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Capturing Provenance, Evolution and Modification of Clinical Protocols via a Heterogeneous, Semantic Social Network

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Abstract. Healthcare delivery is largely based on medical best practices as in clinical protocols. Research so far has addressed the computerized execution of clinical protocols by developing a number of related representation languages, execution engines and integrated platforms to support real time execution. However, much less effort has been put into organizing clinical protocols for use and reuse. In this paper we propose a heterogeneous semantic social network to describe and organize clinical protocols based on their provenance, evolution and modifications. The proposed approach allows semantic tagging and enrichment of clinical protocols so that they can be used and re-used across platforms and also be linked directly to other relevant scientific information, e.g. published works in PubMed or personal health records, and other clinical information systems.

Keywords. Clinical protocols, semantic social network, ontology, provenance.

1. Introduction

Healthcare delivery is largely based on medical best practices. These are typically captured in clinical protocols (or algorithms), that is, detailed statements that set out a precise sequence of activities to be adhered to in the management of a specific clinical condition [1]. Clinical protocols are usually derived from clinical practice guidelines, which are consensus statements, systematically developed to assist health professionals in clinical practice decision-making, and are considered formal general recommendations for prevention, diagnosis, treatment, long-term management of disease or advice and information [2]. Often clinical protocols are merged into care pathways, which are multidisciplinary plans care that outline the optimal sequencing and timing of interventions for patients for integrated care including procedures inside and outside the health care unit [3].

Research so far has rigorously addressed the computerized execution of clinical protocols and this has resulted in a number of related representation languages, execution engines and integrated platforms to support the real time execution [4],[5]. However, much less effort has been put into organizing available clinical protocols. Mainly, they are maintained in data silos of the respective issuing body without means for straightforward seamless integration and open availability.

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In this work we build on the paradigm of social associations among human and non-human entities alike and propose a novel approach to describe and organize clinical protocols for easy use and reuse. The following sections discuss different perspectives of clinical protocol provenance, evolution and modification and present a novel approach for organizing, and managing clinical protocols via a heterogeneous, semantic social network.

2. Clinical Protocol Provenance, Evolution and Modification

The clinical protocol origin is of outmost importance for a number of reasons. The first is provenance: no one could (or should) trust data purporting to represent medical knowledge without the ability to trace it back to its source. Clinical protocols are usually derived as detailed manifestations of clinical practice guidelines, which in turn are based on scientific medical evidence as published in scientific literature. Sources of such evidence can range from small in vitro studies or case reports to systematic randomized clinical trials. Evidence based clinical recommendations can be of different quality, thus information on their grading is essential. Several systems and approaches have been proposed for grading clinical practice guidelines; the most widely adopted being the GRADE system [6].

Clinical protocols are issued by authoritative institutions, such as national and international health organizations and other related regulatory bodies. As legal and financial issues may arise from the use and deployment of a clinical protocol, the issuing body may prove to be a critical factor. Finally, a protocol may be altered as new evidence is available, thus leading to updates and new versions. The time evolution of a clinical protocol and the curation of its different versions are important for maintaining continuity, especially for legal, financial and scientific purposes.

While discussing the origin of a clinical protocol, one should also add another factor: often clinical protocols are subject to changes during their deployment in clinical practice. These deviations may be due to a number of reasons [7]; most common ones include local lack of resources, e.g. diagnostic equipment, a low strength recommendation, specific requirements of a concurrent clinical trial protocol, patient refusal to follow certain protocol's steps (e.g. due to religious or other personal issues), insurance policy requirements (e.g. to firstly perform a lower cost procedure), presenting comorbidities not accounted for in the original protocol, or even health professional's direct disagreement due to new contradicting high level medical evidence. For such justified reasons, clinical protocols may be adapted to local settings. In this case, one has to record the provenance of the adapted protocol i.e. the initial parent protocol.

In this work, the notion of social media is employed to give a different perspective to clinical protocol provenance, evolution and modification, by creating social networks of clinical protocols where, amongst else, provenance, evolution and modification are used as basic social relationships among clinical protocols, issuing bodies and medical practice units in order to drive protocol organization, retrieval, evaluation and reuse.

3. A Heterogeneous, Semantic Social Network for Clinical Protocols

In the broader sense, 'social' means 'association, as the word derives from the Latin 'socius' meaning a companion or associate [8]. In the first days of deploying social internet applications, the term 'social' has been used in the narrower sense to refer primarily to human aggregates among themselves. Following this first generation of human-centered social networks, the notion of object-centered sociality has been introduced to describe the fact that strong social relationships are built mainly when individuals are grouped together around a shared object [9], [10]. In this paper we follow a more radical view [11] for truly heterogeneous social networks where humans and nonhuman entities of various types are integrated into the same conceptual framework and assigned equal amounts of agency.

The proposed heterogeneous network can be viewed as a number of distinctive and interacting networks of clinical protocols, issuing bodies, health units using the protocols, and finally patients who undergo protocols. Interactions and relations between clinical protocols are mainly based on their evolution and modification. Each protocol which has been derived as a new version or a modification of an existing protocol, declares its parent. Following iteratively the 'parents' in a chain of ancestors, the entire 'family' tree of the particular protocol can be compiled. Additionally, there are relationships between protocols and their issuing bodies and healthcare units that use them in clinical practice. Overall protocol relationships in the social network include (Figure 1): (1) protocol provenance from a clinical practice guideline and/or scientific evidence source; (2) protocol provenance from a particular issuing body; (3) protocol evolution as an update to a previous version; and (4) protocol modification due to a variety of reasons, including different language, clinical restrictions due to concurrent clinical protocols, restrictions due to comorbidities, infrastructure limitations, patient choices and objections, insurance policy constraints.

