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The Role of Ontologies for Sustainable, Semantically Interoperable and Trustworthy EHR Solutions

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Abstract. As health systems around the world turn towards highly distributed, specialized and cooperative structures to increase quality and safety of care as well as efficiency and efficacy of delivery processes, there is a growing need for supporting communication and collaboration of all parties involved with advanced ICT solutions. The Electronic Health Record (EHR) provides the information platform which is maturing towards the eHealth core application. To meet the requirements for sustainable, semantically interoperable, and trustworthy EHR solutions, different standards and different national strategies have been established. The workshop summarizes the requirements for such advanced EHR systems and their underlying architecture, presents different strategies and solutions advocated by corresponding protagonists, discusses pros and cons as well as harmonization and migration strategies for those approaches. It particularly highlights a turn towards ontology-driven architectures. The workshop is a joint activity of the EFMI Working Groups "Electronic Health Records" and "Security, Safety and Ethics".

Keywords. electronic health records, interoperability, ontology, EHR architecture, eHealth platform

1. Introduction

Distribution, specialization and integration of health services are becoming globally accepted approaches for meeting the challenge of increased quality and safety of patient care as well as the efficiency and efficacy of care delivery processes, thereby

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turning health systems towards the personalization of care and its augmentation including prevention, home care, elderly and lifestyle services. This approach is also called personal health or pHealth. For supporting such developments, the Electronic Health Record (EHR) as the comprehensive informational reflection of the care subject's status and the related care processes is maturing to become the core application of any eHealth environment.

The necessary communication and cooperation in the context of the advanced care paradigm must be enabled by interoperable information systems, providing different interoperability levels for different purposes. Such health information systems including advanced EHRs have to meet specific requirements such as: openness, scalability, flexibility, portability, being based on standards, service-orientation, user-friendliness, lawfulness, trustworthiness, etc.

2. The Computation-Independent Interoperability Challenge

The interoperability challenge for communicating and cooperating entities has to be met first at a computation-independent level. Intended business objectives, underlying policies, organizational and social constraints including culture, environmental conditions and domain-specific constraints such as care setting workflows, education, specific methodologies and knowledge expression means are essential aspects impacting on interoperability. Therefore, describing those aspects and harmonizing them including the harmonization of the different expressions used and the resulting interpretation is the real challenge of any communication and cooperation.

The principles ruling real-world entities and their interrelations in the sense of describing a domain's inherent structure and behavior are the business of ontologies. Insights into the nature of things are a prerequisite to avoid misconceptions. Therefore, semantic identifiers and formal descriptions representing the (classes of) entities of a domain should be ruled by ontologies. Starting from a generic description using top level ontologies, the description can be refined or constrained by the application of domain knowledge under a domain ontology, going down to the application level (application ontology) or its ICT implementation (ICT ontology), which will be discussed in Section 4. Following this pathway through a system of ontologies, the outcome is increasingly determined by abilities, experiences, knowledge education, but also by the available technologies deployed. For enabling semantically interoperable, sustainable and trustworthy eHealth systems with an appropriate EHR system as core application, the entire system of ontologies (or being less sophisticated and more restricted, the system of descriptions and models) and its harmonization have to be managed.

3. The Architectural Approach to Semantically Interoperable pHealth Systems

The architectural approach to semantically interoperable and sustainable pHealth systems must start with the business process and the required services for achieving the intended objectives supported by the system in question. This business process concerns different aspects reflected by different domains such as medical (with specializations), technical, legal, financial, etc. For meeting the requirements mentioned in the introduction, the system consists of components realizing certain

functionalities. The component aggregation (composition) enables a higher complexity of the system's structure and behavior. The different aspects can be separately modeled by specializing the system model into domain models. These domain models, which have to follow the architectural approach of composition/decomposition (generalization/specialization), are interrelated and constrain each other. Finally, the architecturally and domain-specifically described pHealth system must be formally specified and implemented as ICT solution. This process is defined in ISO/IEC 10746 "Information technology – Open distributed processing – Reference model" (ODP-RM) [1] or in the Rational Unified Process (RUP) [2]. For this purpose, ODP-RM defines the enterprise view, the information view, and the computational view as platform independent perspectives as well as the engineering and the technology view as platform-specific ones. This architectural framework of any system has been comprehensively summarized, e.g., in the Generic Component Model [3].

The challenge of any system architecture is its conceptualization, i.e., the description of the system with its components and their logical interrelations. This has to be done from an overall perspective as well as from the perspectives of the different domains, including the ICT implementation.

This is the point where ontologies come in again. In the past, both Ontology as a philosophic discipline and its applications as domain ontologies have been managed more or less independently from ICT systems developments. Aspects of ontologies (or vocabularies in a broader sense) have been directly bound to individual ICT systems architectures, if considered at all. When modeling is performed independent from reality, the outcome might not meet the real objectives, which is a source of conflicts between modelers and ontologists.

