Why do We Need and How Can We Realize a Multi-Disciplinary Approach to Health Informatics?

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Abstract. Like no other area, health and social care are characterized by a multi-disciplinary nature. This development gets even stronger by the move towards a personalized, predictive, preventive and participative care paradigm as well as by organizational and technological changes leading to highly distributed care setting realized by multiple stakeholder communities from different policy domains. Those paradigm changes result in growing interoperability challenges when enabling communication and cooperation of all the different actors based on shared knowledge and skills. For meeting those challenges, a systems-oriented, architecture-centric, ontology-based and policy-driven approach in health informatics education, but also in modeling, implementing and maintaining health informatics interoperability is inevitable. The paper introduces the aforementioned concepts.

Keywords. Health informatics, interoperability, systems, architectures, ontologies, education

Introduction

Health informatics is defined as a discipline at the intersection of information science, computer science, social science, behavioral science and health care [1]. It is however not just the combination of the aforementioned scientific disciplines, which is challenging us. Also the single fields mentioned are not homogenous at all. Currently, medicine turns from general care addressing diseases by one solution fitting all (phenomenological approach) through dedicated care by stratification of population for specific clinically relevant conditions (evidence based medicine) to personalized, preventive, predictive and participative care considering individual health state, conditions and contexts. The latter implies investigation and understanding of origin and mechanisms of all health related processes [2]. As a consequence, the matter of medicine covers the continuum from chemical elements through inorganic compounds, organic basic elements, macromolecules, cell organelles, cells, tissues, organs, organisms (individuals), population to society [3]. Interrelations between the considered components range from quantum-mechanical effects in the nano-world...
through biochemical processes and interrelations based on classical physics at the cell, tissue and organ level, medical relations at organ and body level, and finally social interrelations in the macro-world [4]. So, quantum mechanics, biochemistry, biophