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Technology applied to geriatric medicine

Knowledge-based modelling applied to synucleinopathies



B. Kamsu-Foguem^{a,*}, P.F. Tiako^b, E. Mutafungwa^c, C. Foguem^d

^a Laboratory of Production Engineering (LGP), EA 1905, ENIT-INPT, University of Toulouse, 47, avenue d'Azereix, BP 1629, 65016 Tarbes cedex, France

^b Center for IT Research, Langston University, OK 73050, USA

^c Aalto University School of Electrical Engineering, PL 13000, 00076 Aalto, Espoo, Finland

^d Center for Food and Taste sciences (CSGA) – UMR 6265 CNRS – UMR 1324 INRA – University of Burgundy, 9E, boulevard Jeanne-d'Arc, 21000 Dijon, France

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ABSTRACT

The adoption of telemedicine technologies has enabled collaborative programs involving a variety of links among distributed medical structures and health officials and professionals. The use for telemedicine for transmission of medical data and the possibility for several distant physicians to share their knowledge on given medical cases provides clear benefits, but also raises several unsolved conceptual and technical challenges. The seamless exchange and access of medical information between medical structures, health professionals, and patients is a prerequisite for the harmonious development of this new medical practice. This paper proposes a new approach of semantic interoperability for enabling mutual understanding of terminologies and concepts used. The proposed semantic interoperability approach is based on conceptual graph to support collaborative activities by describing how different health specialists can apply appropriate strategies to eliminate differential medical diagnosis. Intelligent analysis strategies are used to narrow down and pinpoint medical disorders. The model proposed is fully verified by a case study in the context of elderly patients and specifically dealing with synucleinopathies, a group of neurodegenerative diseases that include Parkinson's disease (PD), dementia with Lewy bodies (DLB), pure autonomic failure (PAF) and multiple system atrophy (MSA).

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1. Introduction

The current medical demography and its uneven distribution, particularly in some medical disciplines, are creating significant challenges in ensuring continuity of care. This has resulted in a pressing need for medical facilities in places where the shortage of specialists is acute. Telemedicine is a tool that enables equal access to medical expertise regardless of place of care [1]. This practice allows physicians of regional institutions to ensure access to competence for different medical investigations or cases and to benefit from the expertise of their colleagues from different specializations (radiology, surgery, psychiatry or neurology) [2]. Indeed, telemedicine has allowed doctors hospitals and clinics to have a network for accessing remote resources and complementary skills [3]. Other benefits of telemedicine include patients who are less tired and stressed and families who no longer have to travel long distances to visit their doctors [4]. Medical practitioners now have in their offices or in their local hospitals capacity identical to those at major hospitals. These advances are potential safeguard measures to ensure the protection of some local

hospitals. In summary, telemedicine provides impact in three key dimensions [5]:

- medical impact through improved medical diagnosis and treatment, as well as, the increased competence of practitioners participating in the network;
- territorial impact by maintaining skills and specialized services in hospitals and clinics in medium and smaller cities, especially in rural areas;
- medico-economic impact through reduction in the number of unnecessary transfers and the increase in the number of vital transfers with a useful gain for patients while controlling costs.

The era of technological networks in medicine is inevitable to improve the quality, safety, and continuity of care, while promoting equal access to high quality local care by promoting coordination and cooperation of all stakeholders. At the technological level, further progress can be made in the field of telemedicine if the main obstacles are overcome [6]. By deploying this technology in all remote hospitals or care centers, one improves connectivity by setting application of quality standards and building a relationship of trust. Telemedicine efficiency should allow equitable management of patients. It allows sharing of

* Corresponding author. Tel.: +33 6 24 30 23 37; fax: +33 5 62 44 27 08.
 E-mail address: Bernard.Kamsu-Foguem@enit.fr (B. Kamsu-Foguem).

quality image viewing stations (adapted diagnostic), flexible usage of resources (possibility of Web access), and, to ensure that the benefits of such telemedicine can be mutual, provides opportunities for technology transfer and improved efficiency in the healthcare sectors of partners institutions. The development of telemedicine is based on strengthening our innovation capabilities and requires sustained cooperation that cuts across the fields of health, industry, research, and defence [7]. A tele-consultation session can show the various documents available: image of a patient or physician, radiographic images, and other clinical data. In some circumstances, remote biotechnology tools can be used to perform enriched diagnostics by molecular techniques, targeting of pathogens, and identification of sensitivities to drugs in order to enhance treatment [8].

