Towards a Multi-Viewpoints Ontological Framework for Knowledge Sharing in E-health*

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Abstract

The field of e-Health has seen the widespread adoption of ontological representations, especially in the semantic description of drugs through various ongoing initiatives. However, it is increasingly recognized that creating a single universal E-health ontology may not be feasible, as different tasks and perspectives require distinct conceptual choices. As a result, there is a need to support scenarios where different stakeholders adhere to different viewpoints that cannot be reconciled by imposing a global ontology. This study addresses the challenge of representing an e-health ontology by considering diverse viewpoints and terminologies used by different domain actors. This unique ontology, termed a "multi-viewpoints e-Health ontology," encompasses multiple partial descriptions of the same domain, each relative to a specific viewpoint. Additionally, these partial descriptions share common ontological elements and semantic bridges to establish a consensus among the various viewpoints.

Keywords

Semantic Modeling, Ontology, Viewpoint, Interoperability, E-health

1. Introduction

Ontologies serve as a formal representation of the collective knowledge held by domain experts, explicitly defining the concepts believed to exist within that specific domain and elucidating the interconnections among these concepts [1]. In the field of engineering, they play a crucial role in facilitating knowledge exchange between different applications.

In recent years, the field of e-Health has undergone a significant transformation with the widespread adoption of ontological representations, particularly in the semantic description of drugs through various ongoing initiatives. The use of ontologies has played a crucial role in enhancing the understanding and interoperability within e-Health systems. Despite these advancements, a critical challenge has emerged in the form of the realization that creating a single universal e-Health ontology may not be a feasible endeavor. This recognition stems from

Joint Proceeding of Second International Workshop on Semantic Reasoning and Representation in IoT (SWIoT-2023) and Third International Workshop on Multilingual Semantic Web (MSW-2023), November 13-15, 2023, University of Zaragoza, Zaragoza, Spain

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the understanding that different tasks and perspectives within the e-Health domain necessitate distinct conceptual choices.

The limitations of a one-size-fits-all approach to e-Health ontology have given rise to the need for innovative solutions that can accommodate diverse viewpoints among stakeholders. There is a growing acknowledgment that imposing a global ontology may not be practical in scenarios where different actors in the domain adhere to disparate perspectives that cannot be easily reconciled.

Given that there are often multiple approaches to comprehending the knowledge within a particular domain, the task of ontology representation can be quite challenging [2]. This complexity arises primarily from the difficulty in achieving consensus on the definitions of concepts within that domain, which should align with each user's unique perspective and viewpoint on the subject.

The challenge of ontology representation primarily arises from the presence of multiple user communities interested in the same domain but approaching it from distinct viewpoints. These diverse communities coexist and collaborate within a multidisciplinary environment, each pursuing its own interests and interpreting the conceptual entities within the same domain in a unique manner. The work in [3] illustrates this complexity in the context of oncology, a multifaceted domain involving various specialties such as chemotherapy, surgery, and radiotherapy, each representing a specific viewpoint. Decisions made within a particular local viewpoint, corresponding to a specific oncology specialty, can significantly impact decisions made within other local viewpoints.

In recent years, there has been an increasing interest in semantic interoperability in the e-Health domain [4]. Semantic interoperability is about sharing data among different systems and actors. It is also related to foster a consistent usage of the terminology (drugs and bio-medical knowledge bases), and the adoption of shared and standard models of clinical data. In short, semantic interoperability goes to the underlying objective of formalizing the health science using shared or linkable models [5].

One of the key aspects to tackle in order to achieve semantic interoperability is the usage of common or interoperable terminologies about drugs, diseases, treatments and so on. Different actors (governmental bodies, hospitals, labs, key industries, etc.) should be able to understand the terminology used by others. To complicate matters, it is quite common that different systems in the same organization do not use the same terminology.

This paper addresses this pertinent challenge by delving into the intricate task of representing an e-Health ontology that considers the diverse viewpoints and terminologies used by various stakeholders in the domain. The proposed solution introduces a novel concept—the "multi-viewpoints e-Health ontology." This latter based on the multi-viewpoints model proposed in [3, 6], encapsulates multiple partial descriptions of the same domain, each aligned with a specific viewpoint. Moreover, these partial descriptions are designed to share common ontological elements and semantic bridges, facilitating the establishment of a consensus among the various perspectives within the e-Health landscape.

As we navigate the intricacies of e-Health ontology representation, this paper aims to shed light on the importance of accommodating diverse viewpoints in a field where collaboration and interoperability are paramount. By addressing this challenge head-on, we aim to contribute to the advancement of e-Health systems that better serve the needs of a wide range of stakeholders.

The remainder of this paper is organized as follows. In Section 2, we briefly revisit the basic definitions of description logics. In Section 3, we provide an overview of ontology development in the context of e-health. Section 4 introduces and identifies the main objectives of the multi-viewpoint approach. We present the approach in Section 5. Finally, Section 6 concludes this paper and discusses future work.

2. Description Logics

Description Logics (DLs) represent a family of knowledge representation languages extensively utilized in ontological modeling. One compelling factor contributing to their widespread adoption is their pivotal role as a foundational component of the OWL Web Ontology Language, standardized by the W3C. The term ”logic” in DLs indicates that they are built upon a logical formalism, complete with a model-theoretic semantics.

The fundamental modeling elements in DLs include concepts (classes of objects), roles (binary relations between objects), and individuals (named objects). Leveraging these modeling elements, Description Logics incorporate constructors to specify concept expressions, which, in turn, define necessary and sufficient conditions for membership in the concept they articulate. Fundamental reasoning tasks associated with these logics involve verifying the satisfiability of an expression (i.e., determining whether it is possible for an object to satisfy the membership condition) and deciding subsumption between two concepts (i.e., deciding whether one concept expression implies another). Let's now delve into these issues at a more formal level.

Let C and R denote countably infinite and disjoint sets of concept names and role names, respectively. Concept expressions are generated by applying specific operators to these concept and role names. Specifically, new concept expressions are derived from existing ones using Boolean operators or by introducing constraints on the type and quantity of objects related to those described within the concept. Formally, the set of concepts (or concept expressions) in the description logic is defined as the smallest set such that:

- $\top$ and $\bot$ are concept expressions for the most general concept and the unsatisfiable concept, respectively;
- every concept name A is a concept expression;
- if C and D are concept expressions, r is a role name and n is a non-negative integer, then $\neg$C, C $\cap$ D, C $\cup$ D, $\exists$r.C, $\forall$r.C, ($\geq$n r.C) and ($\leq$n r.C) are concept expressions.

3. E-health Ontologies

E-health (electronic health) is the transfer of health resources and health care by electronic means, in particular over the Internet. It encompasses three main areas:

- The delivery of health information, for health professionals and health consumers, through the Internet and telecommunications;
- Using the power of IT and e-commerce to improve public health services, e.g. through the education and training of health workers;

- The use of e-commerce and e-business practices in health systems management.

E-health provides a new method for using health resources - such as information, money, and medicines - and in time should help to improve efficient use of these resources. The Internet also provides a new medium for information dissemination, and for interaction and collaboration among institutions, health professionals, health providers and the public. Semantic AI in healthcare, particularly in cancer care, revolutionizes the way data is processed, understood, and applied.

Ontologies have found extensive applications in the field of biomedicine [7] and [8], with many of them being accessible through various online ontology repositories [9] such as Bioportal, Open Biological and Biomedical Ontologies Foundry, or the Protege library [8]. Additionally, several ontology editors have played a significant role in the development of biomedical ontologies. An examination of published biomedical ontologies reveals a clear distinction between two main categories: ontologies related to healthcare management and those focused on specific biomedical sub-domains.

A review of published biomedical ontologies suggests a distinction between ontologies about health-care management (i.e., ontologies about the concepts involved in the organization of health-care activities), and ontologies about biomedical sub-domains (i.e., ontologies about biomedical concepts). Some representative examples of health-care management ontologies are the Actor Profile Ontology [10], an ontology to structure organizational health-care knowledge for home care, and the ontology in [11] which is conceived to describe adaptive medical workflows. On the contrary, the Ontology for General Medical Science [12] is an example of biomedical domain ontologies.

In the field of e-health ontology construction, existing methodologies tend to oversimplify the complex and multifaceted nature of the subject matter. These conventional approaches primarily advocate the development of a single, all-encompassing model based on a solitary perspective of the observed world. In contrast, the viewpoint approach offers a more flexible and nuanced alternative. It allows us to model the same domain from multiple angles or viewpoints, acknowledging the diversity of perceptions and interpretations that can exist within the e-health domain.

4. Viewpoint Approach: Unveiling Multifaceted Perspectives

The viewpoint approach is a strategic lens through which complex systems are comprehensively understood, dissected, and modeled. Rooted in the recognition that a single perspective may not capture the intricacies of multifaceted entities, this approach embraces the concept of viewpoints, each offering a unique vantage point into the system under study.

- Facilitating Multiple Descriptions: The cornerstone of the viewpoint approach lies in its capacity to provide multiple descriptions of a given entity [13]. Recognizing that real-world entities exhibit diverse behavioral contexts and states, this approach allows for the creation of several partial descriptions [14]. Each of these descriptions contributes to a holistic understanding, capturing the entity's nuances from distinct viewpoints. This

multifaceted representation enables a more nuanced and comprehensive interpretation of the subject.

- Mastering System Complexity: Tackling the inherent complexity of systems is a formidable challenge. The viewpoint approach addresses this challenge head-on by breaking down the system into comprehensible components. Through this strategy, researchers and developers can explicitly account for various facets of complexity, creating a clearer and more manageable framework for analysis and design.
- Modeling and Distributed Development: Complexity in system modeling necessitates innovative approaches. The viewpoint approach emerges as a powerful tool for modeling and facilitating distributed development. Recognizing that complex systems demand unique techniques compared to their simpler counterparts, this approach advocates representing every facet of the development process through correlated viewpoints. This not only streamlines the modeling process but also promotes a distributed and collaborative approach to system development.

