision task, under a variety of experimental conditions (Gibson, Fichman, & Plaut, inpreparation; Gibson, 1996; Gibson and Plaut, 1995). Under all of theseconditions, feedback on the outcome of decision makers' actions has been immediate.

The new modeling efforts I will describe focus on the job of bucket 6 collectors at the bank. Bucket 6 collectors manually place outbound calls to creditcard holders who are six months behind on their payments. These cardmembers are in the last stage of delinquency prior to write-off by the bank and thus represent a high pressure situation for collectors. A key determinant of collectors' success in this job is their ability to make multiple, interdependent decisions rapidly while in contact with cardmembers on the phone. The feedback that collectors receive on their success is cardmembers' stated willingness to commit to single or multiple payments in order to resolve their delinquency. This feedback contains important components of delay since cardmembers are reacting not just to the collector's last statement but the whole ensemble of statements given their circumstances. To effectively use this feedback, collectors must retain and integrate information over time.

Extending our computational formulation to account for how collectors learn from outcome feedback while interacting with cardmembers presents two major challenges. First, an artificial task that retains the essential features of collector contacts with cardmembers must be instantiated in a way that the computational model can learn by doing it. Second, we must extend our computational model to retain and integrate information over time. In my talk, I will more fully lay out the computational model, the task of the credit collector, how we are instantiating this task, and how we are extending the model.

Bibliography

Gibson, F. P. (in press). The sugar production factory---a dynamic
decision task. Journal of Computational and Mathematical Organization Theory}, 1 (3).

Gibson, F. P., Fichman, M., and Plaut, D. C. (in preparation). A model-based approach to learning in dynamic decision tasks. Organizational Behavior and Human Decision Processes.

Gibson, F. P., and Plaut, D. C. (1995). A connectionist formulation of learning in dynamic decision-making tasks. Proceedings of the 17th Annual Conference of the Cognitive Science Society. (pp. 512--517). Hillsdale, NJ: Lawrence Erlbaum Associates.

ASYNCHRONOUS TEAMS

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How can arbitrarily large numbers of independent operators (algorithms and other computational procedures) be made to cooperate? One way is to form each operator into an autonomous agent, then form the agents into a strongly cyclic network called an asynchronous team (A-Team). Results circulate continually through such networks. Agents cooperate by working on one another's results. Experiments over a variety of optimization problems have shown this form of cooperation to be extremely effective, even though the agents have little intelligence and no supervision. This article explains why. More specifically, it explains how supervision can be eliminated and its functions--strategic planning and coordination--realized through the emergent behaviors of certain mixes of autonomous agents.

INTRODUCTION

Of the many independent algorithms that are available for optimization and constraint satisfaction, none is without major weaknesses--the rigorous algorithms tend to be too slow and cumbersome, the heuristics, too unreliable. Rather than seeking a new and better algorithm, we have been experimenting with ways to make algorithms and other computer-based operators cooperate, so together they can do what separately they might not. The result is a type of organization, called an asynchronous team (A-Team), that combines features from a number of systems, particularly, insect societies [1], cellular communities [2], genetic algorithms [3], blackboards [4], simulated annealing [5] and tabu search [6].

Definition: an A-Team is a sequence of strongly cyclic data flows. A data flow is a directed hypergraph. Nodes in a data flow are Venn diagrams representing complexes of overlapping memories, or more precisely, the objects these memories could contain. Arcs in a data flow represent agents that read from the memories at their tails and write to the memories at their heads. A data flow is strongly cyclic if all, or almost all, its arcs are in closed loops.

Each A-Team is dedicated to one type of problem. Each data flow is a distinct scheme for solving members of this type, and is implemented in a network of computers. Results (trial-solutions) accumulate in the memories of the data flow (just as they do in blackboards) to form populations (like those in genetic algorithms). These populations are continually modified by the agents in two ways: construction agents add results to the populations, destruction agents eliminate results from the populations.

The numbers of construction and destruction agents can be arbitrarily large and each agent, whatever its type, can be arbitrarily complex. Consequently, the problem-solving skills of a data flow can be arbitrarily apportioned between construction and destruction. (In contrast, other synthetic problem-solving systems invariably concentrate on one or the other. Hill climbing, for instance, concentrates on how to construct new and better solutions while simulated annealing, genetic algorithms and tabu search concentrate on how to destroy or reject weak solutions. Natural systems, however, often benefit from a more symmetric use of construction and destruction. The process of Lamelar bone growth [9], for instance, relies as much for its efficacy on cells that add bone material to surfaces where the stress is high, as it does on cells that remove bone material from surfaces where the stress is low.)

Every agent in every data flow of an A-Team is autonomous, that is, every agent decides for itself what it is going to do and when (just like the adult members of insect societies). Consequently, there can be no centralized control. But new agents can be easily added (there is no centralized control system to get in the way).

The agents cooperate by working on one another's results. Because the agents are autonomous, this cooperation is asynchronous (no agent can be forced to wait for results from another). Rather, all the agents can, if they so choose, work in parallel all the time. (Other synthetic problem-solving systems invariably include precedence constraints to force at least a partial order on the activities of their computational modules. Genetic algorithms, for instance, require destruction to cease while construction is in progress, and vice-versa.)

Since each agent must decide for itself what, if anything, to do and when, if ever, to do it, and since each agent knows nothing about the any of the other agents except for the results that some of them produce, one might think that the agents would work at cross purposes. Surprisingly, this not always the case. Useful A-Teams have been developed for a wide variety of optimization and constraint satisfaction problems, including, nonlinear equation solving [7], [24], traveling salesman problems [14], high-rise building design [8], reconfigurable robot design [9], diagnosis of faults in electric networks [10], control of electric networks [11], [25] job-shop-scheduling [16], steel mill scheduling [17], paper mill scheduling [25], [26], train-scheduling [15], and constraint satisfaction [18]. Not only do the data flows of these A-Teams produce very good solutions, but they appear to be scale-effective, that is, they can always be made to produce even better solutions by the addition of certain agents and memories.

Scale-effectiveness is rare in synthetic organizations. Hence the proverb, ~too many cooks spoil the broth.~ In a scale-effective organization there can never be too many cooks, at least not from the perspective of broth-quality. More precisely, the problem of obtaining better solutions in a scale-effective organization reduces to one of finding which components to add. A non-scale-effective organization usually faces the much more difficult problem of finding which of its parts to eliminate or modify before additions can be of benefit.

Observed Behavior

The A-teams we have built appear to have problem-independent behaviors along certain dimensions. These dimensions and behaviors are:

1. Diversity: solution-quality increases with the range of skills of the construction agents.
2. Scale: there is little, if any, penalty for an excess of construction skills. Rather, scale-effectiveness seems to be commonplace; solution quality can invariably be improved by the addition of construction and destruction agents.
3. Granularity: solution-quality and speed are virtually independent of agent-granularity; there is no penalty for mixing large agents with small ones, or general agents with specialists.
4. Duality: solution-quality can be improved by the addition of either construction or destruction agents.
5. Population size: solution-quality benefits from increasing the sizes of solution-populations, but these benefits are prone to saturation.

6. Expansion: adding autonomous agents to a strongly cyclic data flow
is relatively easy.
7. Parallelism: solution-speed improves as computers are added untill
there are enough computers for all the agents to work in parallel all the time. Often, the speed-up is near-linear.

MODELING THE EFFECTS OF CONCURRENCY AND COORDINATION STRATEGY ON THE PERFORMANCE OF FAST-TRACKED PROJECTS

by
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This talk describes an approach for modeling interactions between design and implementation organizations involved in product development. The model represent s both the activities in each organization's network, as well as the structure of each organization.

Time to market for many kinds of construction, consumer products, and high technology products has become increasingly important. This creates pressures to introduce concurrency between design and implementation to decrease overall project completion time. However, the success of such a “fast-tracked" approach varies widely from project to project. This research will identify the factors that facilitate extensive interaction between design and implementation. In particular , there is a threshold of concurrency beyond which any further overlap between design and implementation will result in increased rework and a longer overall project duration. This model allows investigation of how changes in organizational structures and decision making policies affect that optimal concurrency point.

The Virtual Design Team (VDT) research has primarily focused on representation of design tasks to date. The VDT represents activities in part, by defining their work volume, associated actor/s, required craft skills, and predecessor/successor relationships. It represents actors in an organization completing assigned activities in one network. This work extends that framework by providing several extensions. First, it provides a mechanism for representing implementation t asks. Second, it allows for representation of relationships between two activity networks (design and implementation). Third, it provides for defining separate decision making policies for the two organizations represented.

Implementation activities differ from design primarily in the area of rework. In VDT, rework of design activities is represented by adding more time to the failed task, to represent the additional work. Rework of implementation tasks is often a physical task (rather than on paper), and therefore involves more than just additional time on the failed activity. In particular, it often requires additional design work on several related activities, as well as additional implementation work in order to remedy problem with the failed activity itself. This model's extensions provide a methodology for creating additional work in both the design and implementation activity networks, and assigning those tasks appropriate work volumes and required skills for actor assignment.

This model represents the relationships between the design and implementation organizations' activities. In VDT, the precedence relationships within each organization's activity network are strongly adhered to. That is, Activity A must be completed before Activity B, its successor, may begin. In order to relate the activities in the two organization's networks, this model introduces the Prerequisite concept. That is, Design Activity A is a prerequisite to Implementation Activity A. In this case, Implementation Activity A's probability of success is directly related to the percent complete of Design Activity A when implementation work begins. In highly concurrent environments, implementation must often begin before design is totally complete. This extension provides a mechanism for tracking the percent complete of a given activity during the simulation. It further factors that percentage into the failure probability of activities dependent up on it, as those activities are initiated.

Finally, this model represents the organization structures and decision making policies of the two organizations separately. That is, the Design organization ma y have a conservative decision making policy of expecting all Prerequisite Activities to be 100% complete before work can begin on the dependent Design Activity. The Implementation organization may have a similar policy, or a much more liberal policy. The model then allows for simulations that investigate the effects of these decision making policies on project outcomes. This decision making feature is added to VDT by providing an additional evaluation step before initiating the next activity in the network. Once the predecessor for an activity is complete, the percentage complete of each of the Prerequisite activities is evaluated. These values are then compared to the decision making thresholds set for the organization, and the decision to initiate the activity or wait for more information is made on this basis.

This talk discusses these three extensions to VDT and how they are implemented. These extensions will form a groundwork for future modeling of multiple organiz ations and the effects of their interactions in completing a single interrelated project.