The rest of the paper is structured as follows. Section 2 exposes the material and methods with the conceptual graph operations used to implement the modelling of expert rules in collaborative decision-making processes. Section 3 presents the results with an illustrative case for the telemedicine management within the geriatrics field is presented. Finally, section 4 provides a discussion and section 5 concludes and discusses lessons learned and future challenges.

2. Material and methods

2.1. Knowledge formalization with conceptual graphs

The conceptual graph (CG) formalism is a knowledge representation language, which has a well-defined syntax and a formal semantics that allows one to reason from its representations [9]. The conceptual graph formalism is considered as a compromise representation between a formal language and a graphical language, because it is visual and has a range of reasoning processes [10]. Conceptual graphs can be used in many computer science areas, including text analysis, web semantics, and intelligent systems [11].

A simple conceptual graph is a finite, connected, directed, bipartite graph consisting of concept nodes (denoted as boxes), which are connected to conceptual relation nodes (denoted as circles). In the alternative linear notation, concept nodes are written within []-brackets while conceptual relation nodes are denoted within ()-brackets. The concepts set and the relations set are disjoint.

A concept is composed of a type and a marker [*<type>*:*<marker>*], for example [Disease: Idiopathic Parkinson's disease]. The type of concept represents the occurrence of object class. They are grouped in a hierarchical structure called a concepts lattice showing their inherit relationships. The marker specifies the meaning of a concept by specifying an occurrence of the type of concept.

A conceptual relation binds two or more concepts according to the following diagram:

$$[C_1] \leftarrow (\text{relation's name}) \leftarrow [C_2] \text{ (meaning that "C}_1 \text{ is related to C}_2 \text{ by this specific relation")}$$

In the analysis of telemedicine management, the most common relations are dependency relations, specifically, causal, conditional, temporal, and Boolean connectives, such as AND, alternating-OR and exclusive-OR relations. An example of conceptual graph is shown in Fig. 1: a medical activity is the agent of a telemedicine service and its duration is influenced by the diagnostic criteria. The semantics of the core and extended CGs is defined by a formal mapping to and from a common abstract syntax and

model-theoretic foundation for a family of logic-based notations (ISO/IEC 24707) [12].

A derivation is a finite sequence of these elementary operations that have a formal semantics based on a logical interpretation. As a result, the meaning of graph operations is determined in light of the derivation to be applied, based on a logical interpretation which gives full effect to the visual reasoning [13]. The derivation has one of three conceivable properties on the logical relationship between a starting graph u and the resulting graph v [14]:

2.1.1. Equivalence

Copy and *simplify* are equivalence rules, which generate a graph v that is logically equivalent to the original: the knowledge of u is included in v and the knowledge of v is included in u (logical meaning $u \subset v$ and $v \subset u$).

2.1.2. Specialization

Join and *restrict* are specialization rules, which generate a graph v that implies the original: v contains more specific knowledge than u (logical meaning $v \subset u$).

2.1.3. Generalization

Detach and *unrestrict* are generalization rules, which generate a graph v that is implied by the original: v contains less precise knowledge than u (logical meaning $u \subset v$).

Ontological knowledge provides a formal description of the studied system [15] with associated experiences and lessons learned [16,17].

2.2. Exploitation of conceptual graphs representation in reasoning

A formal knowledge modelled by CGs in experience feedback processes can be a very useful tool for conveying accurate meaning to a collaborative work environment involving domain experts [18]. For a given application, several viewpoints of expertise may be engaged in combination. For example, some investigations to improve the availability of a geriatric health care system can involve expert knowledge in tele-expertise and associated remote practices.

During the knowledge modelling phase of the telemedicine rules, the use of CG properties will help to enrich the telemedicine knowledge base in order to ease their access, sharing and reuse by the members of the telemedicine management in their individual and collective tasks. Furthermore, experience gained and lessons learned from initial problem solving developments will be applied as soon as possible in similar situations in other collaborative telemedicine activities with temporal modelling considerations [19].

In conceptual structures, the operations of visual reasoning with semantic mapping form the bridge from perception to different forms of conceptual operations, ranging from specialization and generalization to unification [20]. When the conceptual graphs operations are used in the visual reasoning, semantic comparisons are deployed at every step, and the only difference between deduction and analogies is the nature of the orientations on the reasoning [21]. Particularly, one conceptual graph is similar to another if there is a semantic mapping (graph homomorphism) from the first graph to the second one. In this context, the case-based reasoning can be engaged to search some unknown features of a new case from its known features and previous cases stored in the cases base. In analogical reasoning, the conceptual structure that describes known features of the new case is compared with the matching features of the conceptual structures associated to previous cases [22]. The assessment takes into account the determined degree of similarity and classified alternative options for other cases. The case that provides the greatest correspondence

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