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A Temporal Reasoning Extension and Framework for Expert System Shells

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Problem Statement

Many management problems that lend themselves to solutions using expert systems include "time" as a problem dimension. Planning and scheduling, diagnosis, and monitoring applications are problems in which representing temporal elements and reasoning about those elements occur. Research institutions and high-tech corporations have developed expert systems that incorporate temporal knowledge and temporal reasoning capabilities (Perkins and Austin, 1990; Prasad, et al., 1994). These capabilities, however, have not been enumerated and analyzed for business applications. A framework that presents the desirable criteria for temporal expert systems would enable developers in business to incorporate these ideas in the development of their own systems. The criteria presented in the framework would also serve as a guide in the evaluation of expert system shells with temporal extensions.

Although applications for temporal expert systems have been primarily aimed at problems in aerospace, factory automation, and alarm systems, opportunities abound for business problems (Benjamin and Blunt, 1992). In particular, expert systems may be quite valuable for marketing management. Marketers often deal with ill-structured problems that require frequent decisions. Potential problem domains that lend themselves to an expert system solution include media planning, new product development, distribution planning, analysis of scanner data, selecting market segments, and promotion planning (Mentzer and Gandhi, 1992; Rangaswamy, et al., 1989). Time constraints play a particularly important role in promotion planning. Decisions concerning such issues as the timing of coupon drops and the placement of in-store advertising are made often. These decisions also need to be coordinated so that they will not undercut other promotions by the same company, and will not be issued when other companies' promotions for similar products are offered. In addition, such promotions must be coordinated with inventory management systems to avoid stock-outs. Variables entering the promotion planning process include customer purchase patterns, coupon redemption rates, prices, and budgetary constraints. The extensions to the expert system shell under development will be applied to a marketing expert system that coordinates the time aspects of promotion planning. Since the planning process also depends on information from consumers, stores, and manufacturers, monitoring activities are also included in the expert system.

The objectives of the research-in-progress are:

1. to provide a framework for developing and evaluating temporal expert systems in business,
2. to apply this framework in the design and development of a temporal extension for an expert system shell, and
3. to apply the extension and the framework in the development of an expert system with temporal capabilities that coordinates promotion planning information.

Problem Background

Representing time elements and reasoning about them has just begun to be included in the development of expert systems, but artificial intelligence researchers have been interested in this area because so many problems include time as a critical factor. The two issues that have most concerned researchers have been 1) the representation of temporal knowledge and 2) temporal reasoning. Means to represent units of time and their interrelationships have fallen into two categories: interval-based and point-based. Interval-based systems assert that actions and events do not occur instantaneously, but instead occupy an interval of time, however small, that can be measured (Allen, 1983). Allen devised thirteen possible temporal relationships among time intervals, and used them to infer conditions under which events could occur. In point-based representations, the time unit is expressed in relation to a point of reference or within a specific problem context (Gonzalez and Dankel, 1993). Point-based representations are well-suited to two ways in which we use time: as absolute dates and times to refer to events, and as time-stamps, which associate a time point with an action or event. Temporal reasoning, which is concerned with the inferences made by combining temporal intervals or points has dealt with the computational complexity of temporal reasoning, and the correctness of temporal inferences (Dorn, 1992). Problems that arise in temporal reasoning include dealing with overlapping or simultaneous events, continuous change, conflicts among actions done in the wrong order, and adapting plans to changing circumstances.

Our marketing expert system will face not only these problems but those specific to the planning and monitoring domains. The problem space for planning requires information on the availability of resources, specific needs such as tasks that must have already been completed, and constraints, of which the most critical is time (Harmon and Sawyer, 1990). In monitoring problems, the system reacts to observations based on the data itself, associated tables or databases, and the environment. Rules which control the actions taken by the system when certain conditions occur, and control structures, such as mechanisms to gather readings at different checkpoints, involve the time element. An expert system for applications in monitoring and planning can benefit from explicit incorporation of temporal capabilities. The framework suggested below establishes those requirements.

Proposed Solution

Although several comprehensive studies set forth evaluation criteria for expert systems in business that outline desirable features in an expert system (Holsapple and Whinston, 1987; Stylianou, et al, 1992), none has identified similar criteria for temporal expert systems. The framework suggested in this paper outlines those capabilities. It is based around four concepts: 1) time representation, 2) the expressiveness of temporal relations, 3) the reasoning process and temporal inferences, and 4) storage and retrieval of historical data. Time representation is concerned with the form in which to express time (e.g., as points or intervals); the granularity of time; the level at which time-stamps should occur (e.g., attributes or events); and the ability to refer to time in a relative sense (e.g., John was hired a week ago), rather than simply by a specific date (McDermott, 1982). Temporal expressiveness includes the ability to construct a time-line from a series of actions; the use of complex operators such as "during" and "overlaps"; the ability to qualify temporal queries; and the ability to interpolate values that are not time-stamped on the time-line. Temporal reasoning issues include rule selection order, control of rule activation and firing, and truth maintenance (Holsapple and Whinston, 1987). Storage and retrieval issues are concerned with efficiency and with the number of values to be stored for trend analysis (Perkins and Austin, 1990; Prasad, et al., 1994).