Construction rules and knowledge representation are becoming more challenging with the greater complexity of the architectural perspective and as more highly complex domains are included in the system. As a consequence, the formalization and expressivity of the model representation regarding concepts and relations has to be adapted to the appropriate ontology language level. On a coarse grained scale, we can distinguish the four ontology language levels: glossaries and data dictionaries; thesauri and taxonomies; meta-data and data models; formal ontologies. For more details have a look at [4]. Between domains, the challenge is even bigger – unfortunately often represented in gobbledygook or technical jargon.

The integrative approach to health information in general and the development of eHealth/pHealth in particular require the integration of ontology-driven and formally modeled system architectures. The need for such a solution became especially obvious in the context of EHR systems as eHealth/pHealth core applications.

4. Existing Standards for Semantically Interoperable EHR Systems

There exists a huge number of current and emerging standards as well as national initiatives concerning EHR architectures and EHR systems. To meet the challenge of delivering semantically interoperable, multi-disciplinary EHR solutions, the problem of concept and knowledge representation and of mapping different representational artefacts between disciplines and jurisdictions in the sense of ontology management and harmonization has to be mastered. This process suffers from immaturity of those specifications. Although the complexity and architectural maturity of the HL7 standards set is increasing, the *open*EHR approach and the Archetype basis of EN/ISO

13606 [5, 6] are so far the only international specifications and standards that are formally based on ontologies. The integration of ontologies is the objective of the International Health Terminology Standards Development Organization (IHTSDO), which came out of SNOMED [7].

On the other hand, the architectural perspective of systems (composition/ decompositions) and the development process from the requirements analysis (functional models, service functional models) up to model-driven development and implementation must be specified. This includes formally modeling systems following an ICT ontology. Here, standards such as HL7, OMG specifications or ISO 12967 Health informatics – Service architecture (HISA) are more successful. Finally, standards harmonization is inevitable, which is the concern of the Joint Initiative on SDO Global Health Informatics Standardization [8].

5. Objectives and Structure of the Workshop

The workshop aims at a discussion of requirements and solutions for sustainable, semantically interoperable and trustworthy EHR solutions, thereby considering the role of ontologies, related principles and international standards. In this context an overview will be given of the main architectural and paradigmatic streams, existing and emerging specifications, and the most important international and national EHR projects. The presentation and discussion of the different competing approaches as well as national programs is organized as a panel, enabling open consideration of potentially controversial viewpoints.

Barry Smith will answer the question, why ontologies are needed to achieve EHR interoperability. After briefly introducing internationally accepted EHR requirements the state of the art for EHR architectures and related standards, Bernd Blobel will present an architectural framework for semantically interoperable and sustainable EHR solutions. Dipak Kalra will discuss ISO 13606 EHR communication as well as the *open*EHR Foundation's achievements. Both specification sets are based on the ontology of clinical processes expressed as Archetypes, representing the only existing ontology-based EHR standard. Marc Koehn will give an overview on Canada's journey towards an ontology driven EHR, claiming: "Let's walk before we run!" He will explain that this journey is driven given a very particular organizational context and political responses, describing this context and the way to tackle Canada's EHR solution in the first instance and positioning for ontology orientation over time. Harmonizing all relevant standards like Canada does, Ken Lunn will highlight the NHS approach, based on UK's unique approach to a national health system. Pekka Ruotsalainen will present the Finnish project "Trusted eHealth and eWelfare Information Space", which considers ontology-based and model-driven methodologies. Stefan Schulz will analyze the role of natural languages in the EHR, thereby focusing on: rationale for using free text in EHR; relation between unstructured text, standardized document formats, ontologies and information models; difficulties of extracting information from free text; importance of new usability paradigms for bridging the gap between textual and structured documentation in the EHR. As trustworthiness is crucial for the acceptance of any eHealth/pHealth solution, Peter Pharow discusses security, privacy and safety requirements in future, personalized care settings. In that context, he will especially emphasize the role of personalized portable devices.

eHealth communication and cooperation cannot be restricted locally, regionally or nationally, but needs to be implemented internationally at a European or even global scale. The harmonization of different solutions, mapping schemes and migration strategies are inevitable. Therefore, the invited experts, and participating scientists and practitioners from the audience, will discuss the pros and cons of the solutions presented, inform about emerging activities with the objective of considering what might be the best practice solutions and migration strategies needed. In the last part of the workshop, experts and participants are challenged with the formulation of candidate strategies and recommendations for fostering international solutions.

The workshop is jointly organized by the EFMI Working Groups "Electronic Health Records" and "Security, Safety and Ethics" and will be moderated by Bernd Blobel.

6. Conclusions

eHealth/pHealth information systems have to meet specific paradigms, in particular: distribution; component orientation; being based on a reference architecture as well as formal concept, context and knowledge representation; offering security and privacy services embedded in the architectural components; following a unified process for analysis, design, implementation and deployment; and many others. In that context, the role of ontologies for domain representations is growing. Meeting clinical and business requirements, the solutions must respond to current challenges as well as offer migration paths and roadmaps to the future.

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