Computers in Biology and Medicine 63 (2015) 157–168

Contents lists available at ScienceDirect

Computers in Biology and Medicine

journal homepage: www.elsevier.com/locate/cbm

Combining conceptual graphs and argumentation for aiding in the teleexpertise

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ARTICLE INFO

Article history:
Received 11 February 2015
Accepted 14 May 2015

Keywords:
Argumentation
Collaboration
Conceptual graphs
Decision making
Ethical problems
Telemedicine
Traceability

ABSTRACT

Current medical information systems are too complex to be meaningfully exploited. Hence there is a need to develop new strategies for maximising the exploitation of medical data to the benefit of medical professionals. It is against this backdrop that we want to propose a tangible contribution by providing a tool which combines conceptual graphs and Dung's argumentation system in order to assist medical professionals in their decision making process. The proposed tool allows medical professionals to easily manipulate and visualise queries and answers for making decisions during the practice of teleexpertise. The knowledge modelling is made using an open application programming interface (API) called CoGui, which offers the means for building structured knowledge bases with the dedicated functionalities of graph-based reasoning via retrieved data from different institutions (hospitals, national security centre, and nursing homes). The tool that we have described in this study supports a formal traceable structure of the reasoning with acceptable arguments to elucidate some ethical problems that occur very often in the telemedicine domain.

1. Introduction

Telemedicine is a component of the health telematics that focuses on health actions requiring Information and Communication Technologies (ICTs) to deliver information across considerable physical distance. Telemedicine can be categorised into five principal groups [13]: teleconsultation, teleexpertise, telemonitoring, teleassistance, and medical response. In this paper, we are interested in the teleexpertise practice in which a physician benefits from professional advices provided by other physicians via ICTs to improve a patient's clinical health status [16].

Teleexpertise is a medical practice that involves at least two medical professionals who collaborate by sharing patients' information and experiences aimed at treating the patient. Communication between the professionals is bidirectional, where one may request for information or advice and feedback or advice is provided. It is the responsibility of each stakeholder to manage the information efficiently. It is in this light that we propose a frameworkor tool that could help to identify the different actors involved in any given teleexpertise process and their advices. Thus in the case of a legal proceeding challenge the proposed tool can potentially facilitate the identification of actors or medical professionals together with their different roles involved in a teleexpertise process. Furthermore, the proposed tool can also serve as a learning or knowledge elicitation for the medical professionals. In other words when confronted with an unforeseen diagnostic or therapeutic problem, a medical professional would have the possibility to search the knowledge base of previous cases to find the most appropriate analysis and solution to a specified problem. If the medical professional does not receive satisfactory responses from the knowledge base, he may engage in a teleexpertise procedure. For the implementation of the proposed framework, we use a Dung [15] argumentation system called also *abstract argumentation system* combined with conceptual graphs [36]. We propose some algorithms to build some semantic extensions [6] such as conflict-free, admissible and preferred extensions. These proposed algorithms form the component often called *argumentative logic* that will highlight the arguments or the accepted advices in a given act of teleexpertise.

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http://dx.doi.org/10.1016/j.compbiomed.2015.05.012
0010-4825/

The novelty of this work is the extension of Dung's argumentation system [15] to combine with conceptual graphs to clarify decisions that are made in a given process of teleexpertise. The conceptual graph component can be very useful for guaranteeing the visualisation of the reasoning traceability that leads to how a decision was arrived at and to solve some ethical problems [7] (e.g. informed consent, privacy, liability consideration [29] and Autonomy, Beneficence, Non-maleficence, Justice [19]).

The remainder of the paper is divided into the 5 sections. Section 2 presents a state-of-the-art review of the domain telemedicine; Section 3 provides background information on the conceptual graph formalism as well as its extensions, reasoning operations and formal semantics for each one. Section 4 presents the methods adopted, which are based on conceptual graphs approach and Dung's argumentation theory under the context of telemedicine. In Section 5 the results of the proposed study or system that makes it possible to ensure a good structured traceability of the medical professionals' reasoning are presented. The paper ends by a way on conclusion in Section 6.

2. State of the art

Several studies [27,28,21,22] have been conducted in the domain of telemedicine. Nowadays the practice of telemedecine is changing the physician–patient relationship and has an impact on the responsibility of doctors to patients and how to treat patients [12]. In fact, not only does the exchange of data between medical professionals facilitates clear decision-making, but also the responsibilities of the professionals involved are engaged.

In this regard, Chopard et al. [12] proposed to store the discussion and make them traceable so that the stored information can be retrieved later on and potentially used to solve some ethical problems.

