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OFFICES ARE OPEN SYSTEMS

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Abstract. This paper is intended as a contribution to analysis of the implications of viewing offices as open systems. It takes a prescriptive stance on how to estalish the information-processing foundations for taking action and making decisions in office work from an open systems perspective. We propose *due process* as a central activity in organizational information processing. Computer systems are beginning to play important roles in mediating the ongoing activities of organizations. We expect that these roles will gradually increase in importance as computer systems take on more of the authority and responsibility for ongoing activities. At the same time, we expect computer systems to acquire more of the characteristics and structure of human organizations.

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General Terms: Management

Additional Key Words and Phrases: Debate, decision making, due process, logic, microtheories, negotiation, offices, open systems

1. INTRODUCTION

In this paper we discuss the nature of office work from an open systems perspective. Coping with the conflicting, inconsistent, and partial information is one of the major challenges in office information systems. Due process is the organizational activity of human and computer systems for generating sound, relevant, and reliable information as a basis of action taking. Within due process logical reasoning takes place within relatively small coherent modules called microtheories. In general the microtheories will be inconsistent with one another. Due process makes use of debate and negotiation to deal with conflicts and inconsistencies between microtheories.

2. OFFICE WORK

We define an *office* as a place where *office work* is done, thus shifting the emphasis of our investigation from the nature of the locale to the nature of the activity performed. Office work can take place in an automobile with a mobile telephone,

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in the anteroom of a lecture hall, or at a networked personal computer. Of course, the situation including place, time, and participants can materially affect the work. All office work takes place within a particular concrete situation. The point that we want to make here is that there is no *special* place where office work has to take place.

Later, we discuss how office work is situated in *particular concrete* space and time and how the situation provides an important part of the context in which the work is done.

We take *office work* to be information processing that is done to coordinate all the work that an organization does with the exception of direct manipulation of physical objects. The organizations in which office work takes place are "going concerns" in the sense of Everett Hughes [11]. For example, they include the processing of beliefs, goals, and mutual commitments as well as the development and management of responsibilities, policies, tasks, transactions, projects, and procedures. Office work is specialized by excluding *robotics*. Robotics involves information processing directly involved in the physical production, transformation, transportation, servicing, or consumption of physical objects.

Office work is situated social action in the sense that it is the action produced by participants at particular times and places. However, we need to extend the usual notion of situated social actions to encompass the social actions of computer systems in their interactions with other computer systems as well as the interactions of computer systems with human participants.

3. OPEN SYSTEMS

Offices are inherently open systems because of the requirement of communication with operational divisions as well as the external world in the task of coordinating the work of the organization. In all nontrivial cases the communication necessary for coordination takes place asynchronously. Unplanned dynamic adaptation and accommodation are required in organizational information systems to meet the unplanned changing needs of coordination since the execution of any plan requires articulation, change, and adjustment.

Open systems deal with large quantities of diverse information and exploit massive concurrency. They can be characterized by the following fundamental characteristics [9]:

(1) *Concurrency.* Open systems are composed of numerous components such as workstations, databases, and networks. To handle the simultaneous influx of information from many outside sources, these components must process information concurrently.

(2) *Asynchrony.* There are two sources of asynchrony in open systems. First, since the behavior of the environment is not necessarily predictable by the system itself, new information may enter the system at any time, requiring it to operate asynchronously with the outside world. Second, the components are physically separated distances prohibiting them from acting synchronously. Any attempt to clock all the components synchronously would result in an enormous performance degradation because the clocks would have to be slowed down by orders of magnitude in order to maintain synchronization.

(3) *Decentralized control.* In an open system, a centralized decision maker would become a serious bottleneck. Furthermore, because of communications asynchrony and unreliability, a controlling agent could never have complete, up-to-date information on the state of the system. Therefore control must be distributed throughout the system so that local decisions can be made close to where they are needed.

(4) *Inconsistent information.* Information from outside the system or even from different parts of the same system may turn out to be inconsistent. Therefore decisions must be made by the components of an open system by considering whatever evidence is currently available.

(5) *Arm's-length relationships.* The components of an open system are at an *arm's-length relationship*: The internal operation, organization, and state of one computational agent may be unknown and unavailable to another agent for reasons of privacy or outage of communications. Information should be passed by explicit communication between agents to conserve energy and maintain security. This ensures that each component can be kept simple since it only needs to keep track of its own state and its interfaces to other agents.

(6) *Continuous operation.* Open systems must be reliable. They must be designed so that failures of individual components can be accommodated by operating components while the failed components are repaired or replaced.

4. CONCURRENCY

The underlying concurrent basis of operation enables due process to react dynamically to asynchronous input and in many cases makes the results indeterminate.

4.1 Asynchronous Input

Concurrent systems differ from Turing machines in that they allow asynchronous communication from the external environment to affect ongoing operations. Sequential systems deal with this problem as a kind of "interrupt" in which they "switch tasks." Organizational information systems rarely have all the material at hand needed to make an important decision. Information that is known in advance to be required arrives asynchronously as the decision making proceeds and is often incomplete. Unanticipated information can arrive at any time in the process and affect the outcome even though it arrives quite late. For instance, an unanticipated story in the *Wall Street Journal* on the morning of a corporate board meeting to give final approval to a merger has been known to kill or delay a deal.