MODELING COORDINATION AMONG ORGANIZATIONAL AGENTS

by
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Coordination is both a problem and a mechanism for organizational problem solving. Given a task and an organization, "for what do the members of the organization need to coordinate?", and "when and how should they coordinate?" are the questions for organization designers. Researchers have developed models of coordination from a structural perspective (Malone & Smith 1988), a distributed search perspective (Durfee & Montegomery 1991), and cognitive perspective (Carley etal 1992). These models have contributed to our understanding of how coordination can be managed for better organizaztional performance.

Our research on coordination attempts to develop a computational model of coordination, called O-Agents, that merges the perspectives described above, clarifies different types of coordination and their roles in organization problem solving, models how agent can learn to coordinate, and explicates how desirable coordination forms can be achieved and maintained by organizational structures and regulations. O-Agents extends our previous model of i-Agents (Jin & Levitt 1993) by modeling a repetitive resource allocation organizational task and explicitly representing different categories and types of coordination.

Given a task (e.g., to design a sports car) and an organization (e.g., an engineering design team), the organization problem solving process includes decomposing the task into subtasks, distributing (assigning) the subtasks to specific organization members, creating (sub)solutions for subtasks, and recomposing the overall solution from the subsolutions. In O-Agents, we categorize the coordination decisions and activities related to task decomposition and distribution into "managerial coordination", since they are either inherent in the task definition itself or can be viewed as processes for task planning. Managerial coordination usually has large impacts on the overall organiational performance because it defines the subsequent functional coordination requirements described below.

Given the assignment of subtasks to organization members or agents, solving the subtasks and recomposing the overall solution can be problematic due to the interdependencies between the subtasks. Substantial coordination may be needed to resolve the interdependencies. We call the coordination decisions and activities related to resolving the interdependencies among subtasks "functional coordination" since they arise mostly from functional relations among the subtasks. While managerial coordination can be impacted "directly" by organizational structures (Malone & Smith 1988), functional coordination is more at "micro-level" depending on agents & capability and knowledge about other agents and can be impacted "indirectly" by the organization structures.

To model the functional coordination, the O-Agents model explicitly represents three types of coordination, namely, preventive, informative, and reactive. A preventive coordination activity is a Request-For-Action communication sent by one agent to another agent before a local decision is made to avoid possible conflicts. An informative coordination activity is a For-Your-Information communication sent by one agent to another after a decision is made to maintain the consistency of information. Reactive coordination activities are the communications carried out to resolve a known conflict. For a given organization task, more preventive coordination activities may cost more in the early stages of the task but can reduce the cost of required reactive actions. On the other hand, preventive coordination requires agents have good knowledge about their tasks about other agents.

In our research on coordination modeling, we have three hypotheses.

1) For a given task, the balance between the three types of coordination is needed for effective and efficient organiational performance.
2) Organizational agents can learn to coordinate through repetitive tasks by acquiring knowledge about others and balaning its coordination activities.
3) Different organization structures and policies may encourage (or disencourage) different types of coordination activities. For a given task, a desirable organization design exists that maintains the balance of coordination.

Our ongoing research explores these hypotheses. In this talk I will present our model in detail and some preliminary results.

MODELING THE EFFECTS OF GOAL INCONGRUENCY ON PROJECT TEAM PERFORMANCE

by

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Goal incongruencies -- or the differences in goals and the means for achieving those goals -- between members of a project team can exert a profound influence on the collective behavior and performance of the project team. The objective of our research is to examine the effect of goal incongruencies between individuals on the larger organization through the use of computational models which attempt to simulate the emergent behavior of the organization. Specifically, we explore how the effectiveness of various organizational parameters is contingent upon incongruencies in goals, and what management strategies or organizational designs might be manipulated to yield organizational forms which function well in spite of significant goal incongruencies. This article discusses the background research and our assumptions regarding the notions of goals and goal incongruencies. It also describes our efforts to incorporate the phenomenon of goal incongruencies into computational models by building on the work of the Virtual Design Team (VDT) at Stanford University, which has created a computational platform for simulating the behavior of multi-agent project organizations. VDT models replicate the execution of highly interdependent tasks by agents who possess a wide range of skills and disciplines. We have developed a conceptual model which will extend the VDT framework through (1) the addition of a system representing managerial monitoring in response to goal incongruency, (2) the addition of a system representing the delegation of authority in response to goal incongruency, and (3) the extension of the exception generation and handling system in VDT to support the first two extensions. The current exception system in VDT is neither sufficiently rich enough to countenance the incorporation of goal incongruency effects, nor can it satisfactorily serve as an intermediary mechanism relating goal incongruency to process quality. We review a case study in which we apply our goal incongruency framework to create computational models of two project teams within a major aerospace company. Finally, we critique our framework, and we discuss future developments and implications for research and industry.

KNOWLEDGE DISTRIBUTION AND COORDINATION IN ORGANIZATIONS: ON SOME SOCIAL ASPECTS OF THE EXPLOITATION VS. EXPLORATION TRADE-OFF

by
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This paper puts forward a preliminary investigation of the relationship between the distribution of knowledge and the capability of learning and adapting to changing environmental conditions in organizations. The main focus of the paper is on the trade-off each organization faces between commonality of knowledge on one side, which enables coordination, and diversity of knowledge on the other side, which favours learning and discovery of new ways of doing things. By means of a simulation model the paper compares the performance, in terms of coordination and learning, of different organizational designs, characterized by the way in which knowledge is distributed among the members of the organization and by the way coordination is achieved through centralized or decentralized coordinating devices.

1 - Introduction.

In every kind of economic organization, be it an organization stricto sensu, or a network of organizations and/or individuals, or a market, there exists a trade-off between commonality and diversity of knowledge. Sharing a common and homogeneous knowledge basis is a necessary condition for agents to communicate and coordinate their actions. But, on the other side, if all the members of an organization were sharing exactly the same body of individual knowledge no form of collective learning from each other would be possible and the organization would ultimately loose its capability of learning and adapting to new environmental conditions.

This is clearly a typically evolutionary argument: collective adaptation and learning require diversity (mutation) but also mechanisms which guarantee the necessary overall coherence (selection). Ultimately, each economic organization can be considered as an evolutionary system which implements a particular balance between mechanisms of variation and mechanisms of selection on what constitutes the organizational knowledge= basis.

In economic organizations, this trade-off between commonality and diversity of knowledge is also strictly connected to the trade-off between exploitation and exploration [cf. March (1991)]: organizations always face the dilemma between concentrating their resources on the exploitation of the knowledge which is already available to them and the exploration of new possibilities. Both exploitation and exploration are necessary for the survival of an organization. Without exploration of new possibilities, the organization would find itself trapped into sub-optimal states and would eventually become ill-adapted to changing environmental conditions. But organizations which devote all their resources to the exploration of new possibilities will face too high a degree of risk, and even in case of successful discoveries they will fail to exploit the knowledge they acquire and will systematically perform worse than followers and imitators.

March stresses the importance of the social context in which organizational learning takes place. A "distinctive feature of the social context .... is the mutual learning of an organization and the individuals in it. Organizations store knowledge in their procedures, norms, rules, and forms. They accumulate such knowledge over time, learning from their members. At the same time, individuals in an organization are socialized to organizational beliefs" [March (1991), p.73].

Within organizations, these two processes normally coexist and interact at different levels: one of the strengths of organizations is their capability of flexibly combining procedures for selection and procedures for innovation. Fast-learning and slow-learning individuals and departments can coexist. Innovation itself can become a largely routinized process, though uncertain in its outcome. Learning by doing can add exploratory value to normally exploitative activities.

Mutual learning and the distribution of knowledge are fundamental factors which determine an organization's balance between the processes of exploration and exploitation. A high degree of differentiation of knowledge among the members of an organization increases the total amount of knowledge possessed by the organization. But differentiation makes coordination more difficult and ultimately can inhibit the social exploitation of this broad knowledge basis. On the contrary, a body of organizational knowledge which is commonly shared by all the members facilitates coordination but reduces the scope for decentralized experimentation, which could prove a vital source of organizational learning.

Hence, there exists a tension between centralization and decentralization in the organizational learning process. Firms require both centralization and decentralization to operate successfully in changing environments. Decentralization in the acquisition of knowledge is a source of variety, experimentation and, ultimately, a fundamental source of learning. But, eventually, knowledge has to be made available for exploitation to the entire organization. When agents differ with regard to their representations of the environment and their cognitive capabilities, there must exist an organizational body of knowledge which guarantees the coherence of the various learning processes. In order to cope with changing environments, the process of generation and modification of such body of knowledge, although fed by the decentralized learning processes, has to undergo some form of centralization. Thus, a tension inevitably arises between the forces which keep the coherence of the organization and the forces which promote decentralized learning.

This paper puts forward a preliminary investigation of these issues by means of a few simulation experiments which make use of a methodology similar to the so-called classifiers systems. The next section outlines a very basic organizational decision-making problem and the simulation methodology which can model substantive learning and the formation of collective knowledge and languages. The following section will run a few simulations of this model in which the adaptive performance of different organizational designs - characterized by different modes of intra-organizational distribution of knowledge - will be tested against simple environments characterized by varying degree of variability and predictability.

TOWARDS A FORMAL THEORY OF FIRM COGNITION

by
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Introduction

Our goal in this paper is to define a formal model for organizational learning. The formal model we define is a natural offspring of the first authors (somewhat informal) Cognitive Theory of the Firm. The formalization of the model is important not only to clarify and sharpen the informal model but also to prepare the ground for an new argumentative structure of the theory. the propositions of the formal theory are not supported by observations and reasonable assumptions. Some insights about organizational learning are taken as axioms; these axioms and the (definitions of the) formal model are the premises for arguments to prove the theorems expressing further insights (and more).

Whatever becomes derivable in addition to the insights the informal theory provided, serves as a basis for the falsification of the formalization attempt. If the insights are accepted as valid, only the formal machinery can be responsible for empirically false, unacceptable consequences. To derive consequences that does not follow from the insight alone makes the formalization attempt falsifiable and so classifies it as a scientific enterprise. Even though we believe that derivations are important, definition of the formal model is in the focus of interest in this paper, and the derivation of the theorems are left (somewhat) informal. More formal proofs are left for future papers.

About the informal machinery

Nooteboom 1995 describes organizational learning as a cyclic process. After a cycle the organization properly assimilates an invention, and proves to be better adapted to the local circumstances. Even though that machinery contains elements to account for the long term cumulative effects of these assimilation/adaptation cycles for the sake of simplicity we leave those feature to future research and focus on the events within one single cycle.

Suppose the big bang of the invention just happened.The result is far from being clear and distinct, full of redundancies.To learn what really belongs to the novelty and what is a result of the survival of the prehistoric structure constitutes the first phase of learning (single loop learning). This phase provides the learning curves of improving efficiency. Learning by doing.