Xiao et al. [39] proposed a new approach to support data transfer and decision making process using ontologies in diagnosis and treatment of human brain tumour. In the proposed new approach by [39], conceptual graphs for unifying local views that can give an interface to local data for reasoning and managing knowledge were used. Similar to our work Xiao et al. [39] used conceptual graphs to manage medical records, but with a focus mainly on security policies while we are interested in the traceability of the decisions taken.

In emergency cases, the response time factor can be overcome by using virtual telemedicine in which a Clinical Decision Support System (CDSS) is deployed at rural stations [4]. This CDSS is an intelligent system that can make diagnosis and treatment (such as medication prescription [5]) for the patient. When no answer is available for a query, the system sends automatically an e-mail to an expert located elsewhere. After the response/feedback from the expert the knowledge base is updated. The general principle behind this CDSS is particularly similar to ours in the way its toolbox includes a teleexpertise system to get the answers of remote medical experts. Nevertheless in detail the operational functioning of a CDSS, only one medical professional (expert) can be contacted at a time while in our proposed tool, several medical professionals can be contacted in a collaborative manner in order to take the right decision. Furthermore, by using ontological approaches we guarantee semantic interoperability, decision support, flexibility of data management and integration [30].

Kamsu-Foguem [18] utilises the conceptual graphs to facilitate the systemic modelling and formal analysis of the requirements of information systems in telemedicine. As our work, he is also interested in ethical problems. However the author does not provide any information on how the proposed framework can be used in the act of teleexpertise to help medical professionals in their decision making process.

Conceptual graphs have also been used by [26,25,20] to represent medical information in order to ensure visual representations in the decision making process. This has been very useful for users because graphs make the information and knowledge modelling more user-friendly [24,25]. However, traceability of the reasoning has not been considered or dealt with in [24,25].

Many other works [20,23] deal with information visualisation applied in medical domain but not in telemedicine domain. Furthermore, [20] does not emphasise on the argumentation of the reasoning while in [23] the underlying reasoning steps are hidden from the user.

3. Conceptual graphs models

Conceptual graphs introduced by *Sowa* [36] meet the expectations of representational frameworks for argumentation. Indeed this representation support includes taxonomic principles and formal semantic to support the reasoning processes (e.g. mapping, deductive inference and constraints checking).

For the ease of understanding, the basic definitions and detailed explanations of conceptual graph models are examined in the ensuing section.

3.1. Basic graphs (BG)

Definition 1 (*Basic graphs support*).
BG support is a tuple $S=(T_C, T_R, I, \sigma)$ such that

- T_C and T_R are finite disjoint sets of types.
- T_C is a set of concept types partially ordered by the relation $\leq$, in which there is a universal element (called superconcept of all elements), denoted $\top$.
- T_R is a set of relation types partially ordered by the relation $\leq$, and partitioned in subsets $T_R^1, \ldots, T_R^k$ of relation types respectively with arity $1, \ldots, k$, and wherein the eventual universal elements are denoted by $\top_1, \ldots, \top_k$. The arity of a relation r is denoted as *arity*(r). Two relations with different arities are not comparable by $\leq$.
- I is a set of individual markers disjointed from T_C and T_R. In addition we denote by $*$, the generic marker. The set of markers is denoted $M = I \cup \{*\}$. This set is provided in the following partial order $\leq$: the elements of I are pairwise incomparable, and $\forall m \in I, m \leq *$. Each element of I can be assigned to several types and to all super-types thereof.
- σ associates to each j-ary relation $(r \in T_R^j)$ a signature namely a j-tuple of concept types $(\sigma(r) \in (T_C)^j)$, where the i-th concept is the maximal type for the i-th argument of the relation. The signatures comply with the orders defined in T_C and T_R namely: $\forall r_1, r_2 \in T_R^j, r_1 \leq r_2 \Rightarrow \sigma(r_1) \leq \sigma(r_2)$, i.e. for all $1 \leq i \leq j$, the i-th argument of $\sigma(r_1)$ is more specific than the i-th argument of $\sigma(r_2)$.

The support defined above represents the *vocabulary*. The ontological knowledge is defined in the vocabulary. This vocabulary helps to support the expression of basic graphs and also the fundamental operation for reasoning called projection, which is a graph homomorphism (i.e. a mapping with respect to the semantic structure of graphs). The facts are represented by basic graphs [9].

A basic graph is in normal form if each of its individual marker appears exactly once. This basic formalism has a semantic in first-order logic through a transformation denoted Φ [36]. The