Proceedings of the International Workshop on Intelligent Information Systems
IIS'2011, September 13-14, 2011, Chisinau, Republic of Moldova

Knowledge representation and reasoning for ultrasound medical diagnostics

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Abstract: Ultrasound medical diagnostics, as well as medicine as a whole, is a poorly formalized domain. This article describes the experience on developing a representation scheme of professional knowledge and creating a module of inference on its basis. The knowledge engineering stage is considered as the key one for the development of knowledge-based systems.
Keywords: medical diagnostics, knowledge representation schema, logic inference, reasoning

1 Introduction

The phase of knowledge formalization is being considered as the key one for the development of any knowledge-based systems (expert systems, decision support system etc.). The main problem at this stage is to find a knowledge representation (KR) and a supporting reasoning system that can make the inferences your application needs.

In order to obtain a well-structured description of the problem domain, the developers are forced to choose a «rigid» scheme of its representation. The problem domain is quite often represented as a decision tree or semantic net.

The main lack is the fact that the logic inference does not correspond to the daily work and habits of the end-user.

The discrepancy between reasoning module of the knowledge based system and the form of the doctor's diagnostic thinking may become the reason of different mistakes or it may lead to the rejection of the user to utilize it in medical practice.

The principles and techniques of knowledge structurization, representation and management, aiming to create an efficient reasoning

for the medical knowledge based systems in ultrasound investigation domain, are described in this article.

2 Knowledge representation schemes

The fundamental goal of the professional knowledge representation (KR) is to represent knowledge in a manner to facilitate drawing conclusions (inferencing) by the medical knowledge based systems.

We distinguish two approaches – single and hybrid KR schemes.

The most popular single KR schemes: Semantic nets, decision trees and their descendants (frames or schemes)[1]; Conceptual graphs, whereas ontologies; Symbolic rules; Fuzzy rules (fuzzy logic)[2]; Case-based representations[3]; Neural networks[4]; Belief networks (or probabilistic nets)[5].

Hybrid schemes are integrations of two or more single KR schemes [6]: Connectionist rule-based representations; Integrations of rule-based reasoning with case-based reasoning; Fuzzy neural networks and the hybrid neuro-fuzzy representations, Neurules.

We will focus on the most popular KR schemes in the medical computer-assisted systems domain.

Semantic nets, decision trees and their descendants (frames or schemes), ontologies represent knowledge in the form of a graph (or a hierarchy). Nodes in graph represent the concepts and edges represent the relations between the concepts. All of these KR schemes are very natural and well suitable for representing structural and relational knowledge.

Symbolic rules scheme is one of the most popular KR methods [10], representing general domain knowledge in the form of IF-THEN rules: if <conditions> then <conclusion>, where the term <conditions> represents the conditions of a rule, whereas the term <conclusion> represents its conclusion. The inference engine uses the knowledge in the rule base as well as facts about the problem at hand to draw conclusions. Efficiency of the inference process depends on the length of the inference chains.

Integrations of rule-based reasoning with case-based reasoning. As compared with "pure" case-based reasoning, their key advantage is the improvement in the performance of the inference engine and the ability to represent heuristic and relational knowledge.

We have chosen the decision tree as a model of acquired knowledge representation. Basing on the principles of the decision tree scheme, the knowledge base of ultrasound examination domain has been established. It consists of a pyramid of meta-concepts, and of a set of rules created on its basis.

3 Reasoning based on alternative KR scheme

The aim of creation of an alternative representation scheme of the knowledge base is the organization on its basis an effective logic inference and the deficiencies elimination, inherent in the reasoning based on the decision tree scheme.

We are not talking about replacing the decision tree as a mean of knowledge representation scheme at the stage of knowledge acquisition. Since, the use of such representations is reasonable, especially, in cases when the developers want to obtain a well-structured knowledge base and have to deal with poorly formalized domain.

The essence of the proposed new representation approach is the separation of knowledge into one, used in the inference, and other, used only in the interface [7].

At the first step of the creation of the alternative representation of the knowledge base there were determined those facts of the decision tree, which are involved in the inference. For each fact, contained in the decision tree, was formulated a question concerning the existence or non-existence of this fact.

At the second step, we have saved all existing relationships between the facts. The main principle that was used was: The separation of the existing relationships between the questions in two groups – those, used in inference, and those, used only in the interface. This, allows us to create a high-quality adaptive interface based on the individual characteristics and habits of the end-user. This is achieved because the user can define himself the subject and the form of the dialogue (by changing the visualization relationships between the questions), without any fear to influence the inference.

Thus, any pathology or anomaly in ultrasound medical diagnostics can be represented as follows:

$Pi=\&Fj(V,VisualCond[i])$, where $i \in \{1, ..., 52\}$, $j \in \{1, ..., 212\}$

Fj.V∈{“1”,”0”,”v”,”-1”}, where “1” – affirmative fact, “0” – negative fact, “v” – fact requires indication of special value, “-1” – fact is not informative for given pathology; Fj.VisualCond[i] indicates conditions at which the fact Fj appears in the interface.

The reasoning algorithms, based on this alternative representation, allow realization of different versions of the user interface.

4 Conclusion

Realization of the described approach has shown, that creation of the alternative KR requires additional time, but it is justified, if we want to be able to organize an effective interactive dialogue with the end-users. In addition, the reasoning based on proposed representation is simple, understandable and transparent, fully corresponding to the daily activities and habits of the end-user, not restricting unreasonably the end-user actions.

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