The next phase is a generalization of the achievement, novel applications of the (successful) invention to neighbouring areas of application.

The phase of generalization is followed by a stage of differentiation. The last two steps constitute what is called "second loop", renewal, or strategic learning.

The result of the strategic learning is a messed up structured, clarity and efficiency seems to be lost again. To find an adequate recombination of the elements constitute reciprocation, and can well be called the third loop learning.

About the formal model

To define the formal model we start with the definition of a structure within which some components are identified as variables that can be substituted by objects (structures) of a given class. We also define a replacement operation, that replaces a component (variable) by an other one. Different variables allow different sets of possible substitutions. The general definition results in an intensionalized version of an algebraic structure called replacement system (see: R. Lunnon, P. Aczel 1991).

If a component of a replacement system is replaced by another element, in the resulting structure new substitutions become possible. This explains why is it in general unclear, what the right/optimal substitutions would be. Redundancies are represented in form of sub-optimal substitutions.

As a result of the replacement variables, i.e. components might get multiple occurrences. If a substitution is optimal in one of the occurrences, might be tried in other occurrences too. Since the occurrences are only extensionally equivalent these tries may or may not work.

Extensional equivalence is a necessary but not sufficient condition for intensional equivalence. If substituting extensionally equivalent components with the same parameter is not a success, the natural thing to do to find out (at least in part) how the intensions differ.

Identification of intensionally equivalent components and the unification of them is the last step one has to carry out before a new invention might be incorporated.

Derivable theorems

In the formal model organizational histories described in the informal part are derivable, and a logical layer provides and additional basis for explaining these organizational histories.

One somewhat surprising theorem is the following: If the organizational structure is well- founded, that is the substitution and the replacement operations are disjoint, then the organization contains elements of tacit knowledge, and no organization can have a complete knowledge of itself. A further consequence is that components are not completely replaceable. For anti-founded organizational structures a complete self-awareness is possible, and components are, sometimes, replaceable.

Conclusion

Representing organizational knowledge and organizational structure in terms of the same mathematical constructions offer a somewhat higher explanatory power for a theory of organizational learning, and some empirical findings (such as the existence of tacit knowledge) are simply logical consequences of the formal counterpart of the theory.

References:

Aczel, P. -R. Lunnon 1990 Replacement Systems and the Axiomatisation of Situation Theory in: Cooper, Mukai and Perry (eds) Situation theory and its Applications CSLI Lecture Notes 22 3-32.

Lunnon, R. 1991 Generalized Universes PhD Thesis Univ of Manchester

Nonaka, I., 1994 A dynamic Theory of Organizational Knowledge Creation Organization Science 5 1: 14-36

Nooteboom, B., 1994 Innovation and Diffusion in Small Firms: Theory and Empirical Evidence Small Business Economics 6: 327-347

Nooteboom, B., 1996 Towards a Learning Based Model of Transactions in: J. Groenewegen (ed) TCE and Beyond Deventer Kluwer 327-349

Nooteboom, B., 1995 Towards a Cognitive Theory of the Firm Issues and the Logic of Change Paper for the AFEE Conference San Francisco 5-7 January 1996

INFORMATION ENTROPY, LANGUAGE, AND ORGANIZATIONAL EVOLUTION

by
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Traditional economic analysis serves to collect statistical information on social phenomena and analyzes this information based on paradigms largely derived from the mathematics of classical mechanics. Financial reporting numbers reflect this penchant of data collection and analysis. Recently, the American Institute of Certified Public Accountants held a symposium which examined the directions financial reporting should take to face the challenges of the new century. One important facet of the situation that the symposium addressed was the fundamental shift in basic technologies from a production and industrial era to an information era.

The proposed paper begins by looking at the process changing models of institutions as seen by their members. It considers Georgescu-Roegen's concepts of informational entropy along with those of organizational evolution and language. First, these concepts are linked to the loss of economic value through the loss of information due to entropy. The work adds to Georgescu-Roegen's concepts by introducing evolutionary organizational processes which provide one component in the production of value and information. Both the production of val ue/information and its eventual and inevitable dissipation are seen to be mediated by institutional factors which are produced by social acts. Next, information value is seen to reflect social value and both values are posited to be created by social organizational activities and reduced by entropy. Finally, the mediating factor in this development is constructed as the tension between the underlying organizational practices and the richness of the available institutional language which is used to describe, communicate, and control those practices. This moves economic analysis away from a purely material notion of the production of value to one in which value is embedded within the social relations of actors.

The paper goes beyond the traditional either positivist or interpretivist conceptualization of economic value. It proposes that the organization is a manifold of diverse cultu res and that the interaction of these cultures is bounded by the languages and communicative acts which are possessed by the actors within the organization. Not all of these actors need to be employees of the organization. Rather, even those individuals working in the development of information systems which are used by the organizations are actors within its manifold since they specify artifacts (the information systems) which define part of the cultural world of the employees. The languages addressed in this analysis range, then, from the natural languages used for everyday speech acts in the office or on the shop floor to the formal languages used to design and therefore control the organization. However, none of these languages provides a strictly complete description of the underlying complexity of the organization. This creates a situation where the tensions between organizational cultures are influenced by the ability of those cultures to sense and react to changes in the complexity of their organization through the evolution of the language(s) they have at their disposal. This evolution of language proceeds both from internal developments and from borrowings from the languages of other cultures.

The conclusion to all of this is that organizational evolution and the production of social and economic value are part of a process in which social actors seek to describe and control their changing material and social environments. This is not fundamentally different from what has been happening throughout history even if the pace of change has increased.

MODELING PROBLEM-SOLVING AND NEGOCIATION USING LEXICOMETRICS

by
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Lexicometrics are a classic solution for information filtering and text-production evaluation. Outside of this bibliometric focus, lexical networks are now successfully used in the field of organizational semiotics, i.e. dynamic retrieval of narratives underlying organizations behavior. An extensive case-study is provided here to fix several methodological issues :

Description of lexical networks;
Global and local analysis using lexical networks; and,
Diachrony in lexical analysis.

Context

During the fall 1995, 60 representatives of french and german agencies gathered in Germany to discuss the content of a new technical deal on robotics. They had to answer to 29 questions, i.e. to solve 29 problems, during 5 days. All the comments were discussed in subgroups, and added to a list of answers once accepted as relevant contributions. As a result, the conference has delivered 29 lists of issues, available in ascii format.

A semiotics-driven approach has been applied on these results to help the french body to master properly the following negociations. The scope of the study was to :

Evaluate each of the 29 solutions;
Build a synthetic model of the discussions; and,
Prepare negociations.

Evaluation

In order to evaluate each of the solutions, each corresponding list of answers has been processed using lexicometrics. The resulting clusters have been characterized using the following templates :

Topological formula :
Saturated clusters, AAFF, FFTT;
Pivot clusters, F (T,T,TT); or,
Transitive clusters, F-F, F-T.

Saturated clusters properties :
Density; and,
Semantic organization.

Pivot clusters properties:
Semiotic value of the pivot;
Homogeneity; and,
Exteriority.

Transitive clusters properties :
Specificity; and,
Semic and topic structure.

Relevance.

Starting from this description, it was then possible to evaluate each of the problem-solving processes, in terms of :

Relationship between the structure of the question and the structure of the answer;
Consistency of the answers -more or less consensual-; and
Depth of knowledge involved in the solution.

Global model

As a second step, we built a global network, considering the 29 questions and answers as a single corpus. At the same time, we processed a factorial analysis of the lexicometric results to study the behaviour of 250 terms in the context of 29 questions.

This analysis showed several global phenomenons which were described and interpreted in comprehensiveness (through lexical networks) and extension (through factorial analysis).

Negociation

Finally, the position of the answers has been interpreted as a potential position in the further space of governmental negociations, in terms of :

common sense, stability and consensus;
uncertainty, recurrence or conflict; and,
connection or dependancy.

Bibliographie

R. Barthes, Elements de semiologie , Mediations , Denoel / Gonthier, Paris, 1965
A. J. Greimas, Semantique structurale , Larousse, Paris, 1966
R. Schleifer, "Introduction" in Structural semantics , University of Nebraska Press, Lincoln, 1983, pp. xii-lvi.

Turner, W.A., (Ed.), "Scientometrics in France", special issue,
Scientometrics Journal, Elsevier, North Holland, 1991
C. Vogel, L'analyse semiotique des reseaux lexicaux , INALF journal, special issue, 1996.

LEARNING TO DELEGATE: DUOPOLISTIC COMPETITION AMONG ADAPTIVE PRINCIPALS AND AGENTS

by
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It is a common view among partisans of bounded rationality that agency models of the firm can be framed as a game theoretic reply to the behavioral theory of the firm, restating in terms of rational behavior the issues of internal conflict and informational asymmetries raised by the pioneering work of Cyert and March (1963).

In this paper, we take the reverse path, analizing a class of agency 20 models through the lens of bounded rationality. The problem we deal with is the so called "delegation" problem. Delegation models extend the principal and agent literature to strategic interaction among firms. The principal and agent theory studies how a principal uses incentive mechanisms to make the agent behave as himself would do. Delegation theory instead deals with a problem of a principal trying to modify the agent's behavior to obtain some specific market goals (D'Aspremont and Gerard -Varet 1980; Vickers 1985; Fertshman and Judd 1985; Sklivas 1987). For example, a principal may induce the agent to behave in a more aggressive way than a pure profit-maximizer agent, by rewarding revenues an not only profits. The reason why this should be the case is that by committing himself (through delegation to his agent) to a more aggressive market behavior, the principal may raise his profits. Thus, in delegation problems a principal may be induced to strategically exploit incentive incompatibility rather than trying to correct it.

In the paper, we model principals and agents in the tradition of the behavioral theory of the firm, introducing simple behavioral learning rules through which principals adjust the incentivation schemes they adopt, and agents learn to predict their opponent's moves. The behavior of such adaptive principals and agents is studied through computer simulation of a duopolistic Cournot game.

The original delegation game is structured as follows. There are two identical firms playing a Cournot game. Each firm is represented by a principal and an agent. The principal's aim is to maximize profits using a managerial reward function M(*) to shape his manager's behavior. The manager maximizes M (or an utility function of M) using as an instrument the quantity to be supplied in the market. Then, in the first stage, principals independently and simultaneously decide the incentive functions, which become public information. In the second stage, agents decide quantities independently and simultaneously . Finally, the outcomes are observed and in each firm payoffs are shared between the principal and the agent on the basis of the previously stated contract. We consider a case of linear demand functions and constant marginal costs. The incentive function is a weighted sum of profits (with weight w) and revenues (with weight 1-w).

It can be shown that rational principals and agents will reach an equilibrium in which incentive functions are such as to induce more aggressive market behaviors of agents, implying thus higher quantities than predicted by a traditional Cournot game in which firms are represented by a unique entrepreneur-manager. But what would happen relaxing rationality assumptions and introducing learning principals and agents?

Simulations allow us to study the evolution of firms' behavior over finite time horizons. In particular, we ask the following questions: under which conditions will adaptive behavior converge to market equilibria predicted by delegation theory? What other adaptation trajectories do emerge? How do adaptation parameters (e.g. learning rates and the adaptation width) affect such trajectories and their stability? How do some features of hierarchical organization affect strategic interaction?

We have studied adaptive behavior of the firms in two different versions of the model. The first version tries to isolate the role of adaptive behavior of principals. Thus, in such version (the "adaptive principals only" model) principals act adaptively, while agents are "Cournot machines" that solve a conventional optimization problem under the constraints given by the incentivation policy adopted by the principal. Although assuming "rational" agents and adaptive principals may seem incoherent, this has the heuristic value of allowing to study in isolation the relaxation of rationality assumptions over the principal only. This allows to better evaluate the outcomes of the second version of the model, in which both principals and agents are adaptive.

A) Version 1: adaptive principals only.

In this version, The adaptive behavior of principals is modelled through a classical reinforcement learning algorithm of the Bush-Mosteller-Estes family. Principals start from an initial incentive scheme which gives a given reward weight to profit and revenue objectives. After observing their firm's performance, principals can resort to three search rules:
a) don't change the incentives 20
b) raise the weight of profits
c) raise the weight of revenues
The probability of resorting to each search rule is revised on the ground of the success or failure observed when a single rule is tried (e.g. if raising the weight of profits leads to a better performance, the probability of further raising the profits weight is reinforced).

Simulation show that adaptive principals do not converge towards the market equilibrium predicted by delegation theory, but rather tend to converge towards the collusion point which, thanks to lowered supply, grants higher profits to both firms. 20

This happens because when both firms randomly try simultaneously the "raise the weight of profits" rule, they tend to increase their profits. This leads to reinforce probabilities of trying again the rule. The process is self-reinforcing until the point is reached beyond which reducing the supplied quantity lowers profits. Than the "don't change" rule tends to be reinforced, stabilizing collusion.

However, collusion may be subject to temporary breakouts: there is still allow probabilty that one firm extracts the "raise the weight of revenues" rule, triggering a wave of aggressive competition that brings back to the competitive (less profitable) equilibrium, until a new sequence of joint collusive moves boosts a new period of market collusion. 20

Notice also that the learning rate of the principals strongly affects the dynamics of the firms. High learning rates will raise the probability that collusive moves become self-reinforcing, increasing the frequency of collusion periods during the simulation. Low learning rates, on the converse, will tend to keep firms close to the competitive equilibrium position most of the time.

B) Version 2: adaptive principals and agents

In this second version, we fully relax rationality assumptions and study both principals and agents under adaptive behavior rules. In this case, agents are supposed to act on the basis of adaptive expectations of their opponent's moves. Expectations are shaped by simple exponential smoothing techniques (agents define their forecasts on the basis of a linear combination of the observed behavior of their opponent in the last period and of their own past forecast).

As one may expect, introducing more simultaneous processes of adaptation considerably complexifies the "ecology of learning" of the system, leading to less predictable dynamics. Rather than exhibiting long periods of stability around the collusion point, now the firms frequently commute between collusion and the competitive equilibrium. One may explain this result suggesting that in this case principals have to adapt to a "noisy" behavior of their agent, due to his imperfect foresight. Misadaptation of the principal feeds-back in turn on the agent moves and on the competitor's adaptation, creating a high instability in incentive schemes and in quantities supplied by each firm (this is also reflected in the frequent divergence of the two firms' behavior). 20

Notice however that this instability can be considerably reduced if one follows Simon's suggestion that hierarchies are characterized by different time scales of adaptation, with higher levels adapting with lower frequency than lower levels. If one introduces this feature in the simulation model, by reducing the frequency with which principals change the incentive function, one observes that principals "filter" the short term noisy behavior of the agents and obtain very long periods of collusive stability. In turn, it's easier for agents to learn when incentives are fixed for some time rather than changing continuously - thus, theri expectations tend to be more accurate. Simon's hypothesis that hierarchy stabilizes the dynamics of complex systems finds thus further support in this competitive example.

Our results suggest a twofold set of general considerations.

On the one hand, the paper tries to show that behavioral models of the firm can vitally dialogue with developments in the "new" theory of the firm, suggesting elements of convergence and alternative explanations of the same phenomena, but also singling out plausible dynamics that bounded rationality can better predict than the "Olympic rationality" assumptions of mainstream economics and game theory.

At the same time, we suggest that computational models of organizational adaptation and learning should more explicitly take into account the implications of strategic interactions among organizations, given that complexities arising from such interactions can significantly alter the analysis of (co)adaptation processes and suggest new reasons for the emergence of hierarchical features in coadapting systems.

THE CONCEPT OF EQUILIBRIUM IN ORGANIZATION THEORY

Henk Gazendam

1. Why the equilibrium concept is needed in organization theory Why are organization theories so difficult to formalize? The answer to this question might be that managers and consultants use organization theories as instruments for diagnosis and therapy, and that popular organization theories are formulated in a way that is suitable for this task. This means that most organization theories have not been built based on the idea that they have to offer clear rules for explaining and predicting organization behavior. Instead, they offer a framework for perceiving to what extent an organization differs from an idealized healthy state, and receipts or mechanisms to let an organization return to that healthy or vital state. In many cases. The idea of an healthy organization is related to the idea of maintaining equilibria.

Researchers trying to formalize organization theories can make a mistake when trying to 'jump to the rules', skipping the interpretation frame of the organization theory, which often is the most important part of the theory from the view of the manager or consultant trying to apply organization theories in a diagnosis-and-therapy process. Sometimes, it is prematurely concluded that an organization theory does not have rules, while the theory is based on the equilibrium concept and therefore implicitly contains rules.

In order to be able to make better formal descriptions and computer models of organization, for instance aiming at computer-supported organization diagnosis and therapy, it is necessary to investigate the equilibrium concept in organization theory further. How is equilibrium defined? How is it related to observables? What data structure does it have? These questions will be answered for a collection of the ories that have been analyzed using the CAST method, namely the theories of Fayol (1916), Mintzberg (1979), Morgan (1986) and Volberda (1992).

2. Equilibrium in four organization theories

2.1. Equilibrium as balance between interests:

Fayol Fayol is the inventor of the concept of organization. In his theory, the following equilibria can be identified:

1. the equilibrium between authority and responsibility;
2. the equilibrium between individual interest and general interest;
3. the equilibrium between the organization's need for personnel and its personnel resources;
4. the equilibrium between learning time and productive time.

The maintenance of equilibria is seen as the task of the managers in the organization.

2.2. Equilibrium as stable configuration:

Mintzberg Mintzberg's (1979) theory of organizations is a synthetic theory using elements from systems theory, decision-making theory, and contingency theory. A major hypothes is in Mintzberg's (1979) theory is that five stable organizational configurations exist, derived from the basic organizational parts and coordinating principles. This means that Mintzberg defines one state for each organization, in terms of all relevant variables (contingency variables, intermediary variables, and structure variables). If this state equals one of the five stable configurations, the organizational state is an equilibrium state. The maintenance of equilibrium is no explicit topic in Mintzberg's theory.

2.3. Equilibrium as variety of images:

Morgan Morgan's (1986) organization theory can be seen as a postmodern theory. Using a postmodern approach, one sees an organization as a construct of the human mind, an artifact. Because of that, organizations exist because of the images of organization people have. Stimulating imagination is important for organizations, and metaphors or images can help imagining. For Morgan, using a single metaphor or image for organization, especially if this is the machine metaphor, is a state that is undesirable. Using different metaphors or images is necessary to understand the complex and paradoxical character of organizational life (Morgan, 1986: 12,13). The state of an organization can be defined in terms of the images used. A desired state is a state in which an adequate variety of images exist. When is a collection of images adequate, that is, when is an organization in an equilibrium state? There are three possibilities:

1. Images have to fit reality.
2. Images have to follow fashions.
3. Images have to fit in the cultural climate of a society.

The equilibrium state of an organization is maintained by people within the organization, especially people with leadership capabilities, imagining new organizational forms that are more adequate.

2.4. Equilibrium as match between turbulence and flexibility: Volberda Volberda's theory is, like Mintzberg's theory, a synthetic theory based on a contingency framework. Its basic idea is that the flexibility of an organization has to match the turbulence of its environment. Based on this theory, a computer-based flexibility diagnosis system called FARSYS has been developed. The measurements of flexibility and turbulence result in a 10 by 15 matrix where 10 aspects of turbulence are confronted with 15 aspects of flexibility. For each of these points an optimal score exists. This means that there are 150 equilibrium points to maintain. Equilibrium has to be maintained by the management function in the organization. Change is based mainly on reorganization.

3. Aspects of the equilibrium concept

3.1. How is equilibrium related to observables? The concept of organization is a complex concept because it can be defined in three ways, each of which refers to observable reality in a specific way. An organization can be defined as:

1. a collection of actors (people or machines) and the events they produce in a stable pattern of cooperative relations (work organization);
2. a construct of the human mind created by symbol structures (legal and financial documents, norms) that reflect an agreement between people about behavior patterns (defined, for instance, in terms of work procedures, norms and contracts) to apply in a work organization (formal organization);
3. a construct of the human mind that, as metaphor or image, guides cooperative behavior of people (artifact organization).

The distinction between work organization and formal organization that is made here has been proposed by Schmidt (1991). According to Schmidt, formal organization is a -not always congruent- layer on top of the work organization safeguarding the interests of the owner and regulatory bodies (Schmidt, 1991: 103). In this context, formal organization is not to be seen as opposed to informal organization, but as a layer adding symbol structures to patterns of cooperation.

If we go back now to our four theories in order to connect them to these organization definitions, we run into problems because Mintzberg and Volberda claim to be based on systems theory, which is an abstract theory. Systems theory as such only offers an abstract model; whether and how this model is related to observables is strongly dependent on the author taking systems theory as a starting point. Mintzberg as well as Volberda seeks most observables in the sphere of formal organization, and some in the work organization.

