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THE EXPERT AND CASNET CONSULTATION SYSTEMS

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ABSTRACT

EXPERT is a system for designing and applying consultation models. An EXPERT model consists of hypotheses (conclusions), findings (observations), and decision rules for logically relating findings to hypotheses. A relatively simple language for describing models is employed. Logical and probabilistic rules are restricted to particular types which implicitly order the tasks performed by the control strategies: classification, question selection, and explanation. Explicit representations of decision rules are emphasized, as opposed to suboptimal scoring functions. This results in more easily predictable and correctable performance for a model. The system is currently being used to develop consultation models in several domains including: rheumatology, endocrinology, and ophthalmology (including the CASNET/Glaucoma model).

INTRODUCTION

The development of knowledge-based consultation programs that exhibit near-expert performance has progressed rapidly in recent years [1-3]. These efforts have focused on specific medical application areas and have relied on one or more experts to build a knowledge base. The hallmark of these consultation systems has been their reliance on large amounts of structured expert knowledge in the application domain [4]. In each system, the choice of knowledge representation has come first, and been a primary determinant of the type of reasoning procedures used for consultation. In contrast to traditional methods of automated diagnosis, little emphasis has been placed on the optimality of decision-making under general criteria (utility, information entropy, etc). Rather, these systems have attempted to develop representations based on simulation of the experts' conceptual structures and reasoning [5]. The various systems have been reviewed and contrasted in [6] and [7]. Szolovits and Pauker [7] point out that there is frequent and general use of categorical (explicit) decision rules in all the systems, although they all also use various kinds of heuristic scoring methods to capture the uncertainty associated with medical decisions. Unfortunately, these

often have side effects of propagation that make results less clearly predictable. Despite the specific applications for which they were first developed, some of the systems (e.g. CASNET, MYCIN) have been generalized to accept knowledge bases in other domains.

After several years of developing the CASNET representation [8] and improving the CASNET/Glaucoma consultation program to a high level of performance, enough new ideas have emerged from our own experience and that of the other AIM (Artificial Intelligence in Medicine) investigators to lead us to develop a new more general representation of knowledge for use in consultation systems. As in CASNET, a model in this new representation may contain descriptive knowledge of causal (and taxonomic) relations between hypotheses (pathophysiological states, diagnostic, prognostic or therapeutic categories). As in MYCIN, and to some extent CASNET, the representation specifies normative knowledge as production rules, but with specific categorizations and orderings that are exploited in the decision strategies.

The new consultation system, EXPERT, is a general system for developing and testing consultation models; it was designed without being tied to a specific application. EXPERT has been used to develop models in ophthalmology, endocrinology and rheumatology. Some of the major themes in the design of EXPERT include:

1) a relatively simple language and notation to represent expert knowledge. The representation is consistent with the traditional two-level view of a diagnostic problem: selecting appropriate hypotheses or conclusions by interpreting a set of findings or observations.

2) an emphasis on categorical reasoning and a de-emphasis of suboptimal scoring functions. A form of probabilistic production rules is available, which can be compatible, with statistically accurate classification when appropriate data is available.

3) descriptive knowledge as a partially-ordered conceptual network, a special type of a semantic net, which, as in the CASNET system, can be pre-compiled for the interpretation of individual cases, hence leading to efficient performance.

4) an emphasis on decision methods which tend to yield predictable, correctable, and empirically verifiable results. This may in some cases require that the expert provide more explicit statements of correlations among findings and a greater number of decision rules. The representation and control strategy simplify the task of correcting erroneous conclusions. Since the interaction among rules and the associated classification strategies is consistently

predictable, it is not difficult to trace the changes in program behavior that will result from modification of individual rules. A novel feature of EXPERT is that it automatically detects differences arising from a change in decision rules, for the conclusions of cases stored in its data base. This is an important tool for incrementally generating and testing an expert model.

As mentioned above, in some of its data structures, the EXPERT representation has similarities to those of predecessor systems. Its production rule representation is a more uniform version of the CASNET-like rules [8]. It differs from MYCIN [2] and PROSPECTOR [9] in that the hypotheses entering into the condition or action part of the rule are single primitive entities, rather than being composed of multiple primitive clauses. In this sense it is similar to the INTERNIST representation. In EXPERT this feature is crucial for producing the compiled model, with its attendant simplicity and efficiency of processing. The loss of general descriptive power inherent in such a compiled model has not resulted in an excessive proliferation of hypotheses, or decision rules. Several new representational structures (such as intermediate hypotheses or selector rules) are used to capture much of the summarization and descriptive power of primitive clauses. Many of the control strategies in EXPERT have similarities to those of CASNET, particularly in the use of heuristic scores, and the fuzzy-logic combining function for multiple rules. In other ways they are quite distinct: in their use of fixed rule orderings, in the evaluation of the appropriate context for rules, and in the propagation of evidence through two complementary structures - the partially-ordered conceptual net, and the production rule system.

The process of creating and running an EXPERT decision-making model is somewhat similar to writing and running a computer program. An editor is used to create a file which will contain statements describing a model. A model is translated into an efficient internal representation by the compiler program, XP. The model may then be executed, and cases may be entered for consultation, using the program EXPERT.

MODEL DESCRIPTION

An EXPERT consultation model consists of 3 sections:

a) hypotheses,

b) findings,

c) decision rules relating findings to hypotheses.

Findings are the facts about a patient elicited during a consultation. In a medical domain, they are the history, symptoms, signs, and laboratory test results. Findings are reported in the form of true, false, numerical, or unavailable responses to questions from EXPERT. Hypotheses are the conclusions that may be inferred by the system. They include diagnostic and prognostic decision categories, therapy recommendations, and intermediate hypotheses about pathophysiological states, expected causes of illness, or typical aggregates of findings. A measure of uncertainty is usually associated with a hypothesis.

There are three types of rules for describing logical relationships among findings and hypotheses:

1) FF - finding to finding rules,

2) FH - finding to hypothesis rules,

3) HH - hypothesis to hypothesis rules.

Examples will be given to illustrate each of these structures in an EXPERT model.

RESULTS AND DISCUSSION

Several applications of the EXPERT system are in progress. Consultation models are being developed in endocrinology (thyroid diseases), ophthalmology, and rheumatology. A consultation system in rheumatic diseases appears to have strong potential for acceptance by the medical community. There is a shortage of rheumatologists in the United States, and keeping up-to-date on the interpretation of many new immunological tests can be difficult for non-specialist physicians. In collaboration with investigators at the University of Missouri we have tested the EXPERT formalism by developing a prototype consultation system for rheumatic diseases. Initially, the set of problems considered has been confined to fewer than 10 important, yet complex diagnostic categories. The model is being expanded to cover additional problem areas. The system has been presented with 150 cases and has diagnoses 94% correctly. Current efforts are in the direction of expanding the numbers of findings and gathering greater numbers of test cases. We are also developing a model in the area of thyroid diseases, in collaboration with investigators at the Pacific Health Research Institute. We are also in the process of transferring the CASNET/Glaucoma [1] model to the EXPERT representation. Models in other disease areas are currently being designed to test the formalism and methods. Some of the applications will be pursued to develop "expert-level" consultation systems, and as such will serve as indicators of the direction of future research

in developing efficient knowledge engineering systems.

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