4.2 Indeterminancy

Concurrent systems are inherently indeterminate. The indeterminancy of concurrent systems does not stem from invoking a random element such as flipping a coin. Instead it results from the indeterminate arrival order of inputs to system components. In general, complete knowledge of the state and structure of a concurrent system together with exact knowledge of the times and values of inputs does not determine the system's output. Concurrent systems are indeterminate for the same reason that other quantum devices are indeterminate.

The indeterminancy of concurrent computation is different from the usual nondeterministic computation studied in automata theory in which coin flipping is allowed as an elementary computational step. In general, it is not possible to know ahead of time that a concurrent system will make a decision by a certain time. Flipping a coin can be used as a method of forcing decisions to occur by making an arbitrary choice. Often as a matter of principle, however, due process refuses to invoke arbitrary random measures such as coin flipping to make a decision. For example, a jury might not return a verdict, and the judge might have to declare a mistrial.[1]

5. CONFLICTING INFORMATION AND CONTRADICTORY BELIEFS

Conflicting sources of information and inconsistent beliefs are a staple of life in organizational information systems. This partly results from dealing with differing external organizations that retain their own autonomy and belief structures.

Inconsistencies inevitably result from the measurements and observations made on complicated physical systems. Higher level abstractions are used to attempt to construct a consistent description of parts of the environment in which the organization operates. For example, a firm's earnings might be labeled "provisional" and then "subject to audit." But, even after being published in the annual report, they might later have to be "restated." In this case "provisional," "subject to audit," and "restated" are attempts to construct a consistent description from conflicting information about earnings.

Whatever consistency exists among the beliefs within an organization is *constructed* and *negotiated* by the participants. In the case of reported earnings, the chief executive officer, finance department, board of directors, and regulatory authorities play important roles in constructing and negotiating the financial reports.

Any belief concerning an organization or its environment is subject to internal and external challenges. Organizations must efficiently take action and make decisions in the face of conflicting information and contradictory beliefs. How they do so is a fundamental consideration in the foundations of organizational information systems.

Conflicting information and contradictory beliefs are engendered by the enormous interconnectivity and interdependence of knowledge that come from multiple sources and viewpoints. The interconnectivity makes it impossible to separate knowledge of the organization's affairs into independent modules. The knowledge of any physical aspect has extensive *spatiotemporal, causal, terminological, evidential,* and *communicative* connections with other aspects of the organization's affairs. The interconnectivity generates an enormous network of knowledge that is inherently inconsistent because of the multiple sources of actors making contributions at different times and places.

For example, suppose that in the middle of 1986 an organization undertakes to consider its knowledge of sales currently in progress for that year for the New England region. In such a situation, there is an enormous amount of information

[1] Agha [1] provides an excellent exposition of the nature of a mathematical model of concurrent computation and its differences with classical nondeterministic Turing-machine-based theories.

about other pieces of information. The following considerations show a small part of the enormous interconnectivity of knowledge:

—*Spatiotemporal interconnectivity.* The organization has a great deal of knowledge about the history of sales in the New England region in the first few months of 1986, including how the sales were generated and recorded. In addition, it has sales projections of what will happen in the remainder of the year.
—*Causal interconnectivity.* The marketing department believes that increased advertising is causing sales to go up. On the other hand, the sales department believes that the increased sales commissions are the real reason for the increase in sales.
—*Terminological interconnectivity.* Some of the sales are really barter agreements with uncertain cash value. Do the barter agreements qualify as sales?
—*Evidential interconnectivity.* The accounting department fears that sales might really not be increasing because many of the products could be returned because of a new 30-day free trial offer. It does not believe that the evidence presented shows that sales are increasing.
—*Communicative interconnectivity.* The organization consists of a community of actors operating concurrently, asynchronously, and nondeterministically. The asynchronous communications engender interconnectivity, which defies any complete description of the global state of the organization at any particular point in time.

Conflicting information and contradictory beliefs are an inherent part of office work that must be explicitly addressed in any foundation for organizational information systems.

6. DUE PROCESS

Due process is the organizational activity of humans and computers for generating sound, relevant, and reliable information as a basis for decision and action within the constraints of allowable resources [4]. It provides an arena in which beliefs and proposals can be gathered, analyzed, and debated. Part of due process is to provide a record of the decision-making process that can later be referenced.

Due process is inherently reflective in that beliefs, goals, plans, requests, commitments, etc., exist as objects that can be explicitly mentioned and manipulated in the ongoing process.

Due process does not make decisions or take actions per se. Instead it is the process that informs the decision-making process. Each instance of due process begins with *preconceptions* handed down through traditions and culture that constitute the initial process but are open to future testing and evolution. Decision-making criteria such as preferences in predicted outcomes are included in this knowledge base. For example, increased profitability is preferable to decreased profitability. Also, increased market share is preferable to decreased market share. Conflicts between these preferences can be negotiated [18]. In addition preferences can arise as a result of conflict. Negotiating conflict can bring the negotiating process itself into question as part of the evaluative criteria

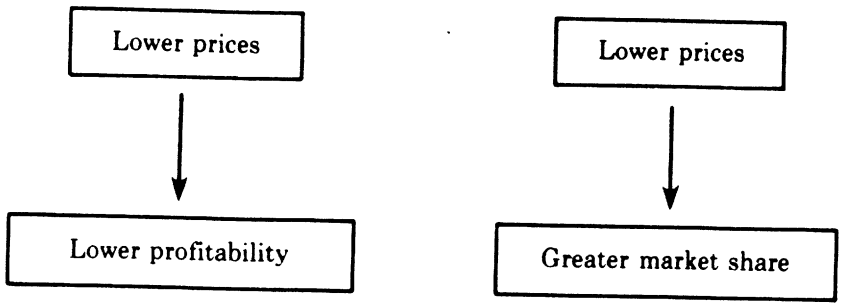

Figure 1

of how to proceed, which can itself change the quality of conflict among the participants [7, 7a].

Changing the price of a product can affect both its profitability and market share in conflicting ways, as shown in Figure 1. Market research and internal cost analysis can help model the effects of lower prices on profitability and market share. The sales and financial divisions can have very different views on the subject. They need to organize their respective positions including counter-arguments to opposing views. The cost-effectiveness of generating new information by market research and new product development can be considered by using due process.

All this activity takes place within a context that sets the time frame for the decision-making process. Sometimes the time frames can be very short, and, at the same time, the decision could be very important to the organization. Consider the sudden appearance of a new product that is drastically undercutting prices and demands a quick decision as to whether or not to cut prices. It is extremely common for a "case" to occur in due process that has to be settled promptly but has implications for more general issues. A company may develop a general vacation policy because a request by a particular employee for certain vacation privileges has to be granted or refused [13]. Due process takes place within action-taking and decision-making situations. It occurs at a particular place and time within a community of actors (both human and computer) that communicate with one another in a historical context involving information gathering, discussion, and debate.

The communications involved in due process can be analyzed along the following dimensions:

Belief. The dimension of belief concerns the propositional content of a message. Belief is an integral part of organizational information gathering and analysis.

Commitment. The dimension of commitment concerns the plans of the actors as to their future actions. Commitment is an integral part of organizational planning. Organizations grant certain of their components the authority to commit the whole organization to certain future actions [2].

Request. The dimension of request concerns the attempt to influence the future actions of recipients of the message. Requests are used in organizational execution.

Declaration. The dimension of declaration concerns the ability to change agreed state of affairs by the performance of the appropriate communicative act. Declarations are used in organizational rearrangements and confirmations.

Expression. The dimension of expression concerns the attitude of the actors (e.g., fear, anger, gratitude). Expressions are used in organizational resource adjustments.

An individual communicative act can involve several of the above dimensions. We take the meaning of each communicative act to be its subsequent effect on the participants whether they be human or computer. An important challenge in organizational information systems is to construct computer systems that can perform appropriately for the above kinds of communicative acts by making use of the information in the implications of communications in the wider context in which they take place.

6.1 Record Making

Due process produces a record of the decision-making and action-taking process, including which organization is responsible for dealing with problems, responses, and questions for the decision made or the action taken. This is the way in which responsibility is assessed for the decisions and actions taken.

The record also includes rationales for various courses of action such as

—*Predicted beneficial results.* Better targeted advertising will increase sales.
—*Policies guiding conduct.* Products may not be returned for credit more than 30 days after sale.
—*Reasons tied to specific institutional roles or processes.* A corporation may not be able to enter the computer business because of a consent decree that it has signed.
—*Precedent.* The organization might always have taken Patriots' Day as a holiday. Precedent may seem like a weak rationale. However, deciding according to precedent in the absence of strong alternatives has the consequences of predictability, stability, and improvement in the general coherence among decided cases.

Due process is an inherently self-reflective process in that the process by which information is gathered, organized, compared, and presented is subject to evaluation, debate, and evolution within the organization. Thus the debate is not just about whether to lower prices, but also about the beliefs used in the decision and the process used by the organization to decide whether to lower them.

6.2 Cooperation

Due process is not a magical way for an organization to make "correct" decisions. Instead it is concerned with the reasonableness with which information is gathered, organized, compared, and presented. It addresses the question, "How can the decision-making process be improved?" instead of the question, "What is the right decision?" Efforts to find the basis for "correct" decision making before the organization goes to work are fruitless. Attempting to critique a

particular course of action chosen by an organization involves us in the very *same* activities that are embodied in due process.

In general due process involves cooperation among the participant actors in the organization. The participants' investment in the process of information gathering, evaluation, debate, and presentation helps to produce the consensus. Every participant knows that his or her views need to be put forth in order to be considered and balanced against the others. In general those actors whose authority and responsibility are most affected by the choice of action must at least give their passive cooperation. Preexisting organizational precedents and traditions are influential in the exact way that a choice of action is made. Even if the course of action taken is not the participant's first choice, the execution of the decision can be tailored to reflect the views and concerns that have been uncovered in due process. Also recompense can often be offered to disgruntled parties by making allowances in other concurrent decision making within the organization.

6.3 Task Performance Assessment

Assessing how well the task was performed or how the performance might be improved can be quite problematical. Each performance is unique. It must be assessed in terms of quality of analysis, planning, and execution, as well as the appropriate balance of these activities. Performance assessment is subject to severe limitations in available knowledge about realistic alternatives because of unknown interactions between details in a performance. For example, the timing of an advertising campaign can affect the results of sales.

7. MICROTHEORIES AS TOOLS IN DUE PROCESS

A *microtheory* is a relatively small, idealized, mathematical theory that embodies a model of some physical system. Prescriptively, a microtheory should be internally consistent and clearly demarcated. Any modification of a microtheory is a new microtheory. Special relativity, a spreadsheet model of a company's projected sales, and a Spice simulation of an integrated circuit are examples of microtheories. Microtheories are simple because they have simple axiomatizations. The physical system being modeled, however, may be enormously complicated. We expect that computer systems will require hundreds of thousands of microtheories in order to participate effectively in organizational work.

In general due process deals with *conflicting* microtheories that cannot always be measured against one another in a pointwise fashion. In due process, debate and negotiation takes place where rival microtheories are compared with one another without assuming that there is a fixed common standard of reference. We do not assume that there is a global axiomatic theory of the world that gradually becomes more complete as more microtheories are debugged and introduced. Instead we propose to deal with each problematical concrete situation by using negotiation and debate among the available overlapping and possibly conflicting microtheories that are adapted to the situation at hand. For many purposes in due process it is preferable to work with microtheories that are small and oversimplified, rather than large and full of caveats and conditions [17].

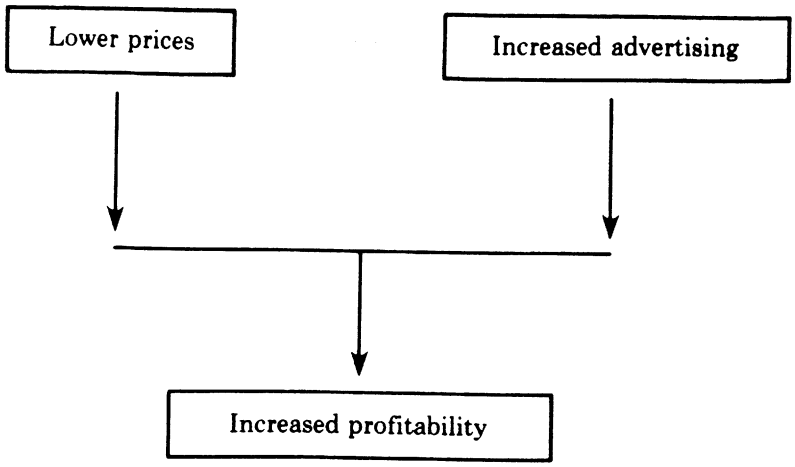

Figure 2

Logical deduction is a powerful tool for working *within* a microtheory. The strengths of logical deduction include

—*Well understood.* Logical deduction is a very well-understood and characterized process. Rigorous model theories exist for many logics including the predicate calculus, intuitionistic logics, and modal logics.

—*Validity locally decidable.* An important goal of logical proofs is that their correctness should be mechanically decidable from the proof inscription. In this way the situation of proof creation can be distinct from the subsequent situations of proof checking. In order to be algorithmic, the proof-checking process cannot require making any observations or consulting any external sources of information. Consequently all of the premises of each proof step as to place, time, objects, etc., must be explicit. In effect a *situational closure* must be taken for each deductive step. Proof checking proceeds in a closed world in which the axioms and rules of deductive inference have been laid out explicitly beforehand. Ray Reiter [16] has developed closure axioms that justify the default rules used in relational databases as logical deductions. Similarly the circumscription technique proposed by John McCarthy [14] is a closure operator on sets of axioms that results in stronger, more complete axiom sets.

—*Belief constraining.* Logical deductions deal with issues about logically entailed relationships among beliefs. If an actor believes P and (P implies Q), then it is constrained to believe Q. Similarly if an actor believes (P implies Q) and entertains the goal of believing Q, then it can entertain the goal of believing P. Examples below illustrate how both of these techniques can be valuable in evolving and managing belief structures.

Let us consider a simple concrete example to illustrate the use of logical deduction in organizational decision making. Commercial enterprises sometimes put their merchandise "on sale" to increase sales. Often this is done by cutting prices and increasing advertising. Consider the microtheory shown in Figure 2, which we shall call *profitable sale.*

We shall use the above deduction rule as a *microtheory* to explore how deduction can be used in organizational decision making. Microtheories are simply very

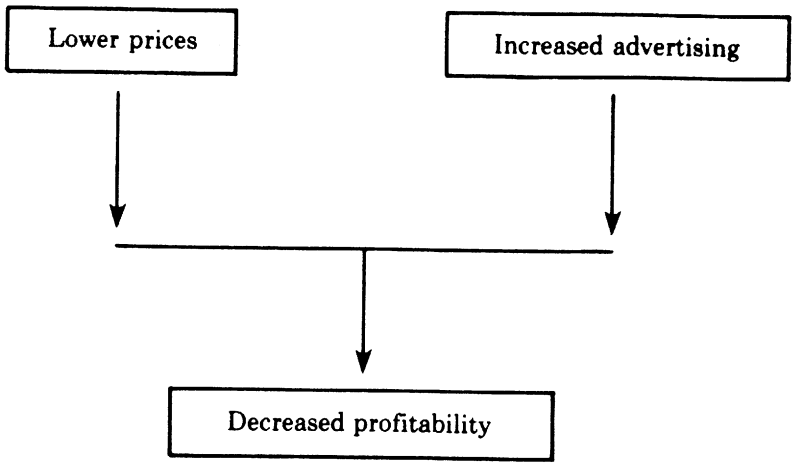

Figure 3

small partial logical theories. They are kept small and partial to avoid the problems of entanglement by interconnectivity, as discussed above.

We take a very general view of deduction: Deductive proofs are tree structures in which a computer can mechanically decide whether a step is valid just by inspecting the premises and conclusion of the deduction.

A microtheory should be internally consistent. Ideally there should even be good arguments for its consistency. If an inconsistency is discovered in a microtheory, then a repair can be attempted. Sometimes the repair attempt will fail in the face of well-justified contrary beliefs. This can be dealt with by splitting the microtheory into more specialized microtheories.

7.1 Contradictory Knowledge

Microtheories are often inconsistent with one another. The financial department might argue that lowering prices brings in less revenue, advertising increases expenses, and therefore profitability could very well decrease. We could express this model in the microtheory shown in Figure 3, which we shall call *unprofitable sale.*

Our second microtheory directly contradicts the first. Proofs are not convincing in a contradictory knowledge base in which we can prove both that the profitability will increase and that it will decrease. Therefore we confine logical deduction to within microtheories that are presumed to be consistent and use due process to mediate contradictory microtheories.

7.2 Counterarguments

The tree-structured, locally decidable character of logical deductive proof cannot take audiences into account. The *profitable-sale* microtheory cannot take into account the counterargument of the *unprofitable-sale* microtheory. We shall use extradeductive techniques such as negotiation and debate to deal with the inconsistencies and conflicts between microtheories.

A *metamicrotheory* has as part of its content axioms about other microtheories as in the work of Richard Weyhrauch [19]. Such metamicrotheories can be very useful. Due process reasoning often involves debate and negotiation between

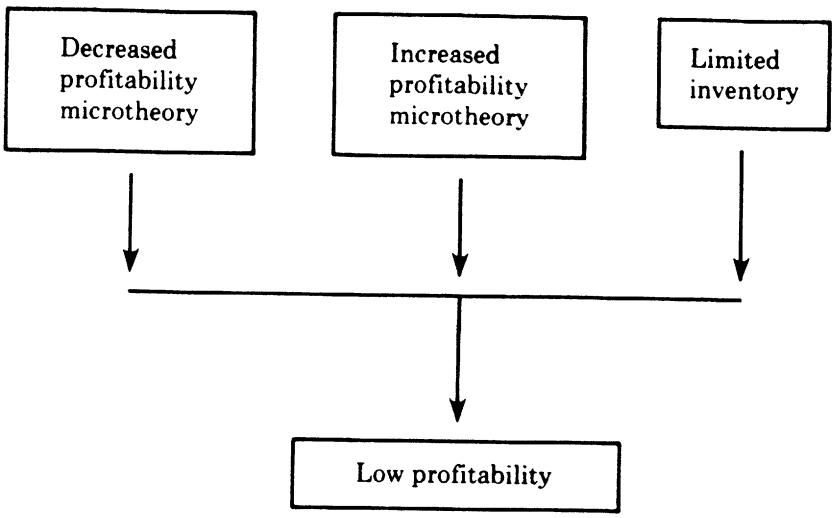

Figure 4

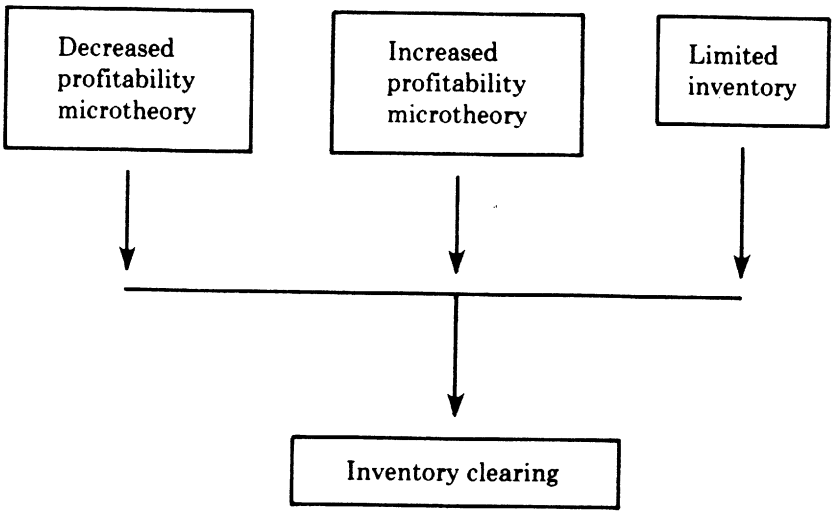

Figure 5

multiple conflicting metamicrotheories [20]. The metamicrotheories arise in the course of debate about the reasonableness and applicability of previously introduced microtheories. Often the metamicrotheories are also inconsistent with one another.

For example, the microtheory shown in Figure 4 takes into account the limited inventory as well as the decreased profitability and increased profitability microtheories to conclude that the sale would be of low profitability because of the limited inventory, whereas the metamicrotheory shown in Figure 5 concludes that desirable inventory clearance would take place as a result of the sale.

7.3 Context

The validity of a deductive proof is supposed to be timeless and acontextual. If it is valid at all, then it is supposed to be valid for all times and places. The timeless and acontextual character of logical deduction is a tremendous advantage in separating the proof-creation situation from the proof-checking context.