Fayol's theory is a work organization theory. Although reasoning about the organization as a whole takes place, all observables are at the level of the work and communication of individual actors. Secondary sources like documents are never mentioned. Morgan's theory is a typical artifact organization theory. What counts are the images of organization people have.

3.2. Which data structure does the equilibrium concept have? For the theories of Fayol, Mintzberg and Volberda it is possible to make a state space model that depicts the structure of the equilibrium concept. A state space model consists of one or more subspaces; each subspace has a coordinate system in which each relevant variable corresponds to a dimension. The state of an organization is described by an ensemble of points, one point in each subspace.

Fayol's theory as described above has four subspaces relevant for equilibrium. Each subspace has two dimensions and has one equilibrium point. This model of multiple subspaces with few dimensions per subspace more or less corresponds to the mu-space-model in statistical mechanics. Mintzberg's theory has only one subspace. In this subspace, all 38 relevant variables correspond to dimensions. In this subspace, five equilibrium points correspond to the five stable configurations. This state-space model, in which each organization corresponds to one point in a major subspace, more or less corresponds to Boltzmann's gamma-space-model. In this model, the ergodic problem of the supposed equality of ensemble averages and time averages plays a role.

Morgan's concept of equilibrium uses a collection mental maps of persons. The contents of these mental maps are metaphors or images. These structures can be described as graphs. A further mathematical handling of these maps, may include counting the graphs that resemble certain prototypes. This handling might, however, be seen as inadequate for this type of theory that uses mainly qualitative reasoning. Furthermore, there are three possible mappings of the collection of mental maps that can determine whether a collection of mental maps is adequate, that is, in the desired equilibrium state. Because of the complications resulting from the qualitative nature of the theory and the possible mappings for determining the equilibrium state, it has not yet been possible to make an acceptable state space model of equilibrium in

Morgan's theory.

In Volberda's theory, the organization has one or more equilibrium point for each combination of an environmental variable and a flexibility variable. If we define equilibrium is in terms of the distance between the environmentally required flexibility and the actual flexibility, there is only one equilibrium point per variable combination; the distance is zero when in equilibrium. This means that, at first glance, there are n*m (in this case, 10*15= 150) equilibrium points, where n is the number of environmental variables, and m is the number of internal flexibility variables. This would correspond to a state space model consisting of 150 mu-subspaces. The variables in these subspaces, however, are not independent. This means that the mapping of the matrix model on the mu-space model leads to information loss. In fact, there are only 25 variables, and we can also reason in terms of a 25-dimensional gamma-space. Because of the way we have defined equilibrium, there is only one equilibrium point. The problem with the mapping of the matrix model on the gamma-space model is that the distinction between environmental variables and internal flexibility variable vanishes, so this mapping also leads to information loss. Therefore, we consider the matrix state space model of Volberda, for the time being, as a separate model.

4. Conclusion

Managers and consultants use organization theories as instruments for diagnosis and therapy. Popular organization theories like the discussed theories of Fayol, Mintzberg, Morgan and Volberda are formulated in a way that is suitable for this task. The concept of equilibrium in its various forms (balance, stable configuration, adequate image variety, match or fit between organization and environment) plays a major role in these diagnosis-oriented theories. When formalizing organization theories or constructing computational models of organization, it is important to be aware of the concept of equilibrium to be able to handle it adequately. Otherwise, one might make the mistake of jumping to the rules (if they exist) or concluding that no rules exist. In handling the equilibrium concept, it is important to find out how it is related to observable reality in the theory that is studied. The definitions of organization as work organization, formal organization or artifact organization each imply a specific relation of theory to observables. Furthermore, it may be important to discover which structure the equilibrium concept has in the theory at hand. Three of the discussed theories can be described by a state space model, with interesting differences between the three theories (mu-space, gamma-space and matrix form).

A PROPOSAL FOR THE STUDY OF SYMMETRY-BREAKING IN GAMES BASED ON A CLASSIFIER-ECHO HYBRID

by
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I propose a simulation model to study the emergent properties of a game between symmetrically-endowed agents modeled as Classifier systems (Holland et al. 1986). The agents will interact via offense and defense capabilities as introduced in Holland's (1995) ECHO ecological model. Computer simulations will be used to explore the impact of symmetry-breaking parameter changes on the survival duration of the agent pair. This class of models can be used to show how stable solutions under conditions of symmetry induce utilization patterns that coincide with random paths through a fractal set and lead to power law distributions. These distributions, in turn, can be used to indicate symmetries in systems of interacting agents outside of the laboratory setting.

My work builds in part upon Bruderer's (1993) work using a computer-based strategy game with Classifier systems as agents. That study demonstrated how an inductive learning mechanism using Holland's (1992/1975) Genetic Algorithm (GA) could perform better than the sequential equilibria approach in a particular reputation game. It also showed how a hierarchical search for moves in the presence of intermediate feedback was significantly more efficient than enumerative search.

As suggested above, my work also builds upon the class of models developed by Holland to utilize the GA. As its name suggests, the GA borrows the genetic paradigm of biology to model sequences of moves. Its key feature is that, on average, it preserves (or "exploits") favorable combinations of moves from the past while allowing new combinations to tried out (or "explored") in the future. This feature makes it particularly well-suited to study complex, ill-defined situations which defy traditional optimization approaches such as mathematical programming (MP).

My intent is not to diminish the importance of MP to management. Modern optimization methods have made remarkable progress in dealing with such problem areas as uncertainty (finance, statistical decision theory, stochastic programming), mixed motives (game theory), insoluble dynamical systems (dynamic programming), and computational complexity (computer-based numerical approximation procedures) to highlight just a few.

Several challenges have made MP approaches difficult to implement, however, in complex, ill-defined environments. The accurate assignment of quantitative costs to strategy-level decisions is one; the linking of feedback with the actions responsible for generating them is another. Mimicking the evolution of biological systems, the GA provides a built in mechanism for identifying and propagating (impairing) moves that perform better (worse) on average with only the most rudimentary level of feedback. (I would urge the skeptic at this point to check what proportion of the mass of biota on our planet consists of "unintelligent" single-celled organisms.) Thus in spite of the fact that an agent may not be able to reliably measure and allocate quantitative cost and response data, it still has a means by which to indicate historical successes and failures and shift its behavior from the latter category toward the former. The goal of agent-based simulation models is to uncover those situations and parameters which accelerate this process.

One of the agent types Holland has built to embody the GA is the Classifier system. It consists of a collection of rules called "classifiers", much like the rules which make up an expert system in artificial intelligence. A stimulus called a "message" is received from the environment in the form of a bit string. The message matches the "condition" portion of some subset of rules, whose "action" portions cause further messages to be generated. Some of these messages trigger even further rules, while others are sent out to the environment, generating performance feedback and closing the loop. The major difference between a Classifier system and an expert system is that the latter typically maintain only a single unified representation of the state of the "world". A Classifier system, on the other hand, can maintain multiple, often contradictory, representations simultaneously (akin to having competing hypotheses within a scientific community). The GA is used to break the classifiers down into their component moves or "building blocks" and assemble them into new combinations. (See Holland et al. 1986 Appendix 12A for a summary).

Holland later created a second type, the ECHO agent. ECHO models differ from classifier systems in several ways. In general terms, ECHO models ecologies while the Classifier system models cognitive systems. ECHO models contain a set of interconnected sites forming a geography and providing renewable symbols akin to physical resources and (ultimately) redeployable in the production of offspring. The Classifier simply "copies" a bit pattern signal presented to its input interface, manipulates other bit patterns within itself, and returns a signal back to its output interface. It contains sufficient resources to produce as many classifiers as it needs, but it has no capability to produce anything corresponding to "physical" offspring.

With every cycle, the Classifier receives fitness feedback from its environment. In the ECHO model, no such fitness feedback is provided. Instead, it emerges implicitly within the model via differential survival rates. This is a key distinction between Bruderer's study and mine. The agents in the game I'm proposing get fitness feedback from a combination of the other agent's actions with a cost function designed to mimic the (simulated) cognitive resource required to both defend against those actions and take actions of its own.

What does it mean to defend against the actions of the other agent? As suggested above, a Classifier agent delivers a bit pattern signal to its output interface. We can extend the Classifier model by borrowing the notion of offense and defense from the ECHO model (Holland 1995 Chapter 3). In that model, each agent maintains an "offense tag" and a "defense tag" each of which consists of a string of resources. When two agents interact they compare tags and, to the extent that the first agent's offense tag matches the second's defense tag, the first agent takes the matching resources away from the second. Likewise, the second agent matches its offense tag to the first's defense tag and gains resources accordingly. One of the agents may be killed by the interaction; on the other hand, both may survive to the next generation. I propose that this phenomenon of mutual survival can lead to significant insight into how the overall system (in the current case, the agent pair) can be sustained over long periods of time (this state is known as "homeostasis").

To extend mutual survival homeostasis to a pair of Classifier systems, we must first find an analog to "having a fatal amount of resources taken from an agent in an interaction". As mentioned above, the Classifier system survives without any "physical" resources. Instead, we can impose a set of costs against each agent, and when the accumulated costs of one agent exceed those of the other by some threshold amount, that agent will be considered to have been killed. To help ourselves keep track of the cost flows, we can be break them down into two classes: rewards (corresponding to the "offense" of the ECHO agent) and penalties (corresponding to the "defense" of the ECHO agent).

Rewards are the costs each agent causes the other to incur in "defending" itself, thus enhancing the cost differential in favor of the attacking agent. When one of the agents employs a strategy (by sending out a particular message to its output interface), the other agent must put up a defense. In doing so it will incur a cost proportional to the message's specificity (as defined in Holland et al. 1986) and inversely proportional to the frequency with which the agent had defended against that pattern in the past. In other words, if one agent were to use a strategy that has been routinely and recently defended by the other, the latter would incur a relatively small cost.

On the other hand, if the strategy is one that's been defended against in the past but only rarely, then the defender incurs a large cost. Finally, if the strategy is one that so unusual that it's never been seen before, then the defender, except for a few rare occasions, incurs no cost of defense. The occasions in which an entirely new move incurs a defense cost are determined randomly and are designed to enable "mutations" to keep the game from settling into an uninformative equilibrium.

On the penalty side of the equation, the execution of each move on offense incurs a cost calculated in the same manner as was done for rewards (i.e. proportional to the pattern's specificity and inversely proportional to its frequency of use). So when an agent chooses to employ a specific, infrequently-used move, it will incur a larger cost than if it had chosen a more generic, commonly-used move.

