A Model-Based Architecture for Fuzzy Temporal Diagnosis*

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Abstract. The application of Model Based Diagnosis (MBD) techniques together with Knowledge Base Systems, points out the need of general modelling frameworks in domains where time management is important. The development of this kind of systems, far from becoming simpler, reveals the additional complexity inherent in each specific domain. This paper describes a general architecture for this purpose using a model based approach for developping temporal knowledge based systems in different domains. This work also relates our experience in applying this architecture in the concrete domain of Intensive Care Units.

1 Introduction

Since its beginnings, Artificial Intelligence has paid special attention to knowledge-based systems and its design. In particular, the application of model-based reasoning has obtained important results in the last decades [1,2].

However, the experience in developing these systems reveals the complexity of the design, the development, and its maintenance. Furthermore, in most of cases, the systems are highly dependent on the domain and the problem to be solved. In our opinion, there are some particular situations where these difficulties are critical, for instance the analysis of knowledge-based systems in order to solve temporal diagnosis problems ([3,4]).

This work presents a general model-based framework for intensive-knowledge domains, where the temporal dimension is considered to deal with the diagnosis problem. Nevertheless, the task of designing a generic architecture is a complex issue. One of the most difficult steps is to establish the set of goals to be reached. Our general framework tries to deal with the following key topics: domain independence, the management of temporal uncertainty, the knowledge acquisition bottleneck, model-based representation, and the diagnosis task. This paper also relates our practical experience in the application of this architecture.

The structure of this paper is organised as follows: firstly there is a general overview of the proposed architecture. After that, the two main modules (temporal/domain and

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decision support module) are explained in detail.Finally, we describe our practical experience in the application of this architecture in the particular domain of the Intensive Care Units.

2 Model-Based Architecture Overview

The architecture proposed is based on a behavioural model in order to solve the temporal diagnosis problem from a Model-Based Reasoning approach (MBR). This section shows the main structure of the architecture, describing each part in detail afterwards. This structure defines two modules, the Temporal/Domain Module and the Decision Support Module.

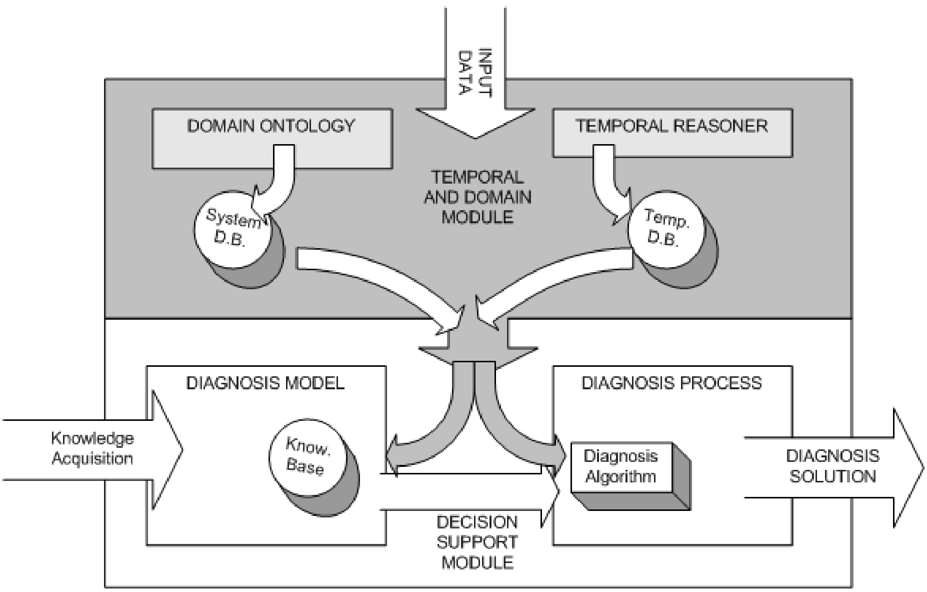

Fig. 1. The General Model-Based Architecture Overview

The Temporal/Domain Module is composed by all those elements that allows the architecture to be independent of the domain, and the management of the temporal dimension. **The Decision Support Module** includes all the elements needed to obtain the diagnosis solution.

3 The Temporal / Domain Module

The design of any system architecture for model-based diagnosis becomes highly difficult if the importance of the knowledge domain is considered, as well as its impact on the design of systems. This work proposes an architecture able to be used in the development of fuzzy temporal diagnosis systems for different domains. To this end, we suggest the use of ontologies and general purposes temporal reasoners.

The temporal/domain module provides the general architecture with two main advantages. Firstly, this module deals with the consistency task: both domain and temporal consistency. Secondly, the use of ontologies to represent part of the domain knowledge gives the architecture flexibility, in order to apply it on different domains.

The complexity inherent to some domain knowledge increases the problems associated to generic architectures. The use of a domain ontology server allows to solve this situation partially by keeping the semantic consistency of the concepts used.

The temporal database stores all the system information as well as some temporal data. However, those tags are not enough to manage the temporal dimension. Thus, the use of temporal reasoning techniques provides the architecture with important advantages. For instance, it guarantees the temporal consistency, and it infers new temporal relations [5]. This architecture relies on FuzzyTIME [6], a general purpose fuzzy temporal reasoner.

4 The Decision Support Module

The main elements of the Decision Support Module are the formal model, the knowledge acquisition tool and the diagnosis process. These elements conform the set of fundamental components of the architecture in order to build a diagnosis solution.

This architecture is supported by a formal model which is a temporal and causal model of failures named TBM (Temporal Behavioural Model). The TBM describes the underlying structure stored in the KB. This model is structured as a causal network in which each failure is connected to the abnormal manifestations and to other caused failures. Time dimension is an important factor to be considered. Therefore, each failure description is extended to include temporal knowledge as a set of temporal constraints among elements. The application of TBM in the medical domain is the result of previous works and can be read in [7].

The model (TBM) that supports the architecture is used and stored in the knowledge base of the architecture. This knowledge base is supported by some knowledge acquisition tools, which must access both the formal model and the domain ontology.

The diagnosis process is the main element of the module. The diagnosis process, is a fuzzy temporal model-based diagnosis. In this kind of process, the role of the diagnosis is to find a diagnosis solution from the temporal data (from the temporal database), from the domain ontology (from the ontology server), from the knowledge base, and with the help of the temporal reasoner. This process is based on an algorithm that obtains a diagnosis solution. This solution must be temporally consistent, semantically consistent, fulfill the temporal and causal constraints of the formal model, and explaining the findings of the temporal database information. Essentially, our diagnosis proposal is based on a causal network (temporally consistent) and a temporal constraint network that are built using and abductive strategy to explain the set of events.

5 Practical Experience. An Application for Intensive Care Unit

This section describes the practical application of the architecture by explaining our implementation for the medical domain, in particular the Intensive Care Unit (ICU).

Physicians at intensive care units have to deal with an overwhelming amount of data provided not only by on-line monitoring but also collected from patients' records (e.g., laboratory results), which are, in most cases, collected manually at different time instants. In order to provide efficient decision support systems and medical research tools in the ICU domain, it is necessary to integrate and analyze the information provided from these different sources. The result is ACUDES , the Architecture for intensive Care Unit Decision Support.

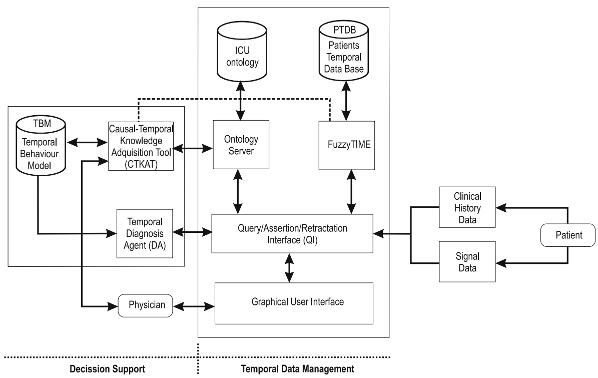

Fig. 2. ACUDES: Architecture for intensive Care Unit Decision Support

ACUDES is an specific system that follows the structure of the architecture proposed. Thus, it includes a temporal Data management Module, where the FuzzyTime temporal reasoner and the Ontology Server are allocated; in this module you can find also the Temporal Data Base (TDB), the ICU Ontology and the interface defined for accessing the module. On the other hand, the Decision Support Module (DSM) contains the diagnosis agent which is in charge of the diagnosis process. This process is the core of ACUDES and it is described by a causal and temporal behaviour model-based algorithm. It is worth mentioning that we have designed and implemented CATEKAT, a web-based tool to acquire the domain knowledge for the diagnosis model.

5.1 Knowledge Acquisition Tool:CATEKAT

The medical domain, in particular ICUs, is hard to classify and its terminology is hard to interpret. In some cases, the definition of terms may leave space for wrong interpretation. Hence, the knowledge acquisition lies on an ontology which allows a consistent use of the medical terms. Thus, using ontologies, KB acquisition could be viewed as a process for enlarging a domain ontology with specific knowledge of a particular domain.

We suggest the use of dictionaries of synonyms and thesaurus for solving cases of equivalent terms that are not considered in the ontology.

Another point that we dealt with was the incompleteness of the knowledge acquisition. For example, the physician could describe some related clinical signs. However , the physician does not specify how this signs must be interpreted when they are present in the patient. This insufficient information must be acquired from some other experts.

The main module in CATEKAT is the web based KA user interface. There are several requirements that characterise its design and implementation:

- a multi-user environment.
- role-aware, i.e. the management of different roles such as expert or knowledge engineer
- avoiding inconsistencies in temporal pattern edition by locking a pattern when a user is working on it
- providing an effective cooperative work platform
- allowing the definition of projects related to different domains
- browsing and querying capabilities.

5.2 Graphical Diagnosis Tool

In our experience at the ICU domain, we had dealt with two problems of the clinical decision support: the gathering of temporal medical information (the input of the diagnosis process); and the representation of the diagnosis outcome.

The aim of the **Evidence Acquisition Tool** is to provide physicians with the data gathering of clinical histories, allowing the system to return the diagnosis outcome. This tool has been designed to facilitate a visual and interactive acquisition of patients' findings, taking into account the temporal dimension of this information, which is critical in ICUs domains.

In decision support systems, the representation of the diagnostis solution is a key question, not only from a practical point of view, but also to provide an understable diagnosis output. To this end, the **Diagnosis Navigator** shows an understable output of the diagnosis process, as well as an explanation of the diagnosis solution. This explanation is made by describing each decision that the diagnosis algorithm has reached through the process of causal network construction within the reasoning process. This functionality allows the physician to understand the behaviour of the diagnosis process. Thus, the expert could criticize it and suggest new modifications by means of the CATEKAT tool.

6 Conclusions

This paper proposes a general architecture based on a causal and temporal behavioural model [7] (TBM) for treating the fuzzy temporal diagnosis problem. This architecture defines two modules, the Temporal/Domain Module, and the Decision Support Module in order to deal with: domain independence, the management of temporal uncertainty, model-based representation, and decision support.

In the design of architectures based on models, the selection of a knowledge model is a critical factor. At this point, an important question to be considered is the degree of dependency of the model and the domain which is modeled. On the one hand, a weak dependence facilitates the design of a generic model that can be reused in other domains. On the other hand, the approach of a highly dependent model on the domain provides an easy design of knowledge acquisition tools. The proposed architecture is based on our research in the representation of temporal behavioural models TBM. The model used in the architecture deals with both, generic model and easy acquisition. However, the agreement of the TBM with the domain provides an easy KA, but also a complete description of the domain behaviour.

As we mentioned in Section 5, this work also describes our experiences in the implementation of this architecture for a Decision Support system in a ICU. One of the problems in this domain is the high difficulty of the knowledge acquisition process, where the temporal dimension plays an essential role in the knowledge domain. Thus, in this work we present ACUDES, an implemented system for decision support in ICU to deal with these problems. We also propose the knowledge acquisition tool CATEKAT, which uses TBM to built the knowledge base.

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