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EXPERIENCE AND PROBLEM SOLVING: A FRAMEWORK

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ABSTRACT

Most research into problem solving has considered each problem to be solved as a unique event. Our observations lead us to conclude that much of the problem solving people do is based on previous experience. Analogy to previous similar problems helps in solving new problems, and each problem solving experience contributes to the knowledge available for later problem solving. This paper presents a framework for those components of problem solving which rely on previous experience. The processes involved and the organization of experience which supports those processes are considered. Examples are drawn from two problem domains: diagnosis and treatment of mood disorders and plan selection for resolution of disputes.

1. EXPERIENCE'S ROLES IN PROBLEM SOLVING

Problem-solving is a widely-studied area in both psychology and artificial intelligence (e.g., [1],[5],[7]). Yet, with rare exceptions [6], there is little study of experience's role in the process. Our observations have led us to believe that experience plays two important roles in problem solving [3]: First, **experience contributes to refinement and modification of reasoning processes.** Successful experiences reinforce already-known rules or previous hypotheses, while failures require analysis of the reasoning and knowledge used originally, and modification of faulty rules and knowledge. Experience's second role is equally important. **Individual experiences act as exemplars upon which to base later decisions.** Analogy to previous cases serves to guide and focus later decision making. An example from medicine illustrates our claims:

Dr. X sees a patient who shows classic signs of Major Depression. She has previously been diagnosed as Depressive, and was treated in a mental hospital with antidepressants. She was sickly as a child, has had a drinking problem, and has had some unexplained physical illnesses. Dr. X concludes that she is suffering from Major Depression, Recurrent, without Melancholia and treats her with antidepressants. They seem to work, but the woman comes back complaining of additional major physical disorders. Taking a further history, the doctor finds that her unexplained medical problems have been numerous. Realizing that this is an important consideration, he makes a second diagnosis of Somatization Disorder (adapted from [11], case #125).

As a result of this case, Dr. X should learn that it is important to consider medical history in choosing predominant clinical features, and that Depression can camouflage Somatization Disorder. Using the first fact, he can

refine his rules for choosing predominant clinical features. The relationship between Depression and Somatization Disorder will be helpful in diagnosing and treating later cases. To illustrate experience's role in providing exemplars, consider Dr. X's capabilities upon seeing a second patient diagnosed for Major Depression who also has unexplained medical problems. We expect him to transfer his knowledge from the previous case to the new one and consider whether the new patient might also have Somatization Disorder.

In building a framework for problem solving which includes experience, we must consider a number of issues:

1. Which reasoning processes use experience?
2. What knowledge is available as a result of experience?
3. How is experiential knowledge integrated into reasoning processes?
4. How does experience change the structure of knowledge in memory?

We are studying these problems in two domains: the common-sense resolution of disputes [10], and the diagnosis and treatment of mood disorders [3].

2. EXPERIENCE CONTRIBUTES TO LEARNING

We begin by considering the reasoning processes which rely on experience. We identify two experiential processes whose primary purpose is refinement and modification of reasoning processes and domain-specific knowledge: **similarity-triggered generalization** and **failure-triggered explanation.**

Similarity-triggered generalization [2] occurs when two cases already classified in the same way share additional features not accounted for by the classification. In that case, a new concept described by the shared features is created. It is a generalization of the cases and a specialization of the original classification. Thus, if most of the cases a doctor has seen in which the patient is diagnosed for Major Depression and has heart problems respond to the same treatment, then a generalization can be made that this medication is good for treating Major Depressives with heart problems. Generalization of this sort can be thought of as confirming hypotheses that might have been made on the basis of one example.

When a hypothesis is violated, or a piece of knowledge (e.g., rule) fails to work as expected, failure-triggered explanation occurs [3], [9]. An explanation for the failure is found, and the failed piece of knowledge is modified. This is illustrated in the psychiatric example above. In general, tracking down a failure and explaining it are hard problems. As we shall see later however, experience can play a role in this process if a failure is reminiscent of a previous one. A third type of learning is the integration of a new case into memory's already existing structures. This is discussed in section 4.

3. EXPERIENCE CONTRIBUTES EXEMPLARS FOR ANALOGY

A second set of experiential processes transfer knowledge from a previous case to a current one. We call the process by which this happens similarity-triggered analogical reasoning. When a new case is reminiscent of previous cases, those cases are used as exemplars to aid in evaluation of the new case. A prerequisite for analogical reasoning is the capability of remembering appropriate previous episodes. This will be discussed in section 4. For now, it will suffice to say that a previous episode can be recalled if it is classified similarly to the current one and has similar features not predicted by

that classification. An attempt to recall previous similar cases occurs each time new features of the current case are discovered. In general, particular past experiences called to mind by a current problem can be useful in any of the following problem solving tasks:

1. They can aid in problem classification by predicting additional features to be investigated or by pointing out alternative classifications.
2. They can help in planning by suggesting procedures or courses of action to be followed or avoided, or by suggesting a means of implementing a plan.
3. They can suggest an explanation and a means of recovery from failure.

We saw experience functioning as an aid in classification earlier when Dr. X diagnosed his second case of Major Depression combined with unexplained physical problems. While the first time he had to wait for the treatment to fail to make the secondary diagnosis of Somatization Disorder, he has an exemplar to base his diagnosis on the second time he sees such a patient.

