EXAMINER: A SYSTEM USING CONTEXTUAL KNOWLEDGE FOR ANALYSIS OF DIAGNOSTIC BEHAVIOR

Charles E. Oleson
Decision Systems Laboratory
University of Pittsburgh
Pittsburgh, Pennsylvania

Abstract

An approach to the use of machine generated contextual knowledge for the analysis of diagnostic behavior in medicine has been developed. The approach is illustrated by reference to EXAMINER, a system whose contextual knowledge is derived through use of the INTERNIST data base and diagnostic system[l]. EXAMINER acquires a user's characterization of a medical case in light of this contextual knowledge and analyzes it to generate commentary regarding notable aspects of the user's characterization.

1. Introduction

1.1 Task Domain

Until 1970 one section of the medical board examinations for internal medicine required a candidate to investigate actual cases and to present his analysis of the cases to a medical examiner. The candidate could ask the examiner for information regarding laboratory findings and other information pertinent to the case. Similarly the examiner would ask questions to get at aspects of the candidates behavior about which he was unclear. In evaluating the candidate, the examiner would be concerned about such questions as "How well does the candidate get the pertinent information?", "How well does he use the information that he does get?", "Is the candidate able to put together an adquate global description of the case?". In his written evaluation the examiner would describe critical incidents in the candidate's analysis of the case, and he would indicate the conclusions with respect to the candidate's competence that he had drawn on the basis of these incidents and the candidate's behavior in general., In the process of carrying out this examination, the examiner used his knowledge of medicine, his knowledge of the principles of good diagnostic behavior, his perception of the case under consideration, and his understanding of the candidate's view of the case.

It might reasonably be expected that a machine-based system intended to provide an evaluation similar to that made by the examiner also requires knowledge of medicine, knowledge of the principles of good diagnostic practice, a perception of the case under consideration, and an understanding of the candidate's view of the case. In this paper we present an approach to the representation and use of these parcels of knowledge by describing a rudimentary system which embodies the approach in order to provide evaluative commentary about a user's diagnostic characterization of a case in internal medicine.

After a brief discussion of the challenging aspects of this task domain, descriptions of the system's external behavior, data structures, and evaluation process are presented. Finally a sample case run is presented to illustrate the system's behavior.

1.2. Characteristics of the Problem

In order for a machine-based representation of the above mentioned parcels of knowledge to be effective as a basis for evaluation, the following concerns seem critical:

1. It must be possible to represent a characterization of the case in such a way that the medical person can express his view of it in adequate detail. This may include general and specific indications of the primary and related problems as well as indications of the findings for which these individual diseases may be expected to account. He should be able to express alternatives to any of the diseases he suggests. And he should be able to indicate his characterization in whatever level of detail he considers appropriate.

2. The principles of diagnosis must be represented in such a way that some process may apply them to these characterizations so as to allow conclusions regarding the value of the characterization with respect to the principles. An example of such a principle is the idea that a simple diagnosis should be preferred to a complicated one provided the two are equivalent in explanatory power.

3. Medical knowledge, both relational and algorithmic, must be available in order to provide a medical context within which the user's characterization of a case can be interpreted.

The manner in which EXAMINER addresses these requirements is the subject of the description which follows.

2. Implementation

2.1. Format

As presently configured, the observable behavior of the EXAMINER system manifests itself in three discrete processes. The first process specifies the manifestations from a case in

internal medicine. The second process elicits from the user his characterization of the disease processes present in the case. The third process presents the analysis in the form of commentary regarding the characterization.

2.1.1. Case Specification

The specification of the medical information from the case to be analyzed may occur in one of two modes. The first provides cases with which the user has had no previous experience. These cases have been defined by medical people who have access to all information regarding the case. A program which elicits and stores this information in machine readable form is used. When the case is selected for use, it is brought into core and the relevant findings of the case are indicated to the user.

The second mode allows the user to specify a case with which he is familiar. The positive and negative findings from the case are entered by the user and used as the basis for analysis.

2.1.2. Character!zation

The characterization phase requires the user to indicate his perception of the important aspects of the case. The process generates a data structure to be used by the next phase.

A number of types of information were found to be of interest in the characterization of a case and primitives were developed to allow the user to express the information he considered critical without burdening him with undue detail. A description of the meanings of these primitives is now given:

The PRIMARY-PROBLEM primitive is used to Indicate the disease or type of disease which is considered to be the likely cause of the important aspects of the case. If alternatives are considered equally likely, they may be specified by the OR primitive here and elsewhere.

If any of the diseases indicated are generic disease, the specific disease or diseases considered most likely may be indicated by the primitive SPECIFICALLY.

The RELATED-POSSIBILITY primitive is used to indicate diseases which are considered by the user to be possibly present and which are linked to diseases already indicated as possible in the case. The related possibilities should include those diseases which are linked to other mentioned diseases either causally, systemically, or by simple co-occurence.

MOTHER-INDEPENDENT-PROBLEM is a primitive used to indicate a disease process which appears to have no connection to the primary problem or other previously mentioned problems.

ACCOUNTING-FOR is the primitive used to specify manifestations which the antecedent disease explains.

Through use of these primitives, the user is expected to indicate his perception of the case. The representation of this characterization then serves as the basis for the analysis that is undertaken.

2.1.3. Commentary

The commentary is made in the form of scripts relating to the observations attendant upon the user's characterization. Indications of the manifestations and diseases pertinent to the comment are put out as appropriate inserts in the context of the scripts.

2.2 Repre sentation

The four types of data requiring special representation in the system are now described.

THE MEDICAL CASE: A pre-stored case is represented as a list of positive and negative findings. These are printed for the user and kept in core for use by the analysis programs.

Similarly with user defined cases, the truth values for the known manifestations are specified by the user and stored as lists for use by the programs.

STATIC MEDICAL KNOWLEDGE: A large data base of medical knowledge is accessable for use by the system. This is the INTERNIST data base. It contains bidirectional pointers between the diseases and manifestations in the domain of Internal medicine as described in [1]•

CHARACTERIZATION OF A CASE: The representation of a characterization of a case uses the structure developed by Pople [2] to specify the general disease processes of a case, their competitors, and the manifestations for which each might account. In addition internal, structures represent whether individual processes are medically related to one another or independent. The individual processes are represented as co-routines and the co-routines are associated according to certain relations, (e.g. TYPE-OF, COMPLEMENT-OF, LINK-OF, ALTERNATIVE-OF etc.). The characterization structure is used to accomodate the user's characterization as well as the alternatives to it generated by the system. An example of the generation and use of these characterizations is given in section *2..4.*

MAXIM-PREDICATES: The principles of internal medicine (called maxims by the system) are represented as LISP functions which take the various data structures as arguments and return values with respect to the case and the knowledge embodied by the maxim. The maxims include principles confined solely to fixed medical knowledge (e.g. the user should associate manifestations with diseases which are medically related), principles confined to the case and the user's characterization of it (e.g. the

important manifestations should be accounted for by the user's characterization of the case), and principles which depend upon comparison between the user's characterization and alternative characterizations of the case (e.g. if there is a characterization which is simpler than the user's characterization, it should be considered a better explanation of the case). The maxims are identified through recognition of the principles inherent in the INTERNIST system and by analyzing critiques of it and other examples of diagnostic behavior which are provided by Myers [1] and other expert practitioners in internal medicine.

2.3 Process

Given the maxim-predicates, the evaluation algorithm is simple: apply the maxim-predicates to the user's characterization of the case. Each of the maxim-predicates involves a separate algorithm. But certain general types of behavior are identifiable as used by many of the maxim-predicates. These types of behavior may be considered under the generic heading: "processes which make use of the medical data base."

The first of these types of process makes direct use of the data base. This is often done to check the validity of assertions. For instance, it may be asserted that hepatic congestion is a type of liver disease or that proteinuria occurs in pneumonia. These tasks require only simple processing, but they are often required in the specification of more complex processes.

Another type *of* process makes inference based upon a user's characterization of a case by invoking simplifying assumptions about the user's characterization. This approach is often used when the system is taking a "best fit" or "benefit of the doubt" approach to the user's characterization. For instance, if the user has made no indication of the correlation between the manifestations of the case and the diseases which he has specified, the system may infer associations based on best potential coverage and then evaluate the characterization on those terms for some of its predicate-maxims.

The third common type of process generates alternative characterizations of the case on the basis of some specified criteria. The specified criteria are intended to induce characteristics which are in some sense optimal. These alternative characterizations are then used as a basis for comparison. They are generated by the INTERNIST diagnostic process using the medical data base.

2.4 An Example of System Performance

2.4.1 Case Run

```
J EXAMINER)
TEST CASE? NEJMV290P10T1

AGE 26 TO 55
SEX MALE
DYSPNEA EXERTIONAL
HEART OUTPUT DECREASED
HEART CATHETERIZATION LEFT VENTRICLE END DIASTOLIC
   PRESSURE INCREASED
HEART FAILURE CONGESTIVE HX
PRESSURE ARTERIAL SYSTOLIC LESS THAN 90
THROMBOPHLEBITIS
LIVER ENLARGED MODERATE
EKG PREMATURE ATRIAL CONTRACTION (S)
EKG PREMATURE VENTRICULAR CONTRACTION (S)
EKG HEART BLOCK FIRST DEGREE
EKG LEFT BUNDLE BRANCH BLOCK
EKG LOW VOLTAGE
EKG ATRIAL FIBRILLATION
COUGH
TACHYCARDIA
PRESSURE VENOUS CENTRAL GTR THAN 10
PRESSURE VENOUS INCREASED INSPECTION
RHONCHI DIFFUSE
HEART SOUND (S) SUMMATION GALLOP LEFT VENTRICULAR
HEART PERCUSSION LEFT BORDER LATERAL DISPLACEMENT
HEART IMPULSE APICAL FORCEFUL
ABDOMEN TENDERNESS RIGHT UPPER QUADRANT
HEART XRAY LEFT VENTRICLE ENLARGEMENT
HEART XRAY RIGHT VENTRICLE ENLARGEMENT
WBC 14000 TO 30000
PLATELET' (s) 50000 TO 200000
CHEST XRAY LUNG (S) CONGESTED
CHEST XRAY PLEURAL EFFUSION (s)
URINE OUTPUT LESS THAN 400 CC PER DAY
UREA NITROGEN BLOOD 30 TO 60
BILIRUBIN CONJUGATED BLOOD INCREASED
SG0T GTR THAN 400
LDH BLOOD INCREASED
CPK BLOOD INCREASED
ABDOMEN FLANK (S) BULGING BILATERAL
ABDOMEN FLANK (S) HEAVY BILATERAL
ABDOMEN DULLNESS SHIFTING
PROTHROMBIN TIME INCREASED
CALCIUM BLOOD DECREASED
PHOSPHATE BLOOD INCREASED
ELECTROPHORESIS SERUM ALBUMIN DECREASED
ALKALINE PHOSPHATASE INCREASED UP TO 2 TIMES
   NORMAL
URINE SEDIMENT RBC

(CHARACTERIZATION)

 PRIMARY-PROBLEM
"CARDIOVASCULAR DISEASE

 RELATED-POSSIBILITY
"HEPATIC CONGESTION

 ACC0UNTING-F0R
"ABDOMEN TENDERNESS RIGHT UPPER QUADRANT
"LIVER ENLARGED MODERATE
"ALKALINE PHOSPHATASE INCREASED UP TO 2 TIMES
   NORMAL
"SG0T GTR THAN 400
"ELECTROPHORESIS SERUM ALBUMIN DECREASED
*PLATELET (S) 50000 TO 20000
"CHEST XRAY PLEURAL EFFUSION (S)
"GO
DONE
```

(COMMENTARY)

1: WHILE HEPATIC CONGESTION DOES EXPLAIN:
ABDOMEN TENDERNESS RIGHT UPPER QUADRANT
LIVER ENLARGED MODERATE
ALKALINE PHOSPHATASE INCREASED UP TO 2 TIMES NORMAL
SGOT GTR THAN 4OO
ELECTROPHORESIS SERUM ALBUMIN DECREASED
IT IS NOT KNOWN TO ACCOUNT FOR:
PLATELET (S) 50000 TO 200000
CHEST XRAY PLEURAL EFFUSION (S)

2: IT WOULD SEEM THAT CARDIOVASCULAR DISEASE COULD BE INDICATED MORE SPECIFICALLY SINCE THE FOLLOWING ARE QUITE SPECIFIC FOR HEART FAILURE:
HEART CATHETERIZATION LEFT VENTRICLE END DIASTOLIC PRESSURE INCREASED
HEART SOUND (S) SUMMATION GALLOP LEFT VENTRICULAR
PRESSURE VENOUS CENTRAL GTR THAN 10

3: AN ALTERNATIVE CHARACTERIZATION OF THE CASE INVOLVING A KIDNEY DISEASE COMPONENT MIGHT SEEM PREFERABLE SINCE THE FOLLOWING ARE NOT ACCOUNTED FOR BY THE ORIGINAL CHARACTERIZATION:
UREA NITROGEN BLOOD 30 TO 60
PHOSPHATE BLOOD INCREASED
URINE SEDIMENT RBC

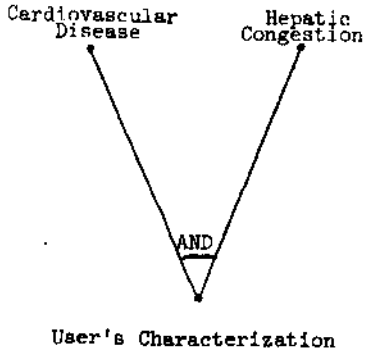
2.4.2. Discussion

The maxim-predicate which generated the first comment above simply checked the relationship between hepatic congestion and the indicated manifestations against the corresponding relationship in the medical data base. The results of that comparison were then output in the context of the script format.

The maxim-predicate giving rise to the second comment is somewhat more complicated. It involves determining which manifestations from the case can be assigned to the cardiovascular problem. Within this subset, the predicate evaluates the manifestations for specificity and finds that a number of the manifestations are quite specific for heart failure. Since heart failure is also rather strongly supported by the other findings, the comment is made.

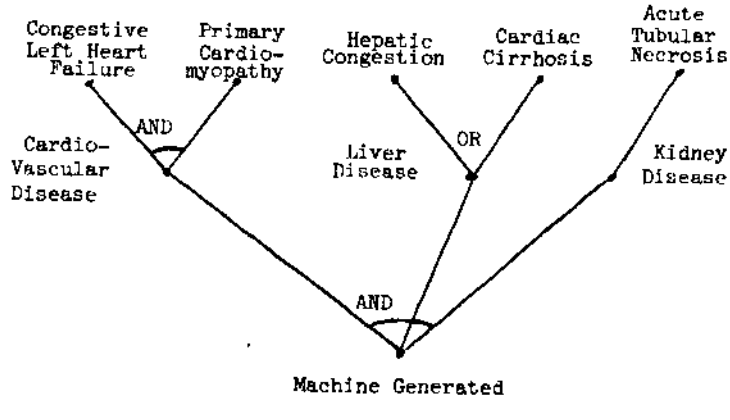
The maxim-predicate associated with the third comment requires that determination be made of the set of manifestations which could not be explained by the user's characterization. This set was then evaluated to determine whether some disease process seemed indicated. Since many of the unexplained manifestations indicated renal dysfunction, a complementary renal component was suggested as an additional active component of the characterization.

Figures 1 and 2 indicate the user's characterization and the alternative machine generated characterization of the case respectively. When the user indicated cardiovascular disease, the eharacterizer set up a cardiovascular coroutine to represent the problem. The



User's Characterization

Figure 1



Machine Generated

Alternative Characterization

Figure 2

"RELATED-POSSIBILITIES" command caused a second complementary co-routine to be generated and a LINK-OF relation to be asserted. The "ACCOUNTING-FOR"command caused the ensuing manifestation list to be associated with hepatic congestion.

The system's characterization was developed in somewhat greater detail. It set up a cardio-vascular co-routine as well, but the characterizer then further specified the problem by setting up conjunctive co-routines to represent heart failure and myocardial disease. It also specified the .liver problem, but here it indicated a dis-junctive choice between hepatic congestion and cardiac cirrhosis. Lastly the system recognized the need for the renal component and set it up as an additional co-routine.

3. Summary

We have presented an approach to the problem of analyzing a person's diagnostic behavior. The approach entails the development of specialized structures for the purpose of representing a person's view of a complex environment. The approach requires the use of sophisticated tools of representation and process taken from the INTERNIST system to provide accurate medical knowledge. The approach also requires that the methodological principles which distinguish good diagnostic behavior from bad be represented in such a way that they can be used to evaluate a user's behavior in light of the medical knowledge. Although much remains to be learned regarding implementation of this approach - especially with respect to the representation of the principles of diagnosis; we hope our description and examples have demonstrated that the approach may be capable of producing interesting behaviors.

The work described here only sets the stage for a system capable of interactive investigations of the type described in the opening paragraph. Many issues involved in the implementation of such a system have not been addressed. Critical among these is the issue of how to direct an interactive investigation. Methods which generate expectations on the basis of the user's initial behavior and then interact with the goal of confirming or disconfirming the expectations seem potentially fruitful here. But time will toll. These issues are the subject of the ongoing work with respect to the system.

References

1. Pople, II.E., Myers, J.D., & Miller, R.A., "The DIALOG Model of Diagnostic Logic and its use in Internal Medicine", Proc. 4, IJCAI, Tbilisi, USSR, September 1975-

2. Pople, H.E., "The Formation of Composite Hypotheses in Diagnostic Problem Solving - An Exercise in Synthetic Reasoning", Proc. 5, IJCAI, Cambridge, MASS, August 1977.