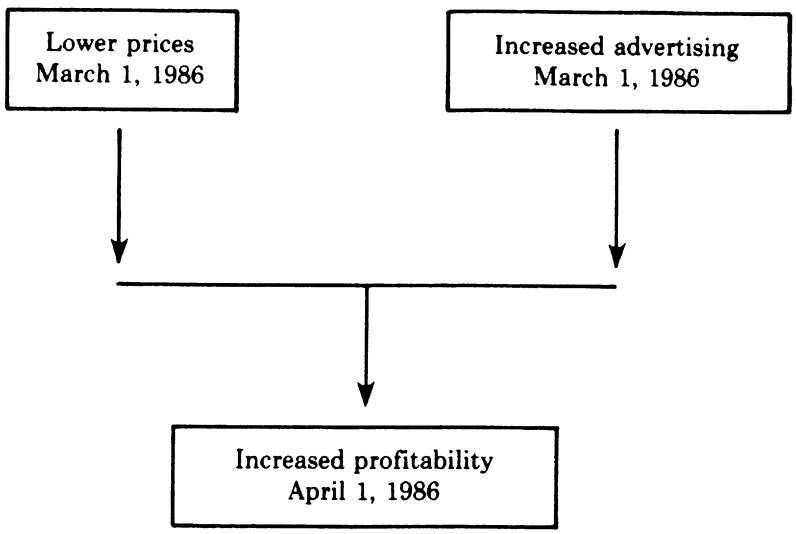

Figure 6

However, applicability of an empirical deductive rule such as the *profitable-sale* rule is problematical in many situations. For example, the rule might be challenged on the grounds that the conditions under which it worked in the past no longer hold because, for example, the market is saturated. To meet this constraint, we take the extradeductive step of dynamically adapting rules to the context at hand. Challenges to the applicability of the deductive rule may need to be entertained and debated [6]. For example, the *profitable-sale* rule might need to be further adapted by specifying that the increased advertising be presented to appeal to new customer needs that are not saturated. Operations like these contribute episodic precedents that are material for the synthesis of new microtheories.

7.4 Indeterminacy

Decisions need to be made on the basis of the arrival order of communications. The arrival order may not be determined by complete knowledge of system state, structure, and inputs. Consequently, the arrival order may not be able to be deduced. For example, decisions on whether to honor a withdrawal request for an account depend on the arrival order of withdrawals and deposits. The order of arrival of communications can drastically affect overall outcomes.

7.5 Description versus Action

Deduction can only *describe* possible actions and their possible effects; it cannot be used to take action [10]. Suppose that an organization wants to decide how to increase sales on March 1, 1986. The optimistic sales rule can be instantiated as shown in Figure 6. However, this deduction does not take any action. Instead it raises useful questions depending on the viewpoint from which it is considered. Considered from a viewpoint after March 1, 1986, it raises questions about the history of what happened. Logical deductions are useful in drawing further conclusions about the relationship of historical beliefs. On the other hand, when considered from a viewpoint before March 1, 1986, it raises questions about

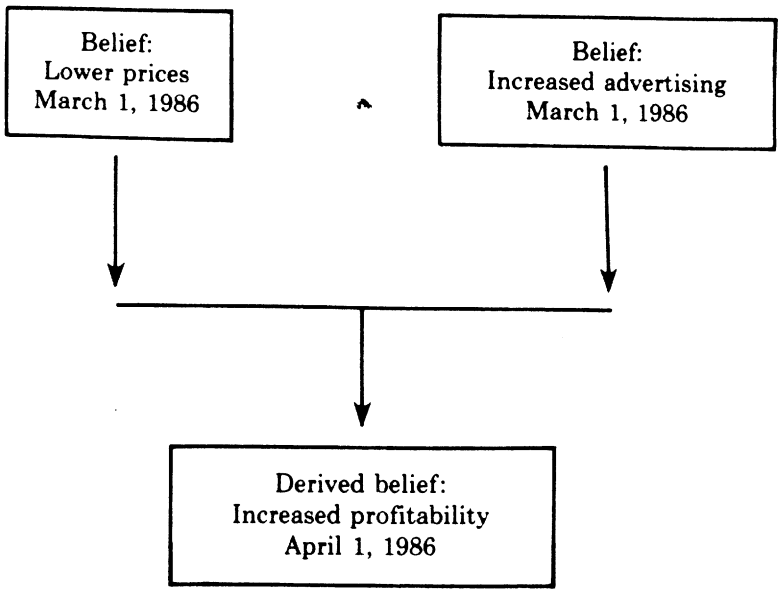

Figure 7

predicting the future. Deductions can be very useful in analyzing the logical relations among the beliefs about the future.

The validity of a deduction is supposed to be decided mechanically solely from the premises and conclusion. In this way the situation of proof checking can be separated from the situation of proof generation so that proof generation and proof checking can take place in completely separate situations. In addition, the proof is supposed to be checkable solely from the text of the proof. In this way proofs can be checked by multiple actors at different times and places adding to the confidence in the deductions. The requirements of logical deduction preclude the possibility of introducing the term *now* into a deductive language. They mean that the validity of the deduction in Figure 6 is independent of whether it is made after March 1, 1986, and thus concerns the past or is made before March 1, 1986, and concerns the future.

Logical reasoning can be used before the happening to *predict* what might happen. It can be used after the happening to *analyze* what did happen. In either case logical proof does not control the action taken.

7.6 Constraints among Beliefs

Deduction is a powerful tool for propagating constraints among the beliefs and goals of a microtheory. For example, the belief that prices are lower and that advertising is increased on March 1, 1986, can be used to derive the belief that profitability is increased on April 1, 1986, as shown in Figure 7. Furthermore, the goal of increased profitability on March 1, 1986, can be used to derive the subgoals of lowering prices and increasing advertising, as shown in Figure 8.