Experience is useful in plan selection in several important ways. First a previous case can suggest a plan for problem resolution or one to be avoided (e.g., a previous treatment that worked or didn't work in a similar case). Analogical reasoning is also useful during plan selection in evaluating potential plans and in choosing between alternatives. The process involves simulating the results of alternative treatments or courses of action and evaluating them in light of previous experience. Simulation of alternatives provides hypothetical situations similar to previous ones. The success or failure of previous attempts at implementing the same plan under similar conditions provides a metric for evaluation of a potential course of action. We see this use of analogy quite often in prescribing treatment. This process is related to Schank's intentional reminding [9] and Wilensky's [12] Projector. Experience can also be helpful in choosing the means for implementing a selected plan (similar to Mostow's [4] operationalization). Any particular plan that is selected for resolution of a problem might be applied in several ways. Application of the common-sense plan "one cuts, the other chooses", for example requires differentiating between the party which will do the cutting and which will do the choosing.

Experience, as part of follow-up, aids with explanation of and recovery from failures [10]. Upon failure recognition, the reasoner attempts to recall a similar previous error. Features available for such recall include the original ones plus those associated with the failure. A previous similar failure may provide an explanation which can be applied in diagnosing the error in the current case. It may also suggest a plan for error recovery.

The following scenerio shows multiple uses of analogy in solving a complex problem. Consider a common-sense reasoner reading in the paper about the dispute between Egypt and Israel over possession of the Sinai. She knows something about the Korean War and the recent dispute between the US and Panama that resulted in the US giving back economic and political but not military control of the canal to Panama. Initial consideration of the Sinai dispute causes reminding of the Korean War since both involve disputes over land, both are competitive, and in neither can the conflict be resolved completely for both sides. Based on this reminding, she predicts that Israel and Egypt will divide the Sinai equally. She later reads that this advice was given and rejected by

both sides. Considering that "divide equally" failed, she is reminded of the time her daughters were quarrelling over an orange. She had suggested that they divide it equally, and they had rejected that, since one wanted to use the entire peel for a cake. Realizing that she hadn't taken their real goals into account, she then suggested that they divide it agreeably — one take the peel, the other the fruit. This reminding provides the suggestion that failures sometimes occur because the goals of the disputants are misunderstood. She therefore attempts an alternate understanding of Israel and Egypt's goals. Considering that Israel wants the Sinai as a military buffer zone in support of national security, and that Egypt wants the land for national integrity, she can now reconsider the conflict as a political dispute with concordant goals. Further reasoning from the orange dispute suggests that "agreeable division" based on the real goals of the disputants is appropriate. This causes reminding of the Panama dispute since it is political with similar goals and named plan. The analogy made possible through this reminding allows operationalization of the "agreeable division" plan. Using the settlement between Panama and the US as a guide, the US is replaced by Israel (the party currently in control of the object) and Panama is replaced by Egypt (the party who used to own it and wants it back). As was the case in the Panama Canal agreement, the prediction is made that Egypt will get economic and political control of the Sinai, while its normal right of military control will be denied.

4. ENCODING AND ORGANIZING EXPERIENCE

A prerequisite for learning from and using experience is the capability of retrieving relevant past experiences applicable to a new situation. The memory structure we propose is based on generalized episodes [2], [8]. These structures hold generalized knowledge compiled from the experiences they organize, and individual experiences are indexed in these structures according to their differences. When two experiences differ from the generalized episode in the same way, a collision, which we call "reminding" [2], [8] occurs. Predictions based on the first episode can be used to analyze the new one (analogy). Similarities between the two episodes can be compiled to form a new memory schema with the structure just described (generalization).

The organization provides a way of locating exemplars to use in evaluating a new case. The process which allows analogical "reminding" is a traversal procedure. When a new case is encountered, appropriate generalized episodes are chosen for it. Features which differentiate a new case from others in the same generalized episode are extracted from it and indices associated with those features are traversed. In the process, the new case collides with previous cases already indexed in memory. It is those cases which are now available for further evaluation. New cases are added to memory by the same process.

Cases are indexed in memory by their differentiating features and also by failures which occur in the course of processing. This allows learning and reminding on the basis of failure. If blame can be assigned for a failure, the case is indexed by those features which caused the failure. When a second similar situation is encountered, the marker serves as an index to a failed episode. If a solution was found to the first failure situation, it can be applied to the second so that the failure won't happen again. When blame has not been assigned, a marker denoting the difference between the failed episode and others is left, again serving as an index when a similar situation is encountered. In this case, a procedure to be avoided will be found.

In the psychiatric domain, for example, diagnostic categories (e.g., Major Depression) act as generalized episodes. The medical example above is differentiated from other cases of Major Depression by (among other things) (1) the fact that there were unexplained physical disorders in addition to those symptoms considered in the original diagnosis and (2) treatment failed in that the patient seemed cured of depression but complained of additional physical disorders.

5. WHERE DO WE GO FROM HERE?

In this paper, we have attempted to provide a framework for experience's role in problem solving. We have named processes which use experience and suggested a memory organization in support of those processes. We have not, however, stated exactly how each of the experiential processes work. We are currently investigating these processes in the two domains cited. Our memory structures, too, need considerably more work. In particular, we must specify the types of features appropriate for indexing and the allowable types of classification structures. Finally, we might be criticized for not taking into account how experiential reasoning interacts with causal reasoning. Each of the problems presented represents an important research area. It is only through investigation of each that we can discover how experiential and more traditionally considered forms of reasoning combine.

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