These interrelated concepts represent the desirable criteria for a temporal expert system. A manager or designer who is selecting or developing a temporal expert system must recognize that meeting some of these criteria may involve a tradeoff in the strengths of others. For example, selecting an attribute level of representation may limit the ability to express event relationships. Similarly, relaxing the degree of rigor may reduce both expressiveness and truth maintenance. All criteria also need to be evaluated in terms of the type of problem to be solved and the domain for which applications will be developed.

The key feature to consider in planning and monitoring problems concerns the level at which time is shown. In planning, we measure a plan's progress by linking time-stamps to events. Monitoring problems, however, measure values of attributes, so time information should be stored at the attribute level. One issue that the research-in-progress must address is whether a marketing promotion system should include two expert system components in order to represent the appropriate time levels for both planning and monitoring activities. Other problems to be solved in the implementation are the acquisition of an expert's body of knowledge in promotions; whether the expert system's problem domain for monitoring should occur at the individual consumer level or the store level; and whether the focus in planning should be from the perspective of the manufacturer, the consumer, or the retailer.

We are using the C Language Integrated Production System (CLIPS) tool to solve these problems. CLIPS is an expert system shell developed at NASA (NASA, 1993). It has been used for military, government, research, medical, and industry applications. Its forward chaining algorithm is wellsuited to problems involving planning and scheduling. The proposed features and enhancements to CLIPS for the planning problem will involve the knowledge base. The knowledge base is that component of an expert system that contains the facts and heuristics for the problem domain. Time will be "linked" to events through rules and templates, which are frame-like structures with named slots and values. The same features in CLIPS will also be used to map time points to interval relations in order to express statements as "event A occurred before event B." Control facts will enforce the desired temporal ordering of events. For the monitoring problem, linking time-stamps to slot values will involve modifying the CLIPS source code to provide a new type of slot-constraint. Mapping specific time points to interval relations requires additional rules or template slots to express temporal relationships. Reading fact values associated with those attributes will also require synchronization so that one value from each attribute-type is evaluated before the next set of readings is obtained.

Evaluating expert systems generally does not lend itself to conventional software techniques. Testing the success of the expert system extension will require the generation of several test cases. The test cases, while not exhaustive, should reveal redundant, conflicting, or cyclical situations. Successful earlier test cases must also be reevaluated as the knowledge base changes to handle more complex conditions. Monitoring cases usually have predetermined sets of conditions and actions, so that specific test cases can be enumerated. Test cases for planning have the objective of determining the "goodness" of the solution. The real measure of monitoring and planning systems is to put it into action for a "real-world" problem. Our temporal expert system should be able benefit promotion planners and managers in their decision-making.

References

Allen, J. F. "Maintaining Knowledge about Temporal Intervals," Communications of the ACM (26:11), 1983, pp, 832-843.

Benjamin, R. and Blunt, J. "Critical IT Issues: The Next Ten Years," Sloan Management Review (33:4), 1992, pp. 7-19.

Dorn, J. "Temporal Reasoning in Sequence Graphs," Tenth National Conference on Artificial Intelligence, Menlo Park, AAAI Press, 1989, pp. 735-740.

Gonzalez, A. and Dankel, D. The Engineering of Knowledge-Based Systems: Theory and Practice, Englewood Cliffs, Prentice-Hall, 1993.

Harmon, P. and Sawyer, B. Creating Expert Systems for Business and Industry, New York, Wiley, 1990.

Holsapple, C. and Whinston, A. Business Expert Systems, Homewood, Irwin Press, 1987.

McDermott, D. "A Temporal Logic for Reasoning about Processes and Plans. Cognitive Science (6), 1982, pp. 101-155.

Mentzer, J., and Gandhi, N. "Expert Systems in Marketing: Guidelines for Development," Journal of the Academy of Marketing Science, (20:1), 1992, pp. 71-80.

NASA. CLIPS Version 6.0 Basic Programming Guide, Houston, Software Technology Branch, Johnson Space Center, 1993.

Perkins, W. and Austin, A. "Adding Temporal Reasoning to Expert-System-Building Environments," IEEE Expert (5:1), 1990, pp. 23-30.

Prasad, B., Perraju, T., Uma, G., and Umarani, P. "An Expert System Shell for Aerospace Applications," IEEE Expert (9:3), 1994, pp. 56-64.

Rangaswamy, A., Elishaberg, J., Burke, R., and Wind, J. "Developing Marketing Expert Systems: An Application to International Negotiations," Journal of Marketing (53), 1989, pp. 24-39.

Stylianou, A., Madey, G., and Smith, R. "Selection Criteria for Expert System Shells: A Socio-Technical Framework," Communications of the ACM (35:10), 1992, pp. 30-48.

[More references are available upon request]