Medical Plans as a Middle Step in Building Heart Failure Expert System

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Abstract— **Knowledge acquisition and presentation are important issues when constructing medical knowledge based systems. In this work medical plans are introduced as a solution for presentation of operational medical knowledge. Plans are not meant to be directly used by the actual decision support systems, but they are created as a middle step between medical doctors' domain knowledge and computer system representation of that knowledge. They are graphical representations of procedures in specific medical domain, typically describing diagnosis and treatment of a certain disorder. They can be created and edited by medical doctors allowing them to express their vast, but often dispersed, knowledge in a systematic way. The goal is to enable technically sound transformation of medical knowledge into the form of rules or in a guideline modeling tool. The problem of treatment of heart failure disorder is used in this work to illustrate the concepts of medical plans and their application in a difficult real world problem.**

Keywords— **medical plans, expert system, knowledge acquisition**

I INTRODUCTION

Expert systems in medicine have a long history. They are most often used in hospitals to help medical doctors in determining the patient's diagnosis. An expert system takes patient's medical details and symptoms and provides a probable diagnosis and corresponding treatment based on underlying knowledge and logic. In order to build an expert system, one must first formalize an extensive domain knowledge.

An expert is a person who is characterized by superior performance within a specific domain of activity [1]. Its knowledge consists of cognitive element (individual's viewpoints and beliefs) and a technical element (specific skills and abilities). Although medical documents, books and guidelines are exhaustive, most of the knowledge is in the heads of medical experts. Large part of their knowledge is tacit; they don't know all they know and all they use, which makes that knowledge hard or impossible to describe [8]. Not every expert has complete knowledge about certain domain and knowledge may vary from expert to expert. Also, knowledge has a "shelf life"; it is continuously evolving: while new facts are constantly coming to life other are made obsolete. Still, in their every day practice experts manage to successfully treat a large number of patients.

Medical knowledge is characterized by time, space, and knowledge complexity. Time complexity denotes that data is collected during days and years while response is expected in the range of seconds. Space complexity refers to the fact that the data may be distributed in different parts of the health care system and in various forms. The knowledge complexity stands for the abundance of the expert knowledge for every medical sub-specialization. Even though a number of guideline modeling tools provide means to address the described complexity issues, the practice indicates that there are major difficulties in expressing knowledge in a strict form by the medical experts.

In this work, a concept based on medical plan design and implementation is explored. This method is currently being used in formalizing medical knowledge for the heart failure domain. The research presented in this work is stimulated by a project aimed at realization of a knowledge based platform called HEARTFAID, that should assist in management of heart failure patients. This research is still a work in progress. The platform will have to intelligently assist in various tasks ranging from patients home monitoring to the decision support in specialized hospitals. Medical plans devised for this kind of project have to be detailed and applicable in many possible situations and they are thus very challenging.

In the next section medical knowledge acquisition and representation is explained. Section III gives several examples of medical plans and discusses their application. Section IV discusses to available tools for the plan implementation.

II MEDICAL KNOWLEDGE ACQUISITION AND REPRESENTATION

Every guideline for a disorder is only a well-formed recommendation and usually does not contain detailed procedures on medical treatment. More specifically, it does not address what exactly has to be done in each case, but rather gives general instructions for the disorder based on

Evidence Based Medicine (EBM) approach. The significance and meaning of every symptom is usually not discussed and all of the contraindications are not presented. Therefore, a combination of medical knowledge from guidelines, medical doctor expertise, as well as from medical articles and other medical resources are required in order to properly describe the disorder and construct a reliable system. This combination of various data regarding the medical problem has to be presented in a form that is convenient for the computer interpretation, as well as for the use by the medical practitioners and sometimes, even patients and their families.

There are several possible ways to acquire the medical knowledge needed for an expert system. First, a number of experts in the field are consulted. Knowledge acquisition can range from questions prepared by the engineer for the expert regarding a medical issue [4; 5], to a computer program built specifically for the purpose of gathering knowledge [3].

Guideline modeling systems (Arden Syntax, Asbru, GLIF, Proforma) [2] should provide syntax for the deployment of knowledge both in machine-readable and human-readable form. However, guideline modeling systems in general have failed to perform in practice (except Arden Syntax, which is used in hospitals). The reasons for that can be summarized to: (1) difficulties in acquisition and verification, (2) difficulties in integration in medical institutions and (3) usage denial by the clinicians [1]. The underlying reason for guideline modeling systems failure is the complexity of the knowledge extraction process. In addition to the omnipresent problem of the extraction of tacit knowledge, the syntax of guideline modeling systems is often not suitable for presenting a complex knowledge for the medical experts (unless they are computer experts at the same time).

A "classic" expert system functions on a set of facts and rules. Facts are gathered static knowledge such as the names and properties of medications, diagnoses, tests, etc. Rules are used in order to gain new knowledge based on the known facts or to draw some conclusions. The presentation of facts is usually done by the use of ontology languages and tools. Although ontology modeling tools are very efficient for knowledge integration, they are still not the preferred way in which knowledge systems engineer and the medical doctors communicate. Since ontology structure can become rather complex, the medical knowledge that it comprises is not always well understood. It has thus become evident that another approach to knowledge systematization and presentation would be required. This type of visualization middle step between the guidelines and other static knowledge that has been acquired on one side, and a working expert system on the other side can be achieved by using so called "medical plans".

We have observed that medical doctors find this type of knowledge presentation intuitive and understandable. They are even willing do create their own plans for a specific aspect of the disorder, because the learning process for drawing these plans is fast. They find themselves more capable of expressing their knowledge through the use of the medical plans syntax.

III Medical plans

Medical plans are textual and visual presentations of the events that can occur while treating patient with a specific disorder. Unlike the guideline modeling tools, medical plans are not machine-readable. They are the middle step between the experts and the guideline modeling tools which persuade the experts to clearly state the procedure they would normally perform when facing a specific problem, and at the same time enabling the technicians to understand it and encode it in a machine readable form.

The syntax of the medical plans highly resembles the traditional workflow management. The difference is that the medical plans will not be executed by machines; they are written in a almost-free graph/text form with main purpose to be fully understandable by humans and at the same time to clearly state the details of the knowledge. The main advantage of the plan is that it allows for a better systematization of the medical procedures and their interconnection than the guidelines do. The second advantage is that their visual presentation facilitates the medical staff interventions in the medical know-how part of the system. The plans can be quickly corrected and maintained. The third advantage is the facilitation of the implementation process. Fourth, they need not be created all at once, but rather can be designed and inspected one or more at the time.

For the heart failure platform, medical plans describe the symptoms that can occur as events to the patient who is treated by the platform. These symptoms have assigned urgency level which corresponds to the type of response from the medical team. For example, pulmonary edema has the highest urgency level, requiring immediate admission to the hospital. An example of a symptom that has a low urgency level is cough. Cough does not require for the patient to report to the hospital, but rather if it is persistent, he should contact his general practitioner.

An example of a medical plan is given in Fig 1. This is a relatively simple plan for the assessment of high temperature if patient already has congestive heart failure. First, patient's symptoms are inspected. If patient has