New beliefs and subgoals derived by deduction in microtheories are useful to actor communities in conducting debates about the results and applicability of microtheories such as the *profitable-sale* and *unprofitable-sale* microtheories. Decisions then can be made on the basis of the results of the debates.

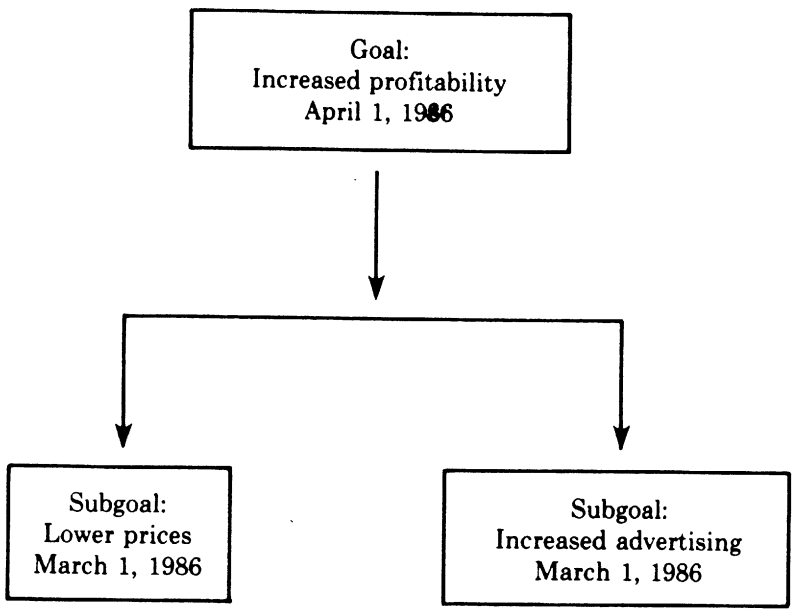

Figure 8

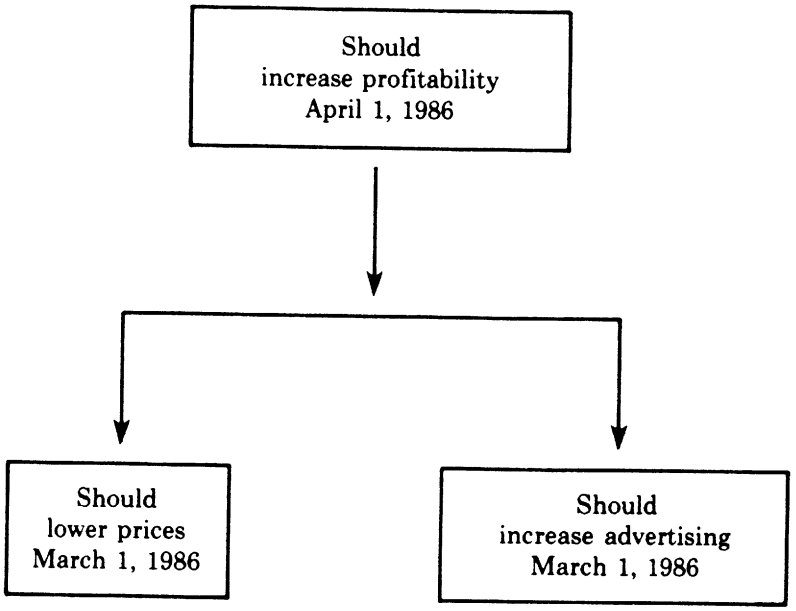

Figure 9

7.7 Recommendations and Policy

Deduction can be used to derive recommendations and to draw conclusions from policies (see Figure 9). However, the recommendations and implications of policy that are produced by deduction do not by themselves determine actions. In general, just as beliefs will be contradictory, recommendations for action will be in conflict (see Figure 10). The inconsistency among the microtheories results in inconsistent recommendations based on them.

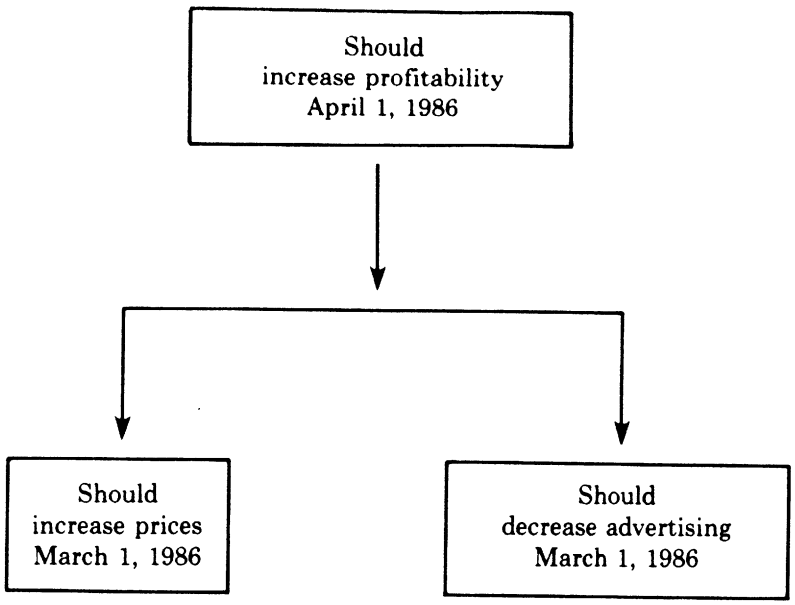

Figure 10

8. CONCLUSIONS

Foundations for organizational information systems are still in a primitive state. The enterprise is inherently interdisciplinary, requiring contributions from anthropology, artificial intelligence, research on indicators and models, cognitive science, computer science, research on needs and organizational factors, economics, management science, philosophy of science, psychology, and sociology. Foundations are needed on which to describe their function, structure, and principles of operation that can serve as the basis for managing, evolving, and designing better organizational information systems.