In essence, the viewpoint approach stands as a methodological paradigm that acknowledges the diversity and intricacies inherent in complex systems. By embracing multiple perspectives, it not only provides a richer understanding of entities but also offers practical strategies for managing and developing intricate systems in a distributed and collaborative fashion.

5. Approach: Embracing Diversity in E-Health Ontology

The landscape of e-Health has witnessed a significant uptake of ontological representations, particularly in the semantic delineation of drugs, driven by numerous ongoing initiatives. However, the realization is growing that the creation of a singular, universal E-health ontology may be impractical. This stems from the understanding that disparate tasks and perspectives within the e-Health domain necessitate unique conceptual frameworks. Consequently, there arises a pressing need to accommodate scenarios where diverse stakeholders adhere to distinct viewpoints, resistant to reconciliation through the imposition of a global ontology.

1. Recognizing Diversity in Tasks and Perspectives:

Acknowledging the multifaceted nature of e-Health, this approach begins by acknowledging that different tasks and perspectives demand tailored conceptual choices. A one-size-fits-all solution is deemed unattainable, leading to the exploration of an alternative paradigm that accommodates the inherent diversity within the e-Health landscape.

2. Supporting Stakeholder-Specific Viewpoints:

The approach advocates for a departure from the pursuit of a singular, overarching E-health ontology. Instead, it proposes the support of scenarios where various stakeholders operate within their unique viewpoints. These distinct perspectives, often arising from different roles and responsibilities within the domain, are acknowledged and accommodated in the ontology design process.

3. Introducing the Multi-Viewpoints E-Health Ontology:

At the core of this approach is the development of a groundbreaking ontology—termed the ”multi-viewpoints e-Health ontology.” Unlike traditional ontologies, this unique construct

encapsulates multiple partial descriptions of the same domain, each intricately tied to a specific viewpoint. This innovative ontology accommodates the diverse terminologies and perspectives used by different actors within the e-Health domain.

4. Fostering Consensus Through Shared Elements:

In navigating the challenge of reconciling divergent viewpoints, the approach emphasizes the inclusion of common ontological elements and semantic bridges. These shared components act as connectors, fostering consensus among the various perspectives represented within the multi-viewpoints e-Health ontology.

For our requirements of multi-viewpoints E-health ontology representation, we apply the following notions [3, 6]:

- Multi-Viewpoints Ontology: Is a multiple description of the same universe of discourse according to various viewpoints. It is defined as a 4-tuple of the form $O = (C^G, R^G, Vp, M)$, where C^G a set of global concepts, R^G a set of global roles, Vp a set of viewpoints, and M a set of bridge rules.
- Viewpoint: Is defined as a triple $VP_K = (C^L, R^L, A^L)$, where C^L a set of local concepts, R^L a set of local roles, and R^L a set of local individuals.
- Global Concept: Is used to represent a concept or entity of the real word which is observed from two or several viewpoints, at the same time, with basic and common properties (i.e. attributes).
- Local Concept: Is used to represent a concept which is viewed and described locally according to a given point of view.
- Global Role: It's a relationship between two local concept defined in two different viewpoints.
- Local Role: It's a relationship between two local concepts defined in the same point of view.
- Stamps: We adapt the stamping mechanism used in [15] to allow multiple representations of concepts. In our approach, stamps (i.e. labels) permits each ontological element (i.e. concepts, roles, individuals) to be known by the viewpoint that it belong to.
- Bridge Rule: The particularity of the multi-viewpoints representation is the existence of a communication channel among various viewpoints. This communication channel, called bridge rule, allows representing links between local concepts of different viewpoints.
- Multi-Viewpoints Instantiation: The multi-viewpoints instantiation mechanism allows an individual to belong to more then one local concept according to different viewpoints.

In essence, this approach advocates for an inclusive and adaptive ontology design that recognizes the diversity inherent in e-Health. By embracing multiple viewpoints and establishing common ground, the multi-viewpoints e-Health ontology stands as a pioneering solution to the challenge of representing the complex and varied landscape of e-Health information.

6. Conclusion and Perspective

The field of e-Health has widely embraced ontological representations, particularly in the semantic description of drugs through various ongoing initiatives. However, there is a growing

acknowledgment that creating a single universal e-Health ontology may not be feasible, as different tasks and perspectives require distinct conceptual choices. Consequently, there is a need to support scenarios where different stakeholders adhere to different viewpoints that cannot be reconciled by imposing a global ontology.

In this paper, we have addressed the challenge of representing an e-health ontology by considering diverse viewpoints and terminologies used by different domain actors. The proposed solution is a unique ontology termed a "multi-viewpoints e-Health ontology," which encompasses multiple partial descriptions of the same domain, each relative to a specific viewpoint. Furthermore, these partial descriptions share common ontological elements and semantic bridges to establish consensus among the various actors in the field of e-Health.

Innovative in its approach, this multi-viewpoints e-Health ontology overcomes challenges associated with the diversity of perspectives in the e-Health domain, paving the way for enhanced understanding and more effective collaboration among stakeholders.

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