TASK DRIVEN SPECIFICATION OF A KNOWLEDGE ACQUISITION TOOL FOR MEDICAL DIAGNOSIS (KAT-MED)

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1. INTRODUCTION

Knowledge acquisition methodology is moving away, from reliance on the knowledge engineer, as a skilled interviewer, to the development of task and model driven tools, such as Mole [3], [5], Opal [6], More [5] and Knack [3]. Such tools, based on strong domain models, are very useful in well structured areas such as medicine [6]. Our project investigates a more general approach based on the decomposition of expertise into generic tasks as advanced by [2], and the epistemological (four layer) description of conceptual/interpretation models of expertise in the KADS methodology [1].

A mapping of the epistemology of these tasks (some are subtasks in a hierarchy), onto the conceptual model, results in a complex model of expertise which will be formalised as a specification for a knowledge acquisition tool.

This specification may either be used as a documented methodology for a structured knowledge acquisition or implemented as a software tool.

Though the generic tasks described here are expressed in domain specific (medical) language, they are similar to tasks that are encountered in other application areas such as electronic and mechanical diagnoses. Thus the conceptual model developed here can be used as an interpretation model or template for the construction of conceptual models of other domains with similar tasks.

To achieve our objective of deriving the tool specification, classic elicitations were conducted in two medical domains, namely :

1. The differential diagnosis of hypovolaemia (acute fluid loss) and myocardial (heart) failure, and

2. The differential diagnosis of infection and rejection in organ transplantation.

Prototype systems were built for each of these domains to illustrate conventional expert system building. The analysis of the elicitations, at this stage, did not take into account the epistemology of the domains.

After further analysis, we abstracted generic tasks and developed a conceptual model of medical diagnosis. Our goal is the derivation of the tool specification from the epistemology of these generic tasks, within the framework of the conceptual model.

2. CLASSIC KNOWLEDGE ACQUISITION

UNSTRUCTURED interviews were used to elicit the requirements for the prototype systems and to gather concepts. FOCUSSING and LADDERING were then used to build the concept hierarchies and their relationships.

A fundamental model of medical diagnosis was abstracted using PROTOCOL analysis and STRUCTURED interviews. This model was used to guide the remaining elicitations and to develop the final model.

Some time was spent in the Adult Intensive Care Unit (AICU), OBSERVING the expert 'going through' the stages of diagnosed cases. The PROTOCOL for interpreting the data from various monitors was elicited (see section 5.2 (d)).

3. KNOWLEDGE REPRESENTATION

The prototype systems for both domains were implemented in the KES environment which uses production rules as its representation formalism. Our analysis of the elicited knowledge was constrained to 'fit' into its representation formalism.

4. CONCEPTUAL MODEL OF MEDICAL DIAGNOSES AND ASSOCIATED GENERIC TASKS

To derive the specification we need to characterize these tasks, at the epistemological level, and map them onto the model.

4.1 CONCEPTUAL MODEL

Conceptual models represent the expertise required to implement a knowledge based system. They are models of generic tasks and subtasks, with communication lines indicating the paths of information transfer. The model in figure 1 forms the framework of our tool specification. It illustrates the main tasks in medical diagnosis.

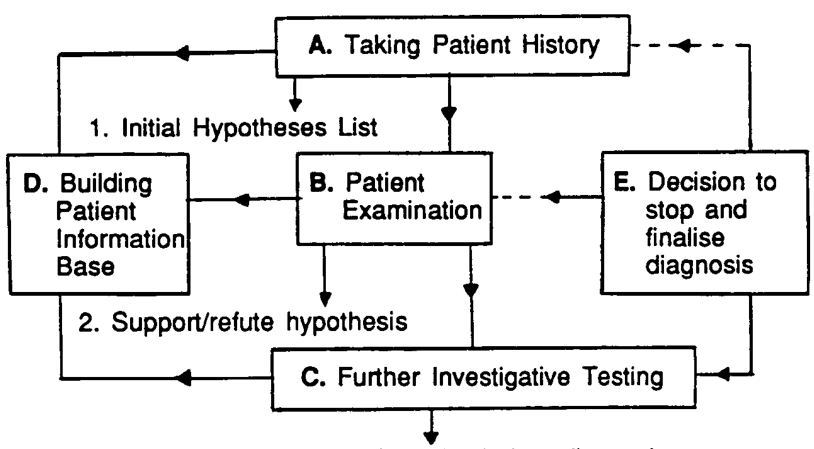

Figure 1. - Simplified conceptual model of medical diagnosis tasks

4.2 GENERIC TASKS

We have identified the main generic tasks in medical diagnosis as (see figure 1):

A Eliciting and receiving patient history (Data gathering),
B Carrying out physical examination,
C Special investigative Tests, which include laboratory analysis of various samples, for bacterial and biochemical content,
D Building patient information base, and
E Deciding to stop and finalise the diagnosis.

5. MEDICAL DIAGNOSIS - description in terms of some generic tasks.

Classically, diagnosis is achieved in the order presented in this section. However, in real life, it is more haphazard than that. Various problem-solving heuristics are used in a complex manipulation of these tasks. The specification must allow editing of the conceptual model, to enable the use of various protocols. We describe, below, some of the subtasks of the main generic tasks.

5.1 ELICITING and RECEIVING PATIENT HISTORY

Knowledge obtained from the patient's medical history can be organised as a hierarchy of sub-tasks, represented at the next level down by:

(a) SELECTION OF DATA ELICITATION PROTOCOL. A specification for this task will enable various medical staff to elicit data properly from patients. The type of elicitation selected is dependent on factors such as, the state of the patient (e.g. his degree of willingness to co-operate), the source of the data (whether it is the patient or his agent), and whether symptoms or signs are being elicited.

(b) ACQUIRING PATIENT PRESENTING COMPLAINT. This consists of obtaining the patients's symptoms (e.g. chest pains) and his observed signs (e.g.breathlessness). The patient is allowed to describe his problem in his own words and in his own time. Occasionally leading questions are asked depending on the type of information required.

(c) CARRYING OUT SYSTEMS REVIEW (SR1). This is a quick review of the body, during which special characteristics which suggest disease are noted. This preliminary inspection of the patient may provide clues to diagnosis which could be missed during a detailed examination (SR2).

(d) ASSESSMENT OF PATIENT CONDITION FROM PAST THERAPY. This task involves the assessment of the patient's condition, e.g. the functionality of certain organs, as a result of, say, drug therapy (obtained from his drug history). The assessment may continue through to the examination and tests.

5.2 CARRYING OUT EXAMINATION (SR2)

Patient examination, which begins during the history taking (SR1), is the result of 'hypotheses formation' from the history and so there is, to some extent, a degree of expectation of its FINDINGS. The examination may give CLUES that reveal signs and abnormalities which correspond with some disease pattern in a 'disease hierarchy'.

The examination itself consists of further subtasks. At the next level down we have :

(a) INSPECTION (Visual). This may involve the concept of examining the patient on the external manifestations of a disease [7] in e.g. face, mouth, or head and neck. This examination is hierarchical and may support a hypothesis, formed from the history.

(b) PALPATION (feeling). This task involves feeling the patient, in this case externally, to associate e.g. the tenderness of a swelling with that of known disorders or diseases.

(c) AUSCULTATION (listening). For example malfunction of a heart valve results in a lot of noise as blood rushes through a small orifice, or as blood is going the wrong way. A stethoscope can be used to listen to and diagnose a valvular heart disease (from the pattern of sound).

(d) INTERPRETATION of PHYSIOLOGICAL VARIABLES. Parameters including blood pressure, cardiac output, urine output, etc. provide vital signs (doctor/medical staff observed) which are used to explain a patient's condition, by hypothesis formation. These hypotheses are confirmed or disproved by further data or findings from more detailed examination or further investigative tests.

5.3 CONDUCTING FURTHER INVESTIGATIVE TESTS

Confirmation of a hypothesis into diagnosis, after examination, may be achieved through further tests, e.g. looking for abnormal patterns in X-rays and ECGs. Laboratory tests of samples and biopsy, also, confirm a hypothesis into diagnosis.

(a) X-ray or ECG ABNORMALITY-MATCHING. This may be classified as 'hypothesis and pattern-matching' or 'hypothesis and test matching'. This involves, e.g. matching abnormal characteristics of an X-ray or an ECG, as a hypothesis, with established disease patterns of X-ray and ECG.

(b) ANALYSIS OF SAMPLES. Blood, urine, stool, and sputum may be analysed for bacterial, and biochemical content. A subtask here may be to 'identify and match' sample bacteria, with some disease in a 'disease hierarchy'.

5.4 BUILDING INFORMATION BASE.

The result of this process/task, is a store of information on the patient e.g. family & past histories, drug and allergy histories. It also contains data from patient examination and further investigative tests. The contents of the information base are used for referencing and inferencing in performing of any of the other tasks and subtasks.

5.5 DECISION TO STOP AND FINALISE DIAGNOSIS.

This task includes factors such as: investigation costs and benefits of a test for a patient, patient discomfort and, danger to the patient, [4] [8]. It describes a criteria for terminating the diagnostic process.

6. TOOL SPECIFICATION

With the conceptual model, as our framework, we may derive the tool specification by : 1. Carrying out an epistemic analysis of each of the generic tasks, 2. Mapping out the conceptual model as an explicit model of generic tasks at the epistemological level, and 3. Establishing communication links and conditions for information transfer between the epistemic components of the tasks to be used in problem solving.

With the characterisation of the generic tasks to include the automatic selection of appropriate elicitation methods and some form of intermediate representation for a methodology, the specification may be implemented as a knowledge acquisition tool.

By incorporating editing facilities in the specification, experts may interact with an implemented tool to enter individual, diagnostic protocols into a knowledge base, utilising some or all of the same generic tasks. This approach is similar to that in Opal [6] which uses a generalised model of oncology protocols to define new protocols which are entered, directly, into the knowledge base of Oncocin, an expert

system that offers advice on protocol directed cancer therapy.

7. DESCRIPTION OF AN EXAMPLE GENERIC TASK, WITH SPECIFICATION FORMAT

We present the characteristics of an example generic task from which the tool specification may be derived.

GENERIC TASK : CARRYING OUT EXAMINATION

i) SPECIFICATION

Given a history, with symptoms corroborated by abnormal physical signs, conduct well-recognized clinical methods of examination.

ii) GOAL

To obtain evidence, as findings or data, to support or refute hypotheses formed from the patient history. New hypotheses may also be formed. In some situations diagnosis may be achieved here, see section 5.2 (c).

iii) KNOWLEDGE FORMS

Diseases are characterized by factual evidence (cause of). These facts support the hypotheses, through some form of inferencing.

iv) KNOWLEDGE ORGANISATION

Patient examination may be organised into a classification hierarchy of concepts. Inspection of the exterior of the body involves hierarchies built from such concepts as : a. facial characteristics, b. abnormalities in the head and neck, c. character and distribution of hair, d. skin, and a few more. Facial characteristics, for example, are supported by other concepts, such as colour and the state of blood vessels. These may be classified into types.

v) CONTROL KNOWLEDGE

Problem solving is a top down search and refinement process, where each concept when called has to justify itself. A failure at justification renders its successors invalid.

vi) EXAMPLE : Examination of the abdomen.

Examining the abdomen, for example, involves all the subtasks listed in section 5.2. INSPECTION will show the condition of the wall of the abdomen, its size and any irregularity in its contour. The cause of this irregularity may also be established. All of these can be, conveniently, specified for suitable representation and implementation.

vii) KNOWLEDGE ELICITATION

The main concepts of patient examination may be obtained through structured questioning. 'Laddering' and 'Focussing' are used to build the concept hierarchy and the classificatory aspects of the concepts. Protocol analysis is then used to obtain the problem-solving knowledge, e.g. in determining the order of testing the hypothesis.

viii) KNOWLEDGE REPRESENTATION

By decomposing the expertise into tasks and subtasks and analysing the knowledge at the epistemic level, we can represent the knowledge, in primitives appropriate for each task. We thus have representation of knowledge, rich in vocabulary. This enables clearer explanation of problem solving.

SUMMARY

The classic elicitation and analysis for the prototype systems revealed the shortcomings of first generation techniques in terms of the level of knowledge abstraction and representation.

By decomposing expertise into generic tasks and specifying these tasks, we are providing a well structured and consistent methodology of acquiring expertise, at a higher level than in conventional methods, for building expert systems. The epistemology of these generic tasks when mapped onto the conceptual model provides an explicit model of the expertise required for the system building.

Characterizing each task, as in section 7, provides a clear guide to knowledge acquisition. The resulting specification may either be used as a documented methodology for a structured knowledge acquisition or implemented as a software tool.

By employing suitable classic elicitation techniques in our specification for the various tasks we are able to achieve further level of knowledge abstraction. Knowledge representation becomes clearer as we are now able to represent the tasks in primitives suitable for each task.

Similarities in tasks between medical, electronic and mechanical diagnoses will enable a common methodology (and hence a tool) to be developed for general diagnoses. The idea of interpretation models, as templates for the construction of conceptual models from one domain to another, points in that direction.

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