The model as described to this point already includes death; it may as well include taxes as well. Each agent will incur an "activity tax" to deter the indiscriminate "babbling" of random messages having no prior foundation to justify their use (though a random message every now and again to test new possibilities wouldn't be out of the question). Each agent will also incur a "metabolic tax" with the passing of time so that if it decides to cease its offense activities it runs the risk of undergoing an unrecoverable atrophy. The assignment of costs to particular classifiers and the recombination of moves to form new classifiers would be performed using the standard Classifier system credit assignment and genetic algorithms.

Another distinction from Bruderer's approach, and perhaps the most subtle feature of this entire model, is the definition of the objective function for the overall system (as opposed to that for each individual agent, which is simply to survive). The quantity to be maximized is the number of generations over which both agents survive. This represents a "symbiotic" notion of optimization as opposed to the "physical/cost efficiency" version more commonly seen in engineering/economics. In fact, compared to traditional optimization problems, this one is ill-behaved right from the start because, under the weak constraints stated so far, its objective function isn't even bounded. The agents could survive as long as the computer simulation is still running. In fact, once the system's symmetry has been broken, this is exactly the type of scenario we are searching for: one in which we would expect one agent to kill the other, but somehow a secondary symmetry emerges to re-establish the homeostasis.

Note how this approach differs from traditional dynamics, which specifies a set of differential equations, solves for the system's fixed points and cycles, and then perturbs the solutions to determine their stability characteristics. In the approach I'm taking, the built-in symmetries place the system in an equilibrium right from the start. Random "jolts" during or even at the start of the game perturb the system from this equilibrium. By having each agent pursue a sub-objective of enhancing its own survival, the move away from the mutual-survival equilibrium will tend to grow larger over time until the dominant agent kills the other. The objective of the overall game, however, is to extend the duration of play as long as possible in the face of these random jolts. The corresponding goal of my study will be to determine what control policies can be introduced to enhance this mutual survival in the face of broken symmetries.

For example, what would be the impact of removing message specificity from the calculation of either offense or defense costs for just one of the agents? On the surface it would seem that the agent being relieved of the cost would gain the advantage and survive the other. On the other hand, it might lead that agent to pursue short-term goals at the expense of long-term survival. An even more subtle answer would be that the result differs depending on the rate at which random environmental jolts are being introduced. In any case, it's not obvious what analytic solution approach could be used to answer this question. With a computer simulation experiment, we can systematically explore such questions.

Finally, I propose that if we were to collect data on the utilization patterns of various agent moves (i.e. messages generated by the Classifier systems), that the symmetries built in to the system would lead to certain corresponding symmetries in utilization. In particular, because the system imposes different costs based on move specificity, we should expect to see a power law relationship between specificity and frequency of use. Furthermore, it can show that such a distribution also arises by tracing a random path through a particular type of fractal called a lexicographic tree. The computer simulation can be used to explore how changes in parameters impact these distributions, with the ultimate goal of being able to use this class of distributions to indicate hidden symmetries in systems of interacting agents outside the laboratory setting.

REFERENCES

Bruderer, E. 1993 " How Strategies Are Learned" , Doctoral Dissertation, University of Michigan

Holland, J. 1992 " Adaptation in Natural and Artificial Systems" , MIT Press edition (revision of 1975 edition, The University of Michigan)

Holland, J. 1995 " Hidden Order: How Adaptation Builds Complexity" , Helix Books, Addison Wesley

Holland, J., Holyoak, K., Nisbett, R., and Thagard P. 1986 " Induction: Processes of Inference, Learning and Discovery", MIT Press Massachusetts; (1977).

SPARSE MODELS IN ORGANIZATIONAL THEORY -- SUGGESTIONS FROM COMPLEXITY THEORY

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Complexity theory holds out the possibility that the use of sparse models of organizations -- severely abstracted descriptions of real organizations -- may have a useful place in the development of comprehensive theories of organizational dynamics. To illustrate the use of sparse models, I take work groups as the organizational unit of interest, and consider workgroup dynamics using sparse models. The models examined are abstracted to near-minimum levels of both form and function. Despite this reduction in model content, an interpretational context survives which allows the identification of self-organized workgroup routine and the quantification of its resistance to specified levels of environmental interference.

Introduction.

An important source of motivation for the use of sparse models is an observation from the theory of complex systems: simple systems can produce complex behavior (e.g., Wolfram, 1986). Complexity in behavior does not have to be designed or "engineered" into every system. Complexity and subtlety may arise as an inevitable result of the interaction over time of a system's numerous but simple parts. This finding suggests that logically spare models may deserve a place in the systematic construction of organization theory. In building theory it would appear advisable to discover and use as fundamentals wherever possible the most elementary organizational assumptions and specifications that can produce significant organizational outcomes.

Work on sparse models that can be seen as relevant has been carried out, some of it in abstract complexity theory, some in biological settings. See Walker and Ashby (1966) and Kauffman (1969) as early examples of abstract and interpreted sparse models, respectively. Apparently only a few attempts have been made to interpret organizational dynamics in sparse models. Walker and Gelfand (1979) and Gelfand and Walker (1980), for example, considered parallels between management styles and certain aspects of sparse models. I remark on some additional work after describing the sparse model of interest here.

The workgroup model.

(a) Structural specification. Informally, the models dealt with here can be seen as very abstracted workgroups with the following properties. Workgroup members interact with one another on a regular basis in time. Interactions among group members are guided by identical and fixed rules: each workgroup is therefore role-homogeneous. Each member of the group has at most two other members who can affect that member. (This is an important specification, both as a matter of interpretation, and as a matter of resulting model dynamics.) The interactions that occur between group members consist of simple binary signs, e.g., yes/no, turn on/turn off, start it/stop it, etc. What a given member does at a particular point in time is strictly a matter of the signs shown, at the just prior point in time, by that member's affecting partners (and the member's own sign) as given by the rule in use by the group.

Any given group has an interaction structure (the specification of which member affects which other members) that is fixed but specified initially at random. The specific configuration of signals that starts a workgroup's work session is also taken to be determined at random.

(b) Model dynamics. The model described above is such that starting from some initial configuration of signals, as a matter of logical necessity the group goes through a period of "warm-up" activity before settling into a repetitive sequence of activities which can be seen as a workgroup routine. As the particular routine is "selected" by the internal dynamics of the workgroup, the routine is self-organized. Unless some influence external to the workgroup intercedes, the group will continue in its selected routine indefinitely.

(c) Resistance of routine to disruption. Given a workgroup executing its routine, a natural question to ask is, How robust is that routine? That is, suppose the group's environment is disruptive, occasionally causing errors as group members execute their workgroup roles. What then happens to the routine? Will the group, without outside help, regain its former routine, or will it instead fall into one of its possible alternative routines? We consider these questions under lightly loaded work conditions, namely, where the environmental pressure is such that the number of errors made in the group is the minimum possible, in the present case, exactly one.

The questions raised above essentially ask about characteristics of an abstract workgroup behavior space: As measured by tendency to return to a given routine, what is the behavior space like in the immediate vicinity of a routine? These questions have seen some work.

Kauffman (1969) found in that in what we would here call role-heterogeneous workgroup models otherwise similar to our workgroup model above, routines are very resistant to low levels of disruption, perhaps especially so in large workgroups. Routine is regained after disruption approximately 95% of the time. While some work is available on resistance of routine behaviors in role-homogeneous models (Walker, 1987), the latter study does not study the specific effects of light disruptive pressure and group size on role-homogeneous workgroup routine. A later paper by Walker and Motwani (1994) did make the extension, but did it in a different context. Their data are reinterpreted and used in what follows.

In outline, the data I refer to here were obtained by setting up simulated workgroups of various sizes (from 10 members to 200) using random interaction structures, starting a given group at random, letting the workgroup proceed through the warm-up to its routine, and then observing what happened after the group was subjected to a single (randomized) mistake. The procedure was repeated for all possible workgroup rules.

Results and discussion.

Two conclusions can be drawn from the data. 1) In contrast to the high resistance to disruption exhibited in role-heterogeneous workgroups, resistance of role-homogeneous workgroups' routines varies widely with the rule governing the group's behavior. About two fifths (41%) of the rules produce routines highly resistant to light disruptive pressure. On the opher hand, approximately one-quarter (26%) of the rules produce workgroup routine that fails under light load at least 60% of the time. 2) Qualitatively, group size does not affect resistance to external pressure on workgroup routine. That is, small groups show much the same resistance as do large groups.

From the perspective of the present paper the data above point to a limited set of assumptions which gives rise to the organizational dynamics observed. This produces an economy in thinking about what causes may be implicated in explaining (or useful in producing) workplace stability. We can say that to produce self-organized and vigorously self-correcting behavioral routines it is sufficient to have: 1) workers interacting among only themselves, 2) on a regular basis with, 3) a sharply limited and fixed set of interaction partners using, 4) a limited interaction vocabulary, and following, 5) a definite interaction rule selected from an appropriate set of rules.

Conclusion.

Developing a more complete theory of the organization should be aided by accumulating knowledge about what is logically required to produce the complexity that is seen in the behavior of organizations. The systematic use of sparse models would seem to be useful in building our knowledge base of behavioral fundamentals. And since instrumentality is so often at the heart of human onganizations, it appears desirable to aim directly at theory competent in the design and engineering of organizational outcomes. Sparse modeling may help provide a tool kit for that kind of theory.

References.

Gelfand, A.E. and Walker, C.C. (1980). A system theoretic approach to the management of complex organizations: Management by consensus level and its interaction with other management Strategies. Behavioral Science, 25, 250-260.

Kauffman, S.A. (1969). Metabolic stability and epigenesis in randomly constructed genetic nets. Journal of Theoretical Biology, 22, 437-467.

Walker, C.C. (1987). Behavior of equilibrial state and limit cycles in sparsely connected, structurally complex Boolean nets. Complex Systems, 1, 1063-1086.

Walker, C.C. and Ashby, W.R. (1966). On temporal characteristics of behavior in certain complex systems. Kybernetik, 3, 100-108.

Walker, C.C. and Gelfand, A.E. (1979). A system theoretic approach to the management of complex organizations: Management by exception, priority, and input span in a class of fixed-structure models. Behavioral Science, 24, 112-120.

Walker, C.C. and Motwani, S.G. (1994). Towards inherently useful theory, a management example. Kybernetes, 23, 23-33.

Wolfram, W. (1986). Approaches to complexity engineering. in: Theory and application of cellular automata. S. Wolfram (Ed.), Singapore: World Scientific Pub. Co. 400-413.

