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Identification and Validation of Knowledge Structures in Organizational Learning: An Algorithmic Approach to Pattern Matching In Cognitive Maps

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Introduction

Organizational learning (OL) has been addressed in many academic fields for several decades, yet there is little consensus as to what OL is or how it occurs. In spite of this controversy, two streams of inquiry have proven to be useful in OL-based information systems (IS) research. One stream has investigated the significance and effects of equivocality. Another important stream has investigated "systems thinking."

Daft and Lengel (1986) defined equivocality in two ways. Their first definition, "the existence of multiple and conflicting interpretations about an organizational situation" (p. 556), is representative of a large segment of mainstream IS thought. Such accord, however, did not extend to the management of equivocality. Early research emphasized the reduction of equivocality and its resulting multiple interpretations (Weick, 1969). Associated with this line of research was Daft and Huber's (1987) call for recommendations regarding the design of support systems for this interpretive perspective of OL. Later research supported the importance of maintaining or increasing equivocality and the advantages of generating multiple interpretations (Huber, 1991; Weick, 1993).

Daft and Lengel's (1986) second definition of equivocality, "a measure of the organization's ignorance of whether a variable exists in an n-dimensional information space" (p. 557), acknowledges the role of information processing within the organization. This definition parallels the "systems thinking" approach to OL. Stemming from early work in systems theory, cybernetics, and systems dynamics, "systems thinking" is often associated with the use of cognitive maps generated by organization members. Deriving these cognitive maps helps organization members understand not only the complex feedback mechanisms that currently exist within the organization, but also the ways in which members might think about feedback mechanisms in future issues.

The intertwining of systems thinking with Daft and Lengel's second definition is evidenced by problems in the development of organizational cognitive maps. Langfield-Smith (1992) reported that groups encountered difficulties in language and word meaning when developing shared cognitive maps. Such difficulties undermine the practicality of data dictionaries such as those developed in Lee et al. (1992). The use of experts to determine equivocality, as employed in numerous studies, provides a different method of analyzing the variables within cognitive maps. However, Laukkanen (1994) reported problems in comparing multiple interpretations of organization members. These problems included data acquisition and standardization of the natural language expressions underlying individual actors' cognitive maps. Laukkanen further argued for "tools to help process and analyze raw data" generated in studies of organizational cognition (p. 323). Finally, the problem of comparing large numbers of individual cognitive maps generated in learning laboratories, such as described in Senge and Sterman (1992), can be computationally complex.

Following Laukkanen's suggestion, a main purpose of the proposed research is to develop tools which process and analyze organizational cognition data. Another purpose of the proposed research is to advance recommendations for the design of systems to support Daft and Huber's (1987) interpretive perspective of OL. Specifically, the research will develop tools to assist researchers in registering patterns of shared

variables and relationships between the cognitive maps of organization members. Such shared, recurring patterns are defined as *knowledge structures*. Knowledge structures are thus a product of Daft and Lengel's second definition of equivocality. By identifying patterns of shared variables and their relationships, knowledge structures help identify those patterns of interpretations which are held in common by individual organization members. Knowledge structures can thus be used to identify conjunctive and disjunctive configurations in an organization's cognitive map, and to help identify the origins of multiple interpretations.

An Object-Oriented Approach to the Analysis of Variables and Relationships

Past investigations of equivocality reduction have relied chiefly on human expertise to operationalize equivocality. These operationalizations include, but are not limited to, pretesting potential equivocal situations, employing independent judges to evaluate similarities, or focusing on a particular level of equivocality. However, these mechanisms often require extensive and cognitively demanding human processing.

The close link between decision analysis and learning is well documented (Keen and Scott Morton, 1978). It is thus natural to explore decision analysis for potential approaches to this research. Decision analysis often employs hierarchical structures to represent decision making processes. A typical implementation of hierarchical structures is found in Gettys et al. (1987). The objective of their research was to determine the completeness of sets of solutions generated by individuals faced with a well-defined decision problem. This objective was met by aggregating all elements of all solution sets, then rearranging them into groups of similar elements. These groups were then structured into the branches and limbs of a hierarchical "tree." The completeness of a subject's solution set could then be analyzed by a comparison to the tree. A solution set with high "completeness" need not have a high number of solutions, but it would be expected to have solution elements on the major limbs and branches of the solution tree.

Gettys et al.'s methodology offers a promising approach to testing the completeness of the set of variables and relationships within an organization member's cognitive map. The tree structure further suggests object-oriented analysis and design (OOAD) as a candidate for analyzing the cognitive maps. This methodology allows one to view the variables and relationships within cognitive maps as entities. These entities can then be encoded as objects. While an OOAD approach does not eliminate the human cognitive effort required to categorize similar variables and relationships between cognitive maps, it does provide several advantages. First, OOAD facilitates the design of data structures (i.e., objects). Second, OOAD supports the categorization of similar objects into classes, an advantage that will be more fully explained in the next section.

An Algorithmic Approach to Pattern Matching in Cognitive Maps

Fu's (1995) pattern matching algorithm offers an efficient and effective method for identifying shared patterns of interpretation between the cognitive maps of organization members. This algorithm was designed to identify matching patterns of nodes and edges between different rooted unsigned digraphs (directed graphs). Yet the cognitive maps used in systems dynamics are generally *signed*-and often *unrooted*-digraphs whose edges represent time delays as well as direct or inversely proportional relationships. Therefore, a major contribution of the proposed research will be adapting Fu's algorithm to signed, time-dependent digraphs. This requires a number of adaptations.

