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Dolphy Abraham
Loyola Marymount University

Rahul De
Bowie State University

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Dolphy M. Abraham* and Rahul De'**
*College of Business Administration, Loyola Marymount University, e-mail: dabraham@lmumail.lmu.edu
**Department of Business and Economics, Bowie State University, e-mail: rahul.de@bowiestate.edu

Introduction

Initial Representations (Simon, 1973) have been identified as a means by which decision makers start the problem structuring process during decision making. The process of initial representation formation serves the role of identifying or creating a concept based on information available about a problem. It is intended to determine when a new concept has been identified at the start of the problem solving process. This process sets the stage for the decision making to occur and in some respects guides the decision scenarios that emerge. Automated support of initial representation formation enables robust and varied Model Management in the decision support context. In prior work, a process model of initial representation formation was developed to be used during the problem-structuring phase (Abraham, 1993, 1997, 1998).

In this paper, we posit that the process model of initial representation formation can also be used in a learning context, specifically, to determine when new decision making situations exist and how those new situations relate to prior instances when similar decisions were made. This type of learning is important in the context of knowledge management because it allows the use of information about decisions that were made in the past while working on a current decision. The literature describes how data in information systems can be used to support organizational learning (Stein and Zwass, 1995). This paper describes a model that be used to learn from the decision making process.

We begin by describing the problem domain of electronic consumer product design that will be used to explore this proposition and the learning issues involved. This is followed by a description of how the process model of initial representation formation can be adapted to the task of learning from instances of decision making.

Product Design Problem

We use the problem of designing electronic consumer products, such as cellular phones. Different components have to be put together to meet consumer preferences. In addition to parts like the housing of the phone or the display that will be used, there are modules or sub-assemblies that have already been designed for other products that may be appropriate for this product. The design of the product is determined by trying to configure the different components to meet certain product features. These product features are determined by marketing needs that are very dynamic. Because of intense competition in the electronics industry, the "shelf" life for a product (during which time the product is profitable) is very short and the penalty for an inappropriate configuration is very steep.

Other factors that impact the design of the product originate from all parts of the corporation. Given the dynamic nature of the market, timing the introduction of products is critical. Therefore, there may be situations where an optimal design can be completed for a product but the product may have to be abandoned because another company is able to release a competing product earlier. Therefore, the product design problem is a complex process including not only technical, but also financial, manufacturing and marketing issues. These factors make the problem poorly structured at the outset of the decision making process and appropriate for the use of the Initial Representation Formation model.

The Process Model of Initial Representation Formation

The process model is a high level description of the Initial Representation (IR) formation process. The model has been abstracted to describe the general processes that take place during initial representation formation and does not contain domain specific functions. This allows us to maintain domain independence to a large extent facilitating the study of this decision making phase in ill-structured problems from other domains. The model consists of an IR structure and an IR processor.

a. Initial Representation Structure

The structure is based on Groen and Patel's (1988) description of a well-structured problem. During IR formation, information necessary to fit the slots is either retrieved from long-term memory or requested from external sources (the user or other systems). There are four slots in the IR structure:

1. The Problem Definition containing information about the current state and the desired state of the world. The states are described in terms of the problem context and not in technical terms. This can be viewed as an external view of the problem.
2. The Goal State identifying a goal state retrieved from memory during the IR formation process. This slot

contains a technical representation of the goal state and can be viewed as an internal view of the problem.

3. The Solution Method(s) contains the information about methods or tools that the problem solver knows (i.e., retrieves from memory) will help him/her get to the goal state.
4. The Constraint(s) are information and assumptions collected from both internal and external sources which restrict the problem solving process.

The IR structure is intended to work as a problem representation during the solution process even after the initial representation process has ended. Therefore, it is not necessary for all the slots to be filled up before the initial representation process is completed. Information may be entered in the slots even after the initial representation process is complete. The DONE? predicate is used determine the completion of the IR process.

b. The Initial Representation Processor

The Initial Representation Processor (IRP) is a collection of functions that accomplishes the tasks observed in the subject's behavior. An overview of the process model is illustrated in Figure 1. In brief, the IRP takes information from an external source (the LISTEN function) and puts each piece in the appropriate slot of the IR structure. When needed, it requests information from an external source (the ASK function). The DONE? predicate takes the IR structure and checks to see if there is sufficient information to proceed with problem solving. If the information is not sufficient, then the IRP generates a request (sent to the ASK function) for additional information to structure the problem.