A Simulated Annealing Model of Organizational Adaptation

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Studies of organizational adaptation often point out that organizational RknowledgeS exists on at least two levels: in the minds of the personnel and in the design of the organization (Huber 1991). Adaptation can occur at both the individual (March and Simon 1958) and the design level (Eccles and Crane 1988; Lawrence and Lorsch 1969). However, most studies of organizational learning do not make a distinction between these levels or they consider only one of these two modes of adaptation. At the individual level, organizational learning can be seen as involving the accumulation of experience by personnel within the organization (Carley 1991b, 1992). At the design level, Eccles and Crane (1988: p. 143) in their comprehensive analysis of investment banking suggest that over time Rreorganizations initiated by top management resemble the annealing process used in crystal formation.S Herein, organizational adaptation is explored from a combined individual and design perspective using a simulated annealing model of organizational adaptation in which the agents within the organization are themselves complex adaptive agents.

In this paper the issue of organizational adaptation is addressed theoretically by using a computational model in which both the personnel learn from experience and the organization adapts by altering its design. This research couples an individual learning with organizational restructuring. At the individual level learning is carried out using a standard stochastic learning model for boundedly rational agents based on work in cognitive psychology. At the organizational level adaptation is carried out using a simulated annealing model. Such a model is presented and its behavior is illustrated using a virtual experiment where the type of organizational learning is varied. Results suggest that the relationship between organizational design and performance, despite the simplicity of the rules for change, may be chaotic. Simple restructuring rules lead to a wide range of emergent organizational structures that increases when individual agents can adapt. Organizations can locate good designs (often through chance and by changing slowly) regardless of the agents' intelligence; however, what designs emerge depends on agent adaptability. Design features are not systematically related to performance; rather, small initial design and environmental response differences can dramatically affect the emergent structures and performance.

The results indicate that there is a relation between organizational design and mode of organizational learning. In this study, organizations had difficulty locating the optimal form where optimal is defined in terms of accuracy in performance. However, most organizations developed a form with vaguely hierarchical characteristics. Most of the organizations that emerged had multiple levels, specialization of function by level, and so forth. As many studies have shown, hierarchical designs, though not optimal from an accuracy perspective do have many advantages from the organizationUs perspective, such as high resiliency in the face of personnel loss, stress, and information errors. Contingency theory suggests that the reason most organizations have somewhat different forms and that performance is not perfectly related to structure is that there must be a match between structure and task or structure and environment for high performance to result. This analysis suggests another explanation. Organizations vary in form, but only slightly because they are searching for the optimal form in essentially a performance plateau where chance more than strategy will lead them to the particular small change in design that improves their performance.

In this study, many organizations with highly similar designs exhibit almost equal performance. These results are consistent with an interpretation that mimicry may be necessary to achieve better organizational designs. Since there are many designs that are equally good, locating the best design will occur largely by chance. Consequently, mimicry across organizations can increase the likelihood of any one organization finding the optimal structure. Assuming of course, that organizations can accurately asses the performance of other organizations. This result also suggest that organizations can redesign with relative impunity. After all, in the market it is not necessary to be optimal, just as good or better than your competitors. Executives can achieve credit for doing Rsomething,S for restructuring their organization.

Moreover, these restructurings, which may not be lead to performance improvements may be advantageous to the organization in other ways, such as making the organization more efficient by lowering isolation, ignorance, and redundancy.

Carley, Kathleen. 1991b. “Designing Organizational Structures to Cope with Communication Breakdowns: A Simulation Model.” Industrial Crisis Quarterly 5: 19-57.

Carley, Kathleen. 1992. “Organizational Learning and Personnel Turnover.” Organization Science 3(1): 20-46.

Eccles, Robert G. and Dwight B. Crane. 1988. Doing Deals: Investment Banks at Work. Boston, MA: Harvard Business School Press

Huber, George P. 1991. “Organizational Learning: The Contributing Processes and the Literatures.” Organization Science 2: 88-115.

March, James G. and Herbert Simon. 1958. Organizations. New York: John Wiley & Sons, Inc.

Lawrence, Paul R. and Jay W. Lorsch. 1967. Organization and Environment: Managing Differentiation and Integration. Boston: Graduate School of Business Administration, Harvard University.

SIMULATION OF LEARNING IN SUPPLY PARTNERSHIP

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The present simulation model studies adjustment processes between industrial buyers and their suppliers that cooperate to produce a certain product. Two kind of learning processes are addressed. The first is learning by doing. Agents try to figure out the optimal set of competencies for production, and their task perception improves as they adapt to their vaguely perceived target. The second form is learning by interaction: cooperators have to develop an understanding that enables the buyer to absorb supplier ouputs.

The adaptive movements take place in an euclidean space where each axis represents a competence the buyer intends to obtain from suppliers. The ideal product characteristics (given the market conditions) are represented by the competence configuration by which the product can be optimally produced (ideal point). The suppliers' actual competencies and the buyer's ability to absorb supplier contribution are also represented as points in the competence space. The distance between supplier and the ideal point tells if the required product characteristics are met; therefore, it serves as a measure of product quality. The distance between buyer and its suppliers stands for the efficiency of cooperation.

The success of a cooperation is evaluated by a utility function. Utility production is high if both the quality and the efficiency criteria are met, that is, if suppliers approach the ideal point and buyers get close to their suppliers. The integral of the utility function over time shows the total accumulated wealth during the adaptive history.

A buyer may employ one or two suppliers. Since the present model version does not address opportunistic partner behaviour, the advantage of having multiple suppliers comes in the form of bigger information diversity. But for the buyer, it is more difficult to adapt to two partners than to a single one.

The goal of the simulation is to clarify the conditions under which multiple supply is more profitable. An earlier implementation of the model and some preliminary insights has been presented in the '95 CMOT workshop in Los Angeles. Now, the focus is on the results obtained from a systematic testing of the model. We made sensitivity runs analysing the impact of three variables on utility production. The first variable is the pace of market change represented by the frequency of ideal point shifts. The second variable measures the minimum quality and efficiency requirements for production. The third (dichotomic) variable discriminates between two product development patterns which we call "routine type" and heureka type" developments, respectively.

In routine type developments, the adaptive process is a subject of reliable planning (for example, because the new product is an improved version of an existing one). The heureka type development rather applies to brand new products with unpreceded technical solutions. In the routine type case, the bonuses of adaptive efforts come gradually and steadily. However, results usually come suddenly in heureka type developments, after a prolonged period of incubation.

Not surprisingly, the simulation showed that the advantages of dual supply are few in routine development tasks. Dual sourcing may perform much better than single sourcing when the heureka type pattern applies. But even then, having two suppliers is rather a necessary than sufficient condition of success. The simulation revealed that the extra advantages come only in a pretty narrow range of external conditions: market change must not be neither "too slow" nor "too fast, and the minimum product quality/efficiency requirements have to be strict.

We introduced a fourth sensitivity variable to learn more about the range of success of dual supply: the ratio of buyer and supplier adaptive speeds. (Previously, we assumed similar speed patterns for both agents, so this ratio was 1). The additional runs revealed that unequal adaptive speed may definitely increase dual supply's advantage, especially when buyer adapts much slower than its suppliers.

The presentation discusses possible interpretations of the findings and their ramifications for supply partnership under different market conditions.

TOWARD A GENERATIVE THEORY OF ORGANIZATION

by
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I present a first formulation of an algebraic theory of organizational structure and dynamics. This mathematical theory a rigorous view of human systems as computation. It depicts organizations and their agents as resource-dependent computational systems each of which is capable of performing a well-defined range of computational algorithms. These algorithms embody agents' and organizations' capacities for action, deliberation, and choice. Our theory is expressed in the algebraic language of automata theory. Because it so strongly identifies human action as computation, it may be viewed as extending the approach embraced in the field cognitive science to the study of social systems.

My talk has two aims, one substantive and the other programmatic. I aim principally to outline a mathematical theory of organizational and agent dynamics. As a secondary objective, I reflect on the role that this type of formal work plays in organizational research employing computational concepts and methods.

My discussion begins by reviewing core, informal concepts of human social agency that our formal theory is aimed to make more precise. The concepts I review are adapted from the contributions of prominent social and psychological theorists such as Kurt Lewin, Anthony Giddens, Pierre Bourdieu, Jurgen Habermas, Noam Chomsky, Herbert Simon, James March, and Chris Argyris. Concepts I review include

* agency and social organization as structure-in-practice;
* the resource- and capacity-limited nature of human practice;
* adaptive rationality as a stronger concept of intended rationality than Simon and von Hayek's notion of bounded rationality;
* knowledge as (tacit) competence and its formalization as "action propositions";
* reflection and symbolic representation as practice;
* communicative competence; and
* social organization as coordination of practices via role relationshiops, resource dependencies, and communication.

Next, I outline our mathematical theory of agency, organization, and their dynamics. I begin by reviewing the basics of the algebraic theory of generative computational processes on which our work is based. More specifically, we develop this theory as a specialization of the mathematical theory of non-deterministic processes (automata), operating on possibly unbounded (rather than finite) and dynamically changing input sequences. I discuss the need for these non-deterministic and non-finite extensions to basic definitions of computational processes. Agents and organizations are then developed as formal networks of these generative processes. I offer formal evidence of the soundness of our formulation. Most importantly, I aim to show that this formal account adequately captures and helps to clarify the core pre-theoretical notions previously discussed. Finally, Finally, I sketch techniques we are now developing that allow us to formally analyze the dynamics of activities produced by these networks of generative processes. Our formal approach to dynamics exploits recent developments in the mathematical theory of symbolic dynamics. I introduce a mathematical object called a "shift space" and outline how it can be used to characterize organizational and agent dynamics in our theory.

Time permitting, my discussion concludes with some reflections on the role of formal theory such as our own generative theory of organization in computational organization theory.

THE LOGICAL CYCLE.

by
Michael Masuch
Center for Computer Science in Organization and
Management (CCSOM).

In 1968, the methodologist A. de Groot proposed the concept of an "Empirical Cycle" to systematize the process of empirical research. In analogy to the empirical cycle, we propose a logical cycle to systematize the process of logical inquiry regarding (new) scientific theories, and in particular theories of organization. The cycle starts with a theory in discursive format that is subsequently transposed into a formal representation. This transposition involves (1) a "rational reconstruction" of the discursive theory, (2) the generation of a "core theory", and (3) the translation of the core theory into a formal logical language. The resulting formal theory (call it "Sigma") can be submitted to a variaty of semi-automated tests, including tests for consistency, contingency, coherence, and explanatory power.

The talk will reiterate how logical and empirical criteria for a theory interact and how logical test can facilitate/improve on empirical testing. Examples are drawn from the formalization projects of the Center for Computer Science in Organization and Management (CCSOM).