The effort to find the basis for decisions before the organization goes to work is meaningless. Understanding decision making is not separable phenomena from understanding the process by which it arrived. It is to forget the very purpose for which the organizational decision-making processes have been fashioned. Due process plays a central role in the operation of organizational information systems and allows for the consideration of multiple inconsistent microtheories. Logical deduction plays a role in analyzing the constraints among beliefs and goals *within* microtheories. Logical deduction is not suited to deciding among conflicting microtheories. Due process is manifested by situated action at the particular time and place when a choice of action is made. Due process specifically includes the social actions of computer systems.

The contrast between correct decision making and the actual organizational processes does not make sense. Due process has a systematicity of its own. It serves to test constantly whether the organization has come to see new differences or similarities. Due process is a situated process: The outside sociophysical world interacts with the organizational processes at particular places and times of the process that result in a particular decision. In general the decision is not determined by these interactions, nor can it be said that the result of due process

is too uncertain to obtain satisfactory choices in organizational course of action. The compulsion of adherence to due process is clear; any fundamental breakdown directly impairs the organization.

Due process is the only kind of system that will work when parts of the organization do not agree completely and represent different responsibilities. The meaning of the words in the rules, policies, and goals changes to receive the meaning that organization gives to them in due process.

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The ideas in this paper are related to previous work in distributed artificial intelligence. In particular we build on the work of Corkill and Lesser [3, 12]. The approach here differs from Davis and Smith [5] in that organizational mechanisms are emphasized instead of market mechanisms.

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REFERENCES

1. AGHA, G. *Actors: A Model of Concurrent Computation in Distributed Systems.* MIT Press, Cambridge, Mass., 1986.
2. BECKER, H. S. Notes on the concept of commitment. *Am. J. Sociol. 66* (July 1960), 32–40.
3. CORKILL, D. D. Hierarchical planning in a distributed environment. In *Proceedings of the 6th International Joint Conference on Artificial Intelligence* (Tokyo, Aug.). Kaufman, Los Altos, Calif., 1979, pp. 168–175.
4. DAVIS, K. C. *Discretionary Justice.* University of Illinois Press, Urbana, Ill., 1971.
5. DAVIS, R., AND SMITH, R. Negotiation as a metaphor for distributed problem solving. Memo 624, MIT Artificial Intelligence Laboratory, Cambridge, Mass., May 1981.
6. GASSER, L. G. The social dynamics of routine computer use in complex organizations. Ph.D. thesis, Computer Science Dept., Univ. of California at Irvine, 1984.
7. GERSON, E. M. On the quality of life. *Am. Sociol. Rev. 41* (Oct. 1976), 793–806.

7a. GERSON, E. M., AND STAR, S. L. Analyzing due process in the workplace. *ACM Trans. Off. Inf. Syst. 4*, 3 (July 1986).

8. HEWITT, C. PLANNER: A language for proving theorems in robots. In *Proceedings of ISCAI-69* (Washington, D.C., May). 1969.
9. HEWITT, C. The challenge of open systems. *BYTE* (Apr. 1985), 223–242.
10. HEWITT, C., AND DE JONG, P. Analyzing the roles of descriptions and actions in open systems. In *Proceedings of AAAI* (August). 1983.
11. HUGHES, E. C. Going concerns: The study of American institutions. In *The Sociological Eye.* Aldines, Chicago, Ill., 1971.

12. LESSER, V., AND CORKILL, D. D. Functionally accurate, cooperative distributed systems. *IEEE Trans. Syst. Man Cybern. SMC-11*, 1 (Jan. 1981), 81–96.
13. MARCH, J. G., AND SIMON, H. A. *Organizations*. Wiley, New York, 1958.
14. MCCARTHY, J. Applications of circumscription to formalizing common sense knowledge. In *Proceedings of the Non-Monotonic Reasoning Workshop* (New Paltz, N.Y.). 1984, pp. 295–324.
15. MINSKY, M. A framework for representing knowledge. In *The Psychology of Computer Vision*, P. Winston, Ed. McGraw-Hill, New York, 1975.
16. REITER, R. A logic for default reasoning. *Artif. Intell. 13*, 1, 2 (1980), 81–132.
17. STAR, S. L. Simplification in scientific work: An example from neuroscience research. *Soc. Stud. Sci. 13*, 2 (1983), 205–228.
18. STRAUSS, A. *Negotiations*. Jossey-Bass, San Francisco, Calif., 1978.
19. WEYHRAUCH, R. W. Prolegamena to a theory of mechanical formal reasoning. *Artif. Intell. 13*, 1, 2 (1980), 133–170.
20. WIMSATT, W. False models as means to truer theories. In *Systematics Symposium on Neutral Models in Biology* (Chicago, Ill.). 1985. To be published.

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