The IRP consists of three groups of functions and the DONE? Predicate which are discussed below.

1. **Process Information Received**: The goal of this group of functions is to determine how the

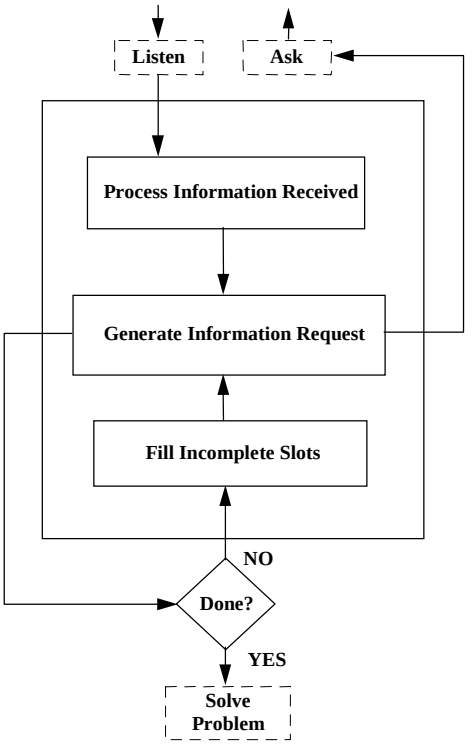

Figure 1: The Initial Representation Processor

information can be used. The functions in this group are CLASSIFY DATA, CHECK FOR RELEVANCY, CHECK FOR REDUNDANCY and CHECK FOR CONSISTENCY.

2. **Generate Information Request**: The four functions in this group are CHECK FOR COMPLETENESS, DETERMINE INFORMATION REQUIRED, RETRIEVE FROM MEMORY, and, PROMPT ASK PROCESS. When there is no more information in the stack that needs to be clarified and when all the relevant pieces of information as well as heuristics have been retrieved from long term memory, the DONE? predicate tests the IR structure to check if the IR process is complete.
3. **Fill Incomplete Slots**: The third group of functions deals with situations when IR structure does not meet the conditions of the DONE? predicate. The conditions of the DONE? predicate are described below. The functions needed are IDENTIFY INCOMPLETE SLOT, TRIGGER GENERATE INFORMATION REQUEST, and MAKE AN ASSUMPTION.
4. **DONE? Predicate**: The DONE? predicate is intended to signal when the process of initial representation formation is complete, so that the IRP can stop working and the problem solution process can take over entirely. During actual problem solution process, some part of the problem solving may take place prior to the problem becoming well-structured. However, in trying to model the process to work on computers, it is necessary to know when

to stop the process of problem structuring i.e., initial representation formation, and when to go on and solve the problem.

Using Initial Representation Formation as a Learning Mechanism

The Initial Representation Structure can be used to represent product design decisions. This enables decisions about different types of products to be compared during the problem structuring process. In addition to the technical information about the product, the initial representation structure will also store information about the context in which the structure was created.

The process model of initial representation formation can be used to characterize features needed in the final product and map them to components or modules that are available. In addition, it can be used to determine when components or modules are not available. Further, information about the components, such as, cost of manufacturing, time to manufacturing and any prior experience in using those components can be made available to the Initial Representation Processor. Thus, the system will have past experience to work from and will provide insights that may not be possible without the model.

As a decision maker uses the initial representation formation model, each decision making instance can be stored, creating an organizational memory of each stage during the design process. This information can be analyzed at a later time to determine patterns in the decision making process and not only the final outcomes of each decision.

To use the stored representations of prior problems, the Initial Representation Formation process can be used onceagain. The process described in the previous section, specifically the steps involved in RETRIEVING FROM MEMORY and the CHECK FOR RELEVANCY can be adapted to the task of identifying past experiences that match criteria that the decision maker can specify. To be used in a learning mode, the Initial Representation structure will need to be adapted to represent the rationale behind the choice of prior problem instances that match user specified criteria. By storing rationales, retrieving information about past decision making situations based not only on a text search but also on the underlying reasons will help reuse historical information more effectively.

Current and Future Work

The problem described above is being carried with the research unit at a large electronics manufacturer. The project entails implementing the process model of initial representation formation to support the product design process. The implementation will use intelligent software agents as the primary design framework (Abraham and De', 1996). As the DSS to assist in the product design process is used, a memory of instances of decisions is accumulated. This collection of prior instances will be used as input to the learning mechanism.

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