Decision Support System for Creativity Management

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Abstract

The Expert System for Creativity Management is designed to provide guidance for managers in R&D laboratories who need to nurture creativity in their technical staff. It is based on the Ginn model of management of creativity, which breaks these management problems down into a series of dichotomies. The expert system uses a blackboard architecture to simplify the software engineering and enhance the user interface.

1 Introduction

The aim of this research is to develop an Expert System for Creativity Management, a decision support tool designed to provide guidance to managers and creative technologists. It is designed to assist them in deciding how best to accomplish projects that require creativity by providing a creative climate for their subordinates. The expert system incorporates the concepts of the Ginn creativity management model [2, 3, 4, 5, 6]. This model is organized as an integrated decision model that focuses on the major dichotomies or critical choices that must be made by technical personnel and their management during the creative process. The first step is the construction of a prototype expert system in Arity/Prolog embodying the Ginn model which was developed after extensive interviews with R&D managers and practitioners.

A blackboard architecture was chosen to simplify the software engineering of the system, to promote modularity and to modularize the system design and implementation. The Creativity Management System is divided into four quadrants, each corresponding to a major decision supported by the system. The blackboard architecture permits the modules implementing these quadrants to function as completely independent pieces of software. Data values are interchanged only through the blackboard. The flow of control is determined by an agenda on the blackboard. This is particularly convenient since the user can reasonably consult the quadrants in any order.

Initial tests of the expert system are being carried out by managers of several local research and development projects. The results of these tests will guide future improvements to the system.

2 Statement of the Problem

The creativity of corporations depends upon the creativity of the individuals and the culture of the corporation. The individuals and the corporations go through different stages of creativity development and their needs may sometimes conflict. [5]. Creativity management is required to balance the creative needs of corporations and their individual employees. Managers have to balance the needs of the individual and the needs of the corporation in order to manage creativity. Flexibility of management style is required. The process of technological innovation is central to organizational survival, but at the same time it is complex [10].

No tool has been produced previously to aid managers in fostering a corporate culture or climate in which individual creativity, inventiveness and entrepreneurship can thrive. Under these circumstances, each manager has had to rely on his own pattern for decision making based on past experience, training and perhaps intuitive and conflicting
strategies. It may take many years for an individual manager to devise a proper pattern to successfully encourage a team of creative individuals. Corporate management needs tools to help them provide a flexible working environment and foster a climate for creative technologists to produce at their highest creative potential.

3 The Ginn Model for Managing Technological Creativity

Ginn's model is based on years of research [2, 3, 4, 5, 6]. One of his basic premises is that creative technologists are multidextrous. They must characteristically opt between choices representing significant dichotomies of behavior. Ginn and Rylander [4] present a preliminary model for managers that incorporates the concepts of the multidextrous nature of the creative process with data derived from interviews with CEOs, top executives, vice presidents, directors, managers, senior scientists, professors and staff members who are known achievers in scientific and technological fields [6].

The model incorporates four principal dichotomies or quadrants. Each quadrant corresponds to a fundamental decision that must be made by the manager or the creative technologist. The integrated decision model is shown in Figure 1. Figure 2 lists the selection or decision criteria. In the model, the four dichotomies are placed in the core. The eight possible choices surround the core. In order to make a possible choice, the user must use the decision criteria shown in Figure 2 (which is adapted from Ongwis-esphalboon 1990).

The model allows the decision-maker, a manager or a practitioner to enter whatever decision mode seems most appropriate at a given point. The next step is to consider the pertinent criteria in that quadrant. A choice is made on the basis of these criteria.

4 Motivation

Computer scientists have an even greater need for creativity management than scientists and engineers in other fields. Since the field is so new, most managers of computer science development projects are not themselves trained in computer science and have difficulties in empathizing with their subordinates. They often feel alienated from those they are trying to manage, while their subordinates feel that the managers do not understand what they are trying to do or what tools they need to work effectively. The main goals in this research are:

- to experiment with the technology of expert systems and find out which interfaces function best in a business environment;
- to provide management with a tool that will guide decision making in complex managerial situations in a systematic, analytical, and objective way;
- to find how to support a manager in formulating rules, discovering problems with those rules, repairing them, and testing them;
- to develop an archive facility which will allow us to collect data about actual decisions made by managers.