COMPUTATIONAL MODELING OF ORGANIZATIONAL ADAPTATION

by
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Organizations are coupled to their physical and social environments. They depend upon the environment for resources, participants, legitimation, support, etc. Their action potential is also constrained by environmental conditions. Clearly then, organizations must adapt to changes in their environment in order to survive and prosper. An organization can improve its ability to adapt by changing its structure, or by manipulating its environment. However, most available evidence suggests that in reality organizations are limited in their ability to adapt.

System theorists use the concept of structure to characterize an organization's capacity to adapt. In contrast, the concept of structure as commonly used in organization theory has not been very successful in explaining organizational adaptation. Moreover, the concept of structure is fraught with multiple interpretations. These interpretations of structure as constraints on action, enabling of action, stable patterns of action or behavior. In addition, organizational theorists commonly view structure prescriptively. Mintzberg defines it as "the sum total of the ways in which its labor is divided into distinct tasks and then its coordination is achieved among these tasks," for example. However, critics have pointed out that, in reality, not only does the actual division of tasks and their coordination deviate from the "prescribed structure," but it may vary significantly from one situation to another.

A more promising approach to structure can be found in the works of Bourdieu, Giddens and cognitive anthropologists such as Hutchins and Lave. They emphasize the process of structuration, the reproduction of structure. Their view claims a duality between structure and practice -- structure shapes practice, but practices shape structure, as well. This view of structure seems to us far more promising. We aim, moreover, to further elucidate this notion of structure by distinguishing among (a) potential or generative structure, (b) mediating structure, and (c) manifest structure. Potential structure consists in the practices of an organization's participants. Mediating structure consists in resources, artifacts, technology, formalized regulatory and legal institutions, and formalized authority relationships. Mediating structure determines the limits of organizational practices. Manifest structure arises in the interplay of potential and mediating structure. It may be observed in the persistent patterns of interactions among an organization's participants, with each other and with those outside the organization. Dually, both potential and mediating structure are shaped by the past actions. In this way, an organization's history of practices influence current and future actions, and structure. However, in the short run manifest structure arises from the way that mediating structure constrains the actions enabled by potential structure.

Among the most important adaptive practices of actors are those that identify, disseminate and apply information that is relevant to the choice of actions. However, since organizations and their actors are boundedly rational, they are limited in the amount of information they can process and the number of decision points they can resolve. Thus, in each situation, only certain information channels are active. These channels correspond to areas where the organization is probing for information. Some channels are actively monitored, with the organization filtering (interpreting) the information it receives and selectively acting upon it. Other channels may be passive, embodying information that is simply ignored. Similarly, some decision points are active. That is, deliberation precedes the choice of action. Others are contingent. That is, deliberation depends upon the occurrence of particular events. Still other choice points may be found at which the organization does not deliberate at all but is committed to a fixed course of action.

We view practice as embodying dispositions toward the full range of actions, including reflective actions such as interpretation such as sensemaking or deliberation such as planning and choice as well as actions that are manifest as overt behavior. Through both learning and reflection, actors become skilled at dealing with the types of situations that they regularly encounter. They develop a sense of the appropriate way to respond to these situations. This includes the use of an appropriate level of deliberation as permitted by time and warranted by importance of the actions toward which the deliberation is oriented. Further, both the choice and interpretation of action is regulated by criteria that are continuously applied. Agents may face impasse when the situation they face is unfamiliar. This usually leads to deliberation over the future course of action. This view of action is a departure from the more common view of actors as fundamentally problem solvers or decision makers, constantly engaged in prospectively choosing the best alternative course of action to achieve specific goals. The contrast between our view and the conventional rational-actor view can also expressed in terms of a distinction introduced by March and Simon. Our view of reflection-in-practice emphasizes a "logic of appropriateness," whereas rational-actor accounts emphasize a "logic of consequence." As March and Simon point out, the role of a logic of appropriateness has been underemphasized in current literature.

Our conception of actors also differs from Newell's "knowledge-level" account which describes agents as "having goals and knowing things about the world, in which knowledge is used in the service of its goals (by the principle of rationality)." In contrast, we view actors as structured relationships among practices, each of which may be depicted in the following form:

In situations S, do actions A, so as to meet criteria C.

Borrowing from Argyris, we call this an "action proposition." In it, A consists of potential actions whose execution is initially triggered by the actor's recognition of some situation of type S. The actor attempts to carry out A consistently with the criteria embodied by C. Thus, new actions may be triggered that modify or even replace the course of action initially promoted by S's recognition. It should be clear, then, how the adaptive capacity is fundamental in our account of agency. An action proposition's criteria, C, stipulate the basis for adapting to violations of expectations, failures to meet norms, etc., that may result from manifest structure. Furthermore, this criteriological aspect of action propositions entails continuous monitoring of, and reaction to, the changing context in which actions take place. This elemental concept of action cannot be simply reduced to the "production-rule"construct so prevalent in previous computational models of actors, such as Newell's model called SOAR.

We have developed a computational construct, called an action schema, intended to implement the notion of an action proposition. In particular, action schemata capture our view practices by emphasizing the distinction between active, monitored and passive information channels and active, contingent and passive decision points. Actors are bundles of action schemata, and organizations are collections of actors, coupled by exchanges of resources, communication, and commitments to specific, interrelated roles. These computational notions are being implemented in a model we call ACCORD (Agency, Cognition, and Coordination, in ORganizational Dynamics). We are using this computational model to gain insight into the way in which an organization's adaptive capabilities arise from it potential, mediating, and manifest structure.

Both structure, especially structure-in-practice, and processes of adaptation are elusive targets of study. Practices are often tacit. The interactions among practices are likely to be quite complex. Similarly, knowing the scope of adaptation and its limits can be equally challenging. More specifically, we are using this model to help us understand the nature and causes of organizational breakdowns -- discrepancies between expected and perceived actions or the outcomes that these actions produce. A closer look at breakdowns is likely to help clarify the nature of organizational adaptation and its basis in structure. We believe that our computational approach and its embodiment in the ACCORD simulator can help us to derive more comprehensive and useful accounts of breakdowns as an important type of failure to adapt. Practically speaking, managers often find that their efforts to respond to change have unexpected consequences. Our work aims to address such practical concerns by providing a computational tool to help managers more accurately describe, analyze, and validate their organizational practices.

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Computational and Mathematical Organization Theory

Instructions to Authors

Computational and Mathematical Organization Theory (CMOT) publishes original research articles concerned with advancing organizational theory and analysis through the use of computational and mathematical techniques. CMOT's major editorial areas are: theory development through mathematical and computational analyses, social network analysis as applied to organizations, empirical testing of mathematical and computational models, and mathematical or computational methods for analyzing empirical data. The refereeing of papers in each of these areas is directed by Area Editors. In addition CMOT will publish didactic papers and task descriptions. The didactic or "how to" articles may explain how to construct specific algorithms, test or measure specific effects, analyze particular outputs, or apply specific procedures. The task descripts should describe a specific task that is used in computational or mathamtical models, discuss it's history, and describe possible extensions of the task. The refereeing of these papers are directed by the editors. The journal publishes relevant book reviews, meeting announcements, and brief notes.

Guidelines for manuscript preparation

Readers will vary in their mathematical and computational experience.The authors should keep this in mind in preparing the manuscript.

For mathematical models:
Define non-elementary mathematical symbols.
Define all terms before they appear in an equation.

For computational models:
We do not require that code be provided or shared. However, we would like to encourage the sharing of code, when possible. If possible, information on how to access and run code should be provided. Otherwise, information should be included on whether it is possible to obtain a copy of the code, and if it is possible, how the reader can obtain the code. Information on what language the code was written in, what it was compiled on, average run time, and special portability constraints should be mentioned in a footnote (or in the text if this is critical to the paper's argument). For new programs details on the input, output, initial conditions, boundary conditions, and internal processes should be clearly described or diagrammed.

Format of text:
Maximum length is 32 pages - including figures, tables, references and appendices. This does not include the title page or the abstract. Moreover, it assumes that the paper is double spaced, 12 point font, and single sided on 8 1/2 x 11 paper. The Palantino or Times Roman or New Century Schoolbook font should be used if possible. The beginning of each paragraph should be indented .25 inch. All pages should be numbered

sequentially, 1,2 ... N (except for the title page and abstract). Page numbers should appear centered at the bottom of each page in the format "- # -."

Format of tables:
All tables should be numbered sequentially, 1,2, ...N. Tables in the Appendices shuold be numbered A1, A2 ... AN. The Palantino or Times Roman or New Century Schoolbook
font should be used if possible. The format for tables is :
line
centered(Table #: Title)
line
line
content
line
Note (if any)
line

Following is an example table.

Table 1: Organizational Design by Performance

	Performance
Organizational Design	
Hierarchy	85.3
Team	99.5

Note: This is the average across performance for 3000 simulations.

Format of figures:
Figures should be numbered sequentially, 1,2 ... N. The Palantino or Times Roman or New Century Schoolbook font should be used if possible both within the figure and in the caption. Figures should be completely described in the text. Figure captions should be a short descriptive phrase, and should be formatted as: Figure #: phrase

Format of equations:
Equations should be numbered sequentially, 1,2 ... N. Number should appear on the left hand side of the equation. All variables in the equation should be explained prior to presenting the equation. All, non elementary mathematical symbols should be defined in footnotes.

Format of code:
When code (or pseudo code) needs to be included in the text it should be set off from the main body of the text by:
1) Leave a blank line both before and after the code segment.
2) Increase the margins by .5 in on both sides.

3) Left justify the code segment.
4) Place all comments in italics.

Format of headings:
Authors should avoid using more than four levels of headings. The format for the first four levels of headings are:
Heading 1: Title Format, i.e., first letter of each word capitalized, 14 point font, bold, centered.
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Heading 3: Title Format, 12 point font, bold, left adjusted.
Heading 4: Title Format, 12 point font, italic, left adjusted.

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Ilgen, D.R., D.A. Major, J.R. Hollenbeck and D.J. Sego (1991), "Decision

Making in Teams: Raising an Individual Decision Making Model to the Team Level," Tech. Rep. No. 91-2. East Lansing: Michigan State University, Department of Management and Psychology.

Levis, A. H. (1988), "Human Organizations and Distributed Intelligence Systems," Proceedings of IFAC Symposium on Distributed Intelligence Systems, Pergamon Press, Oxford, England.

Levitt, R.E., G.P. Cohen, J.C. Kunz, C.I. Nass, T. Christiansen and Y. Jin (1994), "The 'Vitural Design Team': Simulating How Organization Structure and Information Provessing Tools Affect Team Performance," in K. Carley and M. Prietula (Eds.) Computational Organization Theory, Hillsdale, NJ: Lawrence Erlbaum Associates.

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