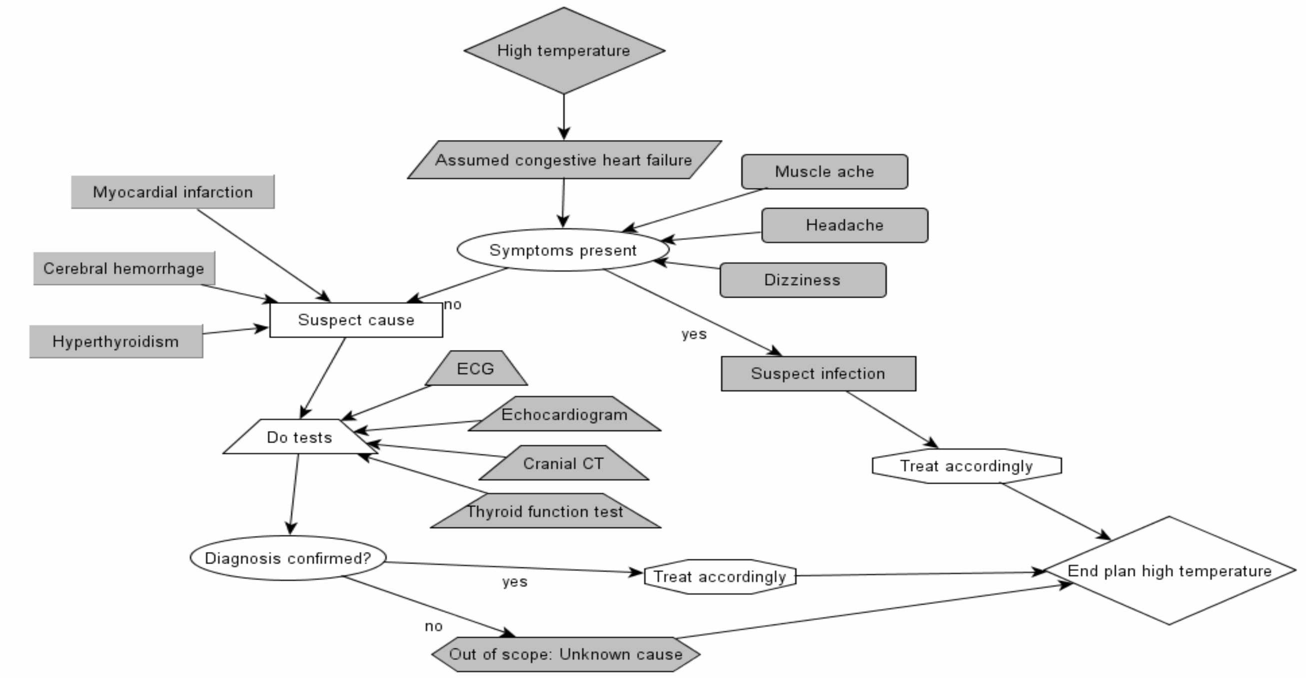

Fig 1. High temperature medical plan

muscle ache, headache or feels dizzy, it is probable that he has infection and that he should be treated in respect to the type of the infection. Medical doctor has to assert that there are no contraindications for the treatment and this is implicitly assumed. If patient does not show these symptoms, three causes for the high temperature of the heart failure patient have to be considered: myocardial infarction, cerebral hemorrhage and hyperthyroidism. These disorders can be diagnosed after the following tests are performed: ECG, echocardiogram, cranial CT and thyroid function test. If the diagnosis is confirmed, it is treated. If not, the platform specifies that the cause is unknown and thus out of its scope.

Types of nodes (and their function) in a plan flowchart are defined by their shape and color. For example, a diamond shape always represents plans, either the beginning (green) or the end (bright yellow) of the plan (note that colors are not used in this article). It is possible to jump from one plan to another by specifying this other plan as a node in the present plan. At the moment, the heart failure system has more than 30 interconnected plans for symptoms treatment and 10 plans for medications dosage. Some of the more serious symptoms and diagnoses presented by plans include heart attack, cerebral stroke, atrial fibrillation and pulmonary edema.

IV MEDICAL PLANS IMPLEMENTATION

It is never easy to choose which knowledge representation technique (or combination) fits the needs of a given medical application best. To make that decision it is very important to define problems that system will be used to resolve and it is very useful to be aware of the possibilities and drawbacks of each technique of knowledge representation. One way of representation may simplify the solution, while an inappropriate choice of representation makes the solution much more difficult to accomplish.

The acquired medical plans should indicate which knowledge representation techniques can be used for knowledge formalizing. Within the HEARTFAID project, for representing heart failure disorder plans, we are using ontologies, workflows and rules.

When knowledge base is being built it is useful to have some kind of a domain description which will contain the description of entities, concepts and terms that are in any way related to the domain. A good way to build a domain description is by means of ontology.

Ontology has the possibility to describe a set of concepts and relations between them. The main purpose of an ontology is to share common understanding of the structure of information between people and/or software agents, to reuse the domain knowledge and to make domain assumptions explicit [6]. Structured domain description will also provide a bridge between "low level" parts of the application (electronic patient records, databases, instruments) and "high level" domain description (medical concepts, medical terms, medical actions, ...). Existence of well defined ontology somewhat eases the segregation and integration of the technical tasks and the medical tasks.

Several guideline modeling tools such as GLIF and Asbru are suitable for representing and formalizing acquired medical plans. GLIF structure highly resembles the given medical plans structure. At the GLIF *conceptual level* guidelines are represented as flowcharts that are easily understood or edited by humans, and not interpretable by machines since the underlying platform implementation details are not formalized. However, the syntax of GLIF is more restrictive than the medical plans syntax [2].

Asbru is a guideline modeling tool that focuses on representing medical plans with high awareness of the time dimension in the medical procedures and actions. A plan in Asbru is a set of actions that is performed when defined preconditions hold. Each plan may have defined plan intentions - a high level goals of the plan. When intentions are defined, the clinicians may for some reason disregard the plan suggestion as long as the defined intentions of the plan will be accomplished. [2].

The most intuitive and by far the most exploited technique for presenting procedural knowledge are "rules". Rule is a statement that defines which actions should be taken when certain conditions arise. Form and the syntax of rules are quite simple, but when the number of rules grows to some amount the complete picture of the knowledge in the knowledge base becomes unclear. This problem is partially handled within the Arden syntax rule-based system by attaching human-readable information to the machine-readable rules, but it remains inherent with the maintenance of the rule base.

Subsequent modifications in the medical plan might cause the uncontrolled propagation of the change in the knowledge base. Most likely the processes of validation, verification and testing should be repeated on every medical plan change in order to insure the knowledge base consistency.

V DISCUSSION AND CONCLUSION

The process of constructing an efficient, reliable and complex medical system is demanding. We have presented a paradigm called medical plans that is able to help the processes of knowledge acquisition and knowledge presentation. It has been used in the construction of heart failure disorder medical platform. Its main advantages are: efficient systematization of medical procedures, facilitation of medical staff understanding of the system, facilitation of implementation process by using ontologies, rules and/or workflows. Experts are willing to participate in designing plans because of the simple graphical solution. Medical plans have been proven as an interesting solution in presenting medical domain knowledge. It remains unclear which is the best method for their implementation. This problem can be solved by manually constructing rules, ontologies or workflows, which is the current paradigm. The authors have found that the introduced medical plans made an important alleviation step in the development of a heart failure knowledge base.

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