5 The Significance of the System

The expert system will perform the following functions:

a) Capturing scarce expertise. Clearly this country is suffering from a lack of creativity in R&D [9].

b) Providing decision support in a systematic rule-based reproducible environment. Decisions will be accompanied by explanations of their derivation or their decision path. By use of the expert system, a manager is encouraged to make his decision based on identifiable factors rather than purely intuitive feelings and undefined strategies.

c) Developing insights into what motivates creative technologists and what kinds of environments are helpful in prompting all the stages of creative process.

d) Serving as a training tool for new managers. By using the system, new managers can access the expertise of experienced personnel. They are free to incorporate new knowledge as they discover it during their tenure as managers.

e) Serving as an educational tool for colleges and universities in behavioral and management sciences. Students can gain insights into the creative process and learn techniques to maximize creative potential. Novices who work with an expert system acquire more insight and experience; in addition, the explanation facility can be used as a teaching device.

f) Testing the hypotheses of the Ginn Model.
Figure 1: An Integrated Decision Model for Creativity Management

<table>
<thead>
<tr>
<th>Information Gathering vs. Deciding</th>
<th>Individual vs. Group Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Prior history and track record</td>
<td>1. Prior processing mode</td>
</tr>
<tr>
<td>2. Stage of creative process</td>
<td>2. Performance to date</td>
</tr>
<tr>
<td>3. Need to generate Information/</td>
<td>3. Motivational needs anticipated</td>
</tr>
<tr>
<td>options</td>
<td>4. Need for creativity</td>
</tr>
<tr>
<td>4. Internal need to reduce uncertainty</td>
<td>5. Need for variety of experiences</td>
</tr>
<tr>
<td>5. External constraints and opportunities</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Coupled vs. Decoupled Mode</th>
<th>Initiating vs. Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Ability to progress further</td>
<td>1. Existence of structural barriers</td>
</tr>
<tr>
<td>2. Ability to manage uncertainty / tension</td>
<td>2. Desire for change and variety</td>
</tr>
<tr>
<td>3. Existence of operating culture barriers</td>
<td>3. Compatibility of key players with contingencies</td>
</tr>
<tr>
<td>4. Consistency of culture and environment with creative needs</td>
<td>4. Imperatives for action and success</td>
</tr>
<tr>
<td>5. Degree of safety, security and challenge</td>
<td>5. Proximity to illumination stage (requiring intuition and analysis)</td>
</tr>
</tbody>
</table>

Figure 2: Selection or Decision Criteria
6 Design Goals of the Expert System for Creativity Management

The user of the expert system can visit the quadrants in any order and examine just one quadrant or several in any visit. Data about any individual may be archived along with the system's recommendations and then recalled; it may be changed at any point. Data may also be flushed from the system, if the manager wants to work on another case or try other hypotheses. The system is structured so that a question about a particular individual or situation will not be asked again in the same session. The user is allowed to change any data value at any time and rerun the system.

7 The Architecture of the System

Blackboard based systems typically have several specialist components that produce hypotheses about the current problem. These hypotheses are stored in a central data structure, the blackboard, and are accessible to all other components [11]. The control mechanism in a blackboard based system is asynchronous with each component acting in response to input data and hypotheses generated by other components. The system develops an overall solution to the problem as a consequence of the interaction between these components as they successively refine and generate new, more correct, hypotheses [7].

A blackboard architecture was chosen to simplify the software engineering of the system. In this architecture the expert components function autonomously and communicate only by posting intermediate results in a central data table called a “blackboard.” This organization promotes modularity in the system design and implementation. The system is divided into four quadrants, each corresponding to a major decision supported by the system. The blackboard architecture permits the modules implementing these quadrants to function as completely independent pieces of software. The domain blackboard consists of central data table that acts as a common repository of data and knowledge that the components may access. The components are controlled by an agenda on the blackboard, which determines what to do next.

The system consists of separate components each with its own knowledge base in the form of rules and facts, and explanation subsystem. These components interact with user through a user interface that furnishes the user with a consistent view of the system. Figure 3 illustrates the components of the system. Figure 4 shows the overall architecture of the system.

7.1 Top Level Blackboard System

The top level component controls the system. It acts as the system executive and, using the agenda as a guide, controls the operation of all the components. It contains the central data table of the system (a common repository of data / knowledge that all the components may access). The answer to each question and the final results of the consultation are stored in the central data table. This information is available to all component modules so that the system never has to ask the user a question a second time.

The top level of the blackboard system supplies the user with a set of alternatives that determine the system's actions: Consult, Display information, Display recommendation, Display explanation, Save information, Resume, Change Information, Help, Quit.

7.2 User Interface

The user interface sends messages to the user and queries the user for information about the circumstance of the working environment at that time. The interface contains all questions for use in quadrant #1 to quadrant #4 [12]. It is designed to be easy to expand as more quadrants are added.

The user interface of this system uses menu selections. This approach is attractive, because it eliminates training and memorization of complex command sequences and users can select an item easily by indicating their choice with one or two key presses [15]. This simplified interaction style reduces the possibility of keying errors, and incomplete input. Guidelines for screen layout and color used in the system follow Shneiderman [15].

7.3 Knowledge Source

Quadrant #1 (Information Gathering vs. Deciding)

The function of this component is to derive a recommendation for whether the group or individual
FIGURE 3: AN OVERALL COMPONENTS OF THE EXPERT SYSTEM FOR CREATIVITY MANAGEMENT
User Interface may employ:

- question and answer
- menu driven

Knowledge base editor

Inference engine

Explanation subsystem

Knowledge base

Performance tool

**FIGURE 4: THE ARCHITECTURE OF THE EXPERT SYSTEM FOR CREATIVITY MANAGEMENT**
should make a commitment to a specific course of action or needs to collect more information first. Several criteria are used to determine the solution.

1. Prior history and track record
2. Stage of creative process
3. Need to generate information/options
4. Internal need to reduce uncertainty
5. External constraints and opportunities

The following questions have been formulated for this quadrant.

Criterion #1.1: Prior history and track record of individual

1.1a. Were the major projects scheduled to be completed in the last one year completed?
1.1b. Were the major projects satisfactorily completed in terms of budget, time and quality restrictions?

Criterion #1.2: Prior history and track record of company

1.2 How is company performance in related areas?

Criterion #2: Stage of Creative Process

2.1 What stage of the creative process is the individual in?

Criterion #3: Need to generate options

3.1 What is the performance to date on the current project with respect to quality, budget and time constraints?
3.2 Does the creative individual feel that he/she is facing a deadlock situation or is he/she fairly confident of current options under consideration?
3.3 Is the end user satisfied with the project so far?

Criterion #4: Internal need to reduce uncertainty

4.1 Does the creative individual feel that the vast number of available options are leading to considerable uncertainty?
4.2 Does the individual feel that he is running out of time and cannot test all the options adequately?
4.3 Does the individual feel that he needs some feedback to ensure that he/she is on the right track?

Criterion #5: External constraints and opportunities

5.1 How is project performance in terms of financial and time constraints?
5.2 How is the feedback from top management?
5.3 How are the environmental constraints in terms of availability of resources?
5.4 How strong is the competitive threat in the market?
5.5 Do you feel that the opportunities outweigh the constraints?

Each question is rated on a scale from 1 to 7 in the degree of flexibility or favor: 1 = nil (no flexibility or unfavorable), 2 = slight, 3 = some, 4 = medium, 5 = substantial, 6 = high, 7 = extremely high (flexibility or favorable). Devising these scales is one of the most difficult aspects of building the system. The user is prompted to enter a value of 1 to 7. The system will store the query answers in the form of facts in its knowledge base. Calculations are performed on input data for deductions. The system uses these facts along with decision rules to advise the manager whether change is called for.

Quadrant #1: Range of Combined Values.

The following are the ranges of the values for each criterion. The inference engine will use this mechanism to figure out the level or degree of the answers given by comparing them with the following ranges.

Criterion 1.1: Prior History and Track Record of Individual

<table>
<thead>
<tr>
<th>Value Range (1-7)</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 - 4</td>
<td>Extremely poor performance</td>
</tr>
<tr>
<td>5 - 9</td>
<td>Rather poor performance</td>
</tr>
<tr>
<td>10 - 11</td>
<td>Fair performance (at least 50% of projects satisfactorily completed)</td>
</tr>
<tr>
<td>12 - 14</td>
<td>Good performance</td>
</tr>
</tbody>
</table>

Criterion 1.2: Prior History and Track Record of Company

<table>
<thead>
<tr>
<th>Value Range (1-7)</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 3</td>
<td>Poor industry performance</td>
</tr>
<tr>
<td>4 - 5</td>
<td>Fair industry performance</td>
</tr>
<tr>
<td>6 - 7</td>
<td>Good Industry performance</td>
</tr>
</tbody>
</table>

Criterion 2: Stage of Creative Process

<table>
<thead>
<tr>
<th>Stage</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Process development stage</td>
</tr>
<tr>
<td>2</td>
<td>Scale up stage</td>
</tr>
<tr>
<td>3</td>
<td>Production stage</td>
</tr>
</tbody>
</table>

Criterion 3: Need to Generate Options

<table>
<thead>
<tr>
<th>Value Range (1-7)</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 - 9</td>
<td>Extreme need to generate options</td>
</tr>
</tbody>
</table>
10 - 15  Some need to generate options
16 - 21  No need to generate options
Criterion 4: Internal Need to Reduce Uncertainty
3 - 9  Substantial need
10 - 15  Some need
16 - 21  No need
Criterion 5: External Constraints and Opportunities
5 - 15  High
16 - 25  Some
26 - 35  No

Sample Rule for Information Gathering vs. Deciding

IF
  individual track record is POOR,
  and industry track record is POOR,
  and stage is PROCESS DEVELOPMENT STAGE,
  and need to generate options is EXTREME,
  and internal need to reduce uncertainty is SUBSTANTIAL,
  and external constraints and opportunities are NO,
THEN Gather More Information.

Sample Explanation for Rule3 Gather more information. The need to gather more information and the internal need to reduce uncertainty seem to suggest that the individual should revert to the data gathering stage. This is further emphasized by the fact that there are no external constraints restricting the individual. It is true that the individual track is poor but then the entire industry performance in related areas has been poor.

8 Implementation

8.1 Organization

The expert system follows naturally from the integrated decision model, each quadrant evolving into a segment of the system. Decision rules have been developed to cover the choices that need to be made in each dichotomous area. For example, whether the working environment should be in initiating or implementation mode [13]. The criteria associated with each segment of the model must be translated into questions asked to the user. The combination of the decision rules, along with the facts about this particular situation evolved from user interaction, enable the system to suggest to the manager which of the choices is best at the present time.

Rule-based knowledge is most useful in a system whose results are in the form of recommendations, directives, or strategies. Rules are very appropriate for representing domain knowledge developed by experts having experience in solving problems in a particular area. The rule-based approach seems to be the best fit for this kind of conceptual model.

Our model incorporates expertise obtained from a panel of independent experts and from the current literature. The panel consists of managers of creative individuals, and inventors - the creative individuals themselves. That expertise will be transferred to the expert system.

8.2 Tools

A prototype was developed in Arity / Prolog available for the IBM PC or an IBM compatible. A knowledge of Prolog is definitely not required to run the system, nor even a knowledge of more than rudimentary skills with a desktop computer.

The system has been implemented in Prolog rather than using an expert system shell since use of Prolog gives us maximum design and implementation flexibility in several areas:
- Prolog makes it easy to combine rules with numerical computation.
- the user interface can be expanded to suit our own evolving needs.
- Prolog can be interfaced to other languages easily in an IBM-PC environment; this is particularly useful in developing the user interface since we can take advantage of the graphics and windowing capabilities of languages such as C.

7.4 Archiving Facility

This module will function during the consultation session. It records information about the user interaction with the system. The module serves several purposes:
1. collecting data about actual decisions made by managers.
2. tracing actual decision processes in the management of creative research and development.
3. applying statistical tools and performing analyses to gather information about the system for future improvement.

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Prolog has a built-in inference engine that attempts to find proof of the truth of specified relationships by a common artificial intelligent technique called "Backward Chaining."

9 Testing and Validing the System

Several considerations concerning users need to be addressed when developing new systems. One of the most important has to do with identifying the characteristics of typical users and then designing the system specifically for them [15].

The users of our system will mainly be R&D managers. Typically, managers tend to have little understanding, appreciation, or even interest in directly using many computer systems. Most managers will use the system only occasionally and will not spend time on a system without realizing some relatively straightforward direct benefits. Because managers are in a position to reject a system, designers should develop systems for management that are highly usable from the beginning [1].

The purpose of testing and validation is to apply the principles of Human-Computer Interaction (HCI) to the expert system for creativity management. There are two key elements in the study of HCI, the computer and the user [8]. Our user interface has been designed so that the system is easy and pleasant to use, helpful when difficulties arise, and efficient as a viable tool in solving user problems [14]. Results of test runs will be used for future system improvement.

We have already communicated with managers who have agreed to test the model and its implementation in the Expert System for Creativity Management. Objectives and test methods will be defined.

10 Summary

Developing an expert system for creativity management forces us to express our model in explicit rules, to work out all the details of the model, to explore all alternatives, and to provide for all combinations of circumstances. The expert system also makes it possible to test the decision model in real situations, to discover whether its advice can help to solve actual management problems. Managers of research and development projects - the creative researchers themselves - will test this system for usability in making day to day decisions about the conduct of creative projects. This will give us an actual functional test of the system. Future users of the system have been of great help in the building process so far, identifying situations the system had left uncovered and making helpful comments on the interface. The next step is to carry out detailed and careful testing of the system and of the model that it embodies. In this process the users of the system will pose new questions and stretch the model in new directions. The archive facility makes it possible to record user answers to questions from the system describing the problems to be solved, the recommendations made by the system, and what actual decisions were made. This facility allows the collection of data about actual decision made by managers. Then this data can be discussed and actual decision processes in the management of creative research and development can be analyzed in a scientific and systematic way.

References