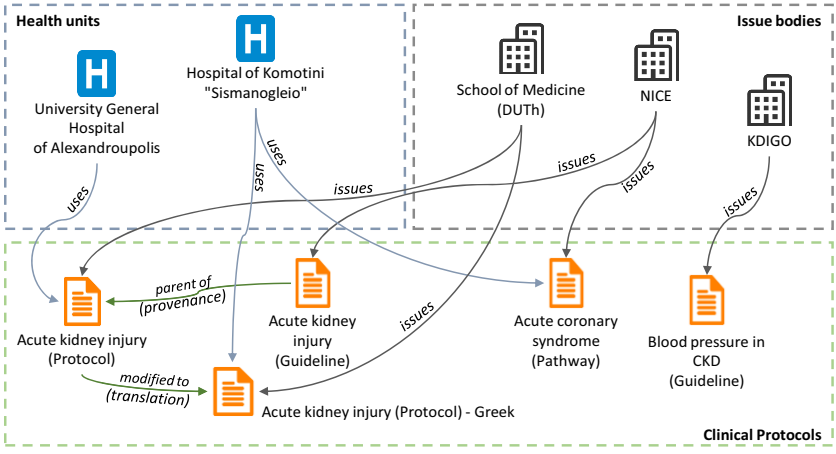

Figure 1. Clinical Protocols' relationships in the semantic social network.

In implementing such a network, major challenges include a unified treatment and representation of all types of possible actors as well as the development of a social behavior for various nonhuman actors, and subsequently their own associations and networks. Both challenges can be addressed by semantic technologies. The profile of

the clinical protocol is described by the formal care plan eCP ontology [12] (available at *http://purl.bioontology.org/ontology/ECP*). This includes attributes that pertain to (1) general information, e.g. title, date published, short description; (2) protocol classification based on related health issue, and/or clinical goal; (3) issuing body, evidence source and quality and level of recommendation; (4) medical condition for initializing the protocol; (5) protocol outcomes or exit points; (6) required resources, e.g. imaging or therapeutic equipment; and (7) technical information on the protocol source files. Issuing bodies and healthcare units are described following the SWRC ontology [13]. Also, the social aspect of non-human actors can be created in a variety of ways, including (a) the obvious connections via common tags that are used in their profile description; (b) connections based on collective usage and other related interaction of human users, i.e. what human users do with the nonhuman entities; (c) social connections based on some type of inheritance, i.e. non-human entities that are generated or are the product of other resources, in the sense of the genealogy tree; and (d) semantic connections and similarities that can be built based on profile data enrichment via controlled medical vocabularies, e.g. UMLS.

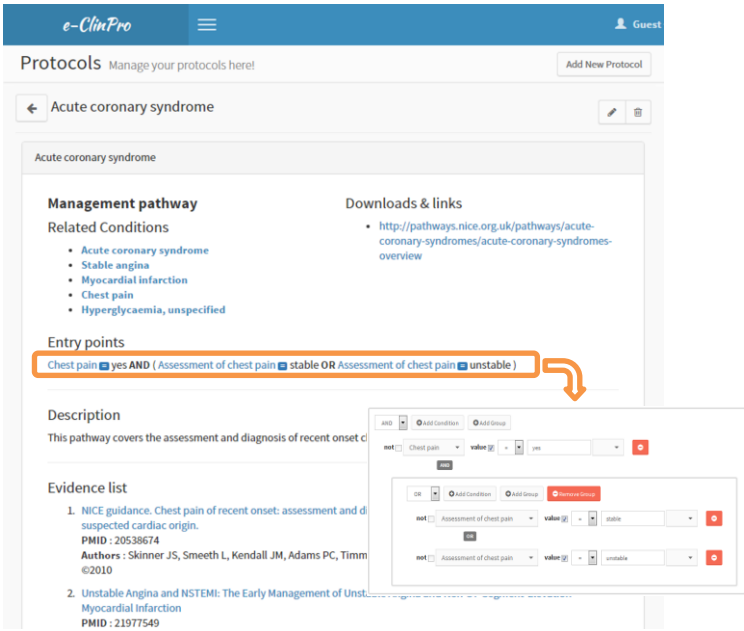

Figure 2. Preview of care plan profile including a preview of the editor for the initialization condition.

The current deployment of the proposed social network engine (Figure 2) is implemented using LoopBack framework (http://loopback.io) and is accessible at http://iris.med.duth.gr/research/ecp. Data storage is based on the MongoDB (https://www.mongodb.org) and is publicly available through the Swagger programming interface (http://swagger.io/swagger-ui). The social network frontend is powered by AngularJS framework (https://angularjs.org) and the graph visualizations use Vis.JS library (http://visjs.org). Integration with controlled vocabularies and ontologies is via the NCBO BioPortal programming interface

(http://data.bioontology.org), while scientific evidence source information is automatically retrieved via the PubMed programming interface.

4. Discussion

This paper proposes a heterogeneous semantic social network to describe and organize clinical protocols based on their provenance, evolution and modifications. The goal of our network allows semantic tagging and enrichment of clinical protocols so that they are easily accessible from different platforms and also be linked directly to other relevant scientific sources and vocabularies. Future plans involve the expansion of this social network engine in order to support relationships between doctors and patients. This feature promises to reveal clinical protocols' popularity and acceptability in the medical community and additionally the differentiation between the actual results of their application and their defined outcomes.

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