First, in order to use Fu's algorithm, a mechanism must be devised to designate an appropriate node in each cognitive map as the root node. This process should choose those nodes which facilitate the efficiency of the pattern matching algorithm. Second, edges within the cognitive maps must be evaluated as to their sign and whether they represent time delays. This evaluation could be accomplished via the use of class structures and polymorphism from the object-oriented paradigm. That is, node and edge objects could be

categorized in a hierarchy of a class (e.g., class *component*) with two subclasses (class *node* and class *edge*). Fu's algorithm would then be encoded in an object-oriented program which accepts input at the class *component* level. The dynamic form of the object being processed (i.e., whether it is a node or an edge) and the appropriate method versions to apply would be determined via poly-morphism. A final adaptation will effectively yet efficiently choose appropriate patterns from one cognitive map to compare to another cognitive map. This can be achieved by comparing the nodes of two cognitive maps at issue, then determining which of those nodes are shared. Such shared nodes could then express the limits of the patterns to be tested. This mechanism would thus reduce the problem's time and space complexity by reducing the number of patterns to be tested.

Contribution

The proposed use of OOAD and pattern matching algorithms can engender useful tools for research into the interpretive perspective of organizational learning. These methods may not significantly reduce the initial task of identifying similar variables in the cognitive maps of organization members, nor would they ensure the validity of such identifications. Both would still depend on the size of the problem space and the skill and expertise of the researcher.

Nonetheless, OOAD and pattern matching algorithms, when successfully implemented in a suitable information technology, can dramatically increase the efficient processing of larger number of cognitive maps. This ability produces several advantages. First, statistical power can be increased through larger sample sizes. Second, the validity of some future research projects can be strengthened by facilitating the use of a greater number of evaluators. More evaluators means that researchers can draw from a larger pool of expertise, or they can broaden the scope of their research (e.g., through longitudinal studies or by investigating more organizational units). Finally, an improved tool might support the identification of similar variables. This could make the evaluation of variables less burdensome and the recruitment of evaluators less duplicitous.

Additional Research Directions

As the research evolves, additional directions need to be considered. For instance, the claims of increased efficiency and effectiveness must be validated. If such claims are not valid, then modifications to the tools would be necessary. It was assumed in this research that the use of experts to identify similar variables between cognitive maps would be more practical than the use of data dictionaries, yet this assumption remains to be validated. A comparison of the proposed tool to Lee et al's (1992) COCOMAP could be fruitful.

Another direction concerns the identification of knowledge structures within organizations. Knowledge structures can facilitate future research in equivocality management because their terminal nodes are the roots of multiple interpretations between organization members. Such identification can increase the efficiency of behavioral studies of the reduction, maintenance, and increase of equivocality. Knowledge structures could prove useful in extensions of group studies such as Langfield-Smith (1992) or management organizational cognition studies such as Laukkanen (1994).

Finally, this research may engender innovative IS analysis and design tools which rely on cognitive maps as input. For instance, cognitive maps have been used to construct quantitative computer models of organizational behavior. Such models might one day be used by IS designers to test and possibly predict the effects of their designs on organizational performance. This kind of testing would be similar to the way aircraft engineers currently test their designs with computer simulations.

References

Daft, R. L. and Huber, G. P. "How Organizations Learn: A Communication Framework," *Research in the Sociology of Organizations*, (5), 1987, pp. 1-36.

Daft, R. L. and Lengel, R. H. "Organizational Information Requirements, Media Richness and Structural Design," *Management Science*, (32:5), 1986, pp. 554-571.

Fu, J. "Pattern Matching in Directed Graphs," in *Combinatorial Pattern Matching*. Z. Galil and E. Ukkonen (eds.), Springer-Verlag, Berlin, 1995, pp. 64-77.

Gettys, C. F., Pliske, R. M., Manning, C. and Casey, J. T. "An Evaluation of Human Act Generation Performance," *Organizational Behavior and Human Decision Processing*, (39), 1987, pp. 23-51.

Huber, G. P. "Organizational Learning: The Contributing Processes and the Literatures," *Organization Science*, (2:1), 1991, pp. 88-115.

Keen, P. G. W. and Scott Morton, M. S. *Decision Support Systems: An Organizational Perspective*, Addison-Wesley, Reading, MA, 1978.

Langfield-Smith, K. "Exploring the Need for a Shared Cognitive Map," *The Journal of Management Studies* (29:3), 1992, pp. 349-368.

Laukkanen, M. "Comparative Cause Mapping of Organizational Cognitions," *Organization Science*, (5:3), 1994, pp. 322-343.

Lee, S., Courtney, J. F., Jr., and O'Keefe, R. M. "A System for Organizational Learning Using Cognitive Maps," *Omega*, (20:1), 1992, pp. 23-36.

Senge, P. M. and Sterman, J. D. "Systems Thinking and Organizational Learning: Acting Locally and Thinking Globally in the Organization of the Future," *European Journal of Operational Research*, (59:1), 1992, pp. 137-150.

Weick, K. E. *The Social Psychology of Organizing*, Addison-Wesley, Reading, MA, 1969.

Weick, K. E. "The Collapse of Sensemaking in Organizations: The Mann Gulch Disaster," *Administrative Science Quarterly*, (38:4), 1993, 628-652.