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# Teaching Classification Problem Solving

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A logic-based analysis of heuristic programs suggests a problem solving model that is strongly supported by cognitive science studies of categorization and understanding. This extended abstract describes the model, then outlines epistemologic considerations for constructing instructional programs that can both generate and recognize such problem solving behavior.

A broad range of familiar problems--embracing forms of diagnosis, catalog selection, and skeletal planning--can be characterized in terms of classification [3]. Solutions to these problems have a characteristic inference structure, involving systematic relation of data to a previously known set of solutions by processes of data abstraction, heuristic association to a schema network, and refinement. Previous research has described classification problem solving almost exclusively in terms of identification of an unknown object or phenomenon, what we commonly call "diagnosis." However, a study of the heuristic programs called "expert systems" indicates that reasoning involved in selecting a product or service is characterized by the same inference structure. Moreover, a common kind of problem involves sequential classification problems: first stereotypically characterizing a user's needs or requirements and then heuristically selecting a product or service [11]. Routine software configuration and experiment planning problems are similar: a template solution is found and then refined [6]. Studies of routine physics problem solving [2] show the same process of problem feature abstraction, heuristic association, and refinement.

A computer program called NEOMYCIN implements a form of classification problem solving in a general way [4]. The epistemologic distinctions made in the implementation make it possible to use NEOMYCIN for both generating and recognizing classification problem solving behavior. These distinctions were previously put forth by logic theorists [8, 9]. In our view they are:

- The knowledge to solve a problem is distinct from its implementation in some information processor [10]. Specifically, in AI research representation/interpreter descriptions of computational models have been frequently confused with more abstract descriptions of what the problem solver is doing and what he knows.

- These abstract descriptions of reasoning should make a distinction between inference structure (logic terms and relations) and process structure (rules of inference and strategic operators). Rule-based programs like MYCIN and R1 combine factual knowledge with procedural information about how inferences are to be made.

- There is a distinction between statement of a relation or procedure and its justification or basis. For example, heuristics are justified by some, generally unstated, model of the world. Making explicit the process structure requires not only stating the procedure in computational terms (such as input, sequence, iteration), but also in terms of underlying assumptions and constraints that justify the procedure, from which it can be derived.

We briefly relate these considerations to NEOMYCIN. The classification problem solving model describes what NEOMYCIN does, independent of its representational scheme (rules, frames, etc.). The program's facts and heuristic are stated separately from the inference procedure. The inference procedure is represented in a special language that allows us to "declaratively" express computational constructs, as well as to annotate some of the underlying constraints that are useful for student modeling. This combined design enables us to use NEOMYCIN to directly solve problems independently, or to "run the program backwards" to predict and recognize behavior that fits its model. The program can also provide a trace of its reasoning, serving as a crude form of explanation [7].

With a general model of problem solving implemented that uses a body of "expert" knowledge, we are now investigating student behavior. Specifically, we can use the program to provide partial interpretations of what students are doing, with differences indicating where the model must be extended (and what kinds of assistance students require). Following from some proposals made by J. S. Brown [1], we are designing a sequence of instructional programs by which we can explore students' reasoning as they explore NEOMYCIN. The first of the series includes GUIDON-WATCH (for learning that classification problem solving has a certain structure), GUIDON-MANAGE (for learning the effects of problem solving operators [5]), and GUIDON-ANNOTATE (for integrating operators with domain knowledge and recognizing patterns of efficient problem solving).

In conclusion, a synthesis of theories of logic, experience in writing expert system programs, and cognitive science studies has enabled us to develop a computational model of problem solving that can be useful for teaching. The ke idea is that epistemologic distinctions--knowledge/processor, inference/process, and relation/justification--are an intricate part of the computational model, providing the basis for not only generating problem solving behavior, but also explaining and recognizing it.

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