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A pattern-based knowledge editing system for building clinical Decision Support Systems

Aniello Minutolo *, Massimo Esposito, Giuseppe De Pietro

National Research Council of Italy – Institute for High Performance Computing and Networking (ICAR), Via P. Castellino 111, 80131 Naples, Italy

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ABSTRACT

Decision support in medicine is being more and more configured as an innovative and valuable way for promoting more consistent, effective, and efficient medical practices. The broad acceptance and efficient application of Decision Support Systems to medical settings strongly require some mechanisms to conveniently update and handle these systems with respect to medical progress or adaptation in the treatment of individual diseases. In this respect, this paper proposes a pattern-based knowledge editing system to guide and assist the creation and formalization of condition-action clinical recommendations to be used in knowledge-based Decision Support Systems (in the following, DSSs). This system has been devised with the aim of: (i) offering a set of patterns for easily inserting and editing such clinical recommendations; (ii) synergistically combining multiple knowledge representation techniques to instantiate these patterns within hybrid knowledge bases (KBs), made of if–then rules built on the top of ontological vocabularies; (iii) reducing the complexity of the formalization process, by graphically guiding the definition of hybrid KBs that could be functional in the context of clinical DSSs and enabling their automatic encoding into machine executable languages. A usability evaluation has been carried out, showing a good satisfaction of medical users with respect to the system implemented, and, thus, proving both the feasibility and usefulness of the approach proposed.

1. Introduction

In the last years, decision support in medicine is being more and more configured as an innovative and valuable way for providing clinicians or patients with clinical knowledge and patient related information, intelligently filtered or presented at appropriate times, in order to enhance the overall quality of care. Clinical knowledge of interest could range from simple facts and relationship to best practices for managing patients with specific disease states, new medical knowledge from clinical research and other types of information [23]. Several recent studies have suggested that decision support in medicine without advanced systems designed to help doctors to make decisions by providing motivated suggestions [30] may not provide the promised improvements in patient safety or quality of care [13,18]. In this respect, a Decision Support System (in the following, DSS) for healthcare applications can be defined as an active knowledge resource that uses patient data to generate case-specific advice which supports decision making about individual patients by health professionals, the patients themselves or other concerned about them [19].

Recent implementations of DSSs in medicine, known as knowledge-based, encode clinical practice guidelines into a logical formalism for simulating the process followed by the physicians [8,25]. The knowledge base (KB) is their key element, since it includes the corpus of relevant knowledge, coming from the clinical recommendations. This kind of DSS is being more and more widely adopted, since it is expected to promote more consistent, effective, and efficient medical practices and improve health outcomes when used [26,35].

With respect to the typology of clinical guideline encoded, up to now, several DSSs have been focused on condition-action clinical rules rather than time-oriented guidelines [2,4,22]. Condition-action clinical rules represent elementary, isolated care recommendations, which specify one or at most a few conditions which are linked to specific actions [29]. It is interesting to note that the most diagnostic and therapeutic clinical guidelines can be distilled in terms of a set of condition-action clinical rules, although this discards the control flow structure [24].

Building a DSS strictly based on condition-action clinical rules mainly requires their collection, systematization and technical formalization within the KB. Typically, clinicians are not supposed to directly access the clinical recommendations encoded in the KB, but they can only ask for the assistance of the DSS, which can then decide to use the KB for its decision making process. It means that,

* Corresponding author. Tel.: +39 081 6139515; fax: +39 081 6139531.
E-mail address: aniello.minutolo@na.icar.cnr.it (A. Minutolo).

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the KB is not accessible and editable directly by clinicians and it can be altered and updated only by means of an intervention made by technicians. However, to perform such an intervention, knowledge of both medicine and formal languages must be combined to create a valid and medically useful DSS. Thus, all the process absolutely requires the cooperation of both clinical experts and experts in medical informatics [27].

Nevertheless, it is extremely worth highlighting that the need of technical experts for editing and upgrading clinical recommendations in a knowledge-based DSS is a strong limitation for medical users. As a matter of fact, actually, one prerequisite for the broad acceptance of such DSSs and their efficient application to medical settings is the guarantee of a high level of upgradability and maintainability, (i) to change clinical rules according to their evolution to implement medical progress in the treatment of individual diseases, or (ii) to adapt generic, site-independent clinical rules to a patient to be treated [9]. Since updating the KB can require a continuous intervention, it is unthinkable that it cannot be done directly by doctors when needed. Also, by providing a direct access to the KB, doctors are encouraged to use clinical DSSs built on the top of it, since mostly entrusted with the suggestions generated starting from their expertise, especially if encoded by them.

In contrast to the intensive efforts made to develop knowledge-based DSSs, the issue of providing solutions for easily editing and upgrading condition-action clinical rules into their KB has been widely neglected thus far.

In this respect, this paper proposes a pattern-based knowledge editing system to guide and assist the creation and formalization of condition-action clinical recommendations to be used in knowledge-based DSSs. This system has been devised with the aim of: (i) offering a set of patterns for easily inserting and editing such clinical recommendations; (ii) synergistically combining multiple knowledge representation techniques to instantiate these patterns within hybrid knowledge bases (KBs), made of if–then rules built on the top of ontological vocabularies; (iii) reducing the complexity of the formalization process, by graphically guiding the definition of hybrid KBs that could be functional in the context of clinical DSSs and enabling their automatic encoding into machine executable languages.

The rest of the paper is organized as follows. Section 2 introduces an overview of the state-of-the-art solutions for building KBs within clinical DSSs and addresses the motivations underlying the development of the proposed approach. Section 3 depicts the pattern-based approach as well as the methodology chosen for representing medical knowledge and linking it to the defined patterns. Section 4 outlines the results achieved, in terms of the editing system implemented, and reports some illustrative examples about how to use the system for inserting clinical rules according to the patterns defined. Section 5 details an evaluation of usability with respect to the system implemented, Finally, Section 6 concludes the work.

2. Background and motivations

Traditional methods to develop KBs for decision support implementations involve drawing out information from medical experts and range from informal or semi-structured interviews and observations between clinicians and technicians to more structured methods, like the transcription and analyses of verbal reports, or conceptual techniques such as graph construction, etc. [7]. Thus, they result cumbersome and time consuming, generating the need for a simple and easy-to-use knowledge editing tool that clinical experts could directly use to encode their knowledge.

In the last years, many studies have analyzed and compared different knowledge editing frameworks for assisting the elicitation of clinical knowledge in a graphical and interactive fashion and its encoding in a formal, executable format [1,17]. These frameworks are visual-oriented and tailored for specific classes of guidelines, specific users, and specific organizations. Each framework supports specific guideline representation languages, and various tools and techniques have been developed to ease the guideline modeling and visualization process.

In particular, AsbruView [15] supports the development of guidelines and protocols into the Asbru language [28] by using graphical metaphors to represent medical knowledge as plans. Arezzo and Tallis [31] support the creation, visualization, and enactment of clinical processes expressed into PROforma language [10] using graphical symbols representing the specific syntactic elements of the language. Protégé [12] is a knowledge acquisition tool that supports the translation into different guideline representation languages, such as EON [21], GLIF [3], and PROforma [10]. It uses specific ontologies for these languages, whereas parts of the formalization process can be accomplished with predefined graphical symbols. GLARE [33] is a domain-independent system for acquiring, representing and executing clinical guidelines. Its graphical interface is quite similar to Tallis and Protégé. The different language elements are coded by simple graphical icons and the guideline flow is represented similar to a flowchart.

All these frameworks have been essentially devised to acquire and represent clinical guidelines in the form of a set of schematic plans, defined at varying levels of abstraction and detail, for managing patients who have a particular clinical condition. In detail, this kind of guideline includes workflow information, modeled in terms of a complex flowchart-like structure, which defines basic medical actions according to the state of the patient.

On the contrary, to the best of our knowledge, so far, none of the existing tools is specifically concerned with the editing of condition-action clinical rules that need to be applied whether a specific critical situation is happened, as opposed to representation of long-term plans [27], neither system-oriented researches appear to have been developed in that direction.

Indeed, the editing of workflow-based guidelines requires more advanced capabilities at the price of being scarcely understandable and usable for a non-technical expert. Thus, the advanced frameworks previously described for encoding workflow-based guidelines can be considered too complex to be used for editing simpler condition-action rules.

Moreover, they often speak the language of knowledge representation formalisms supported, rather than providing some facilities for reducing the gap between these formalisms and the language of the domain for which the KB has to be developed. This issue demands a deeper insight into the underlying formalisms, and thus, highlights the lack of a good usability [11]. It appears clear that doctors, who have knowledge and competencies to edit condition-action recommendations, are not able to directly use those existing tools to edit the KB by creating the conceptualization of the domain and the decision making procedures.

As a result, the most important issue emerged is the need for knowledge editing tools expressly devised to easily guide the insertion and editing of condition-action clinical recommendations. Indeed, since simple guidelines are intended to be modeled in the form of condition-action recommendations, only the facilities needed to build them on the top of a very simple collection of useful terms should be offered and, in addition, exposed in a very simple and familiar fashion, so as to reduce complexity and simplify the overall editing process. Moreover, this simplicity of use should contextually imply the correctness of the clinical rules edited, by granting different levels of consistency in their development, from the syntactical composition to their verification in terms of logic integrity. Summarizing, all these considerations represent the rationale for the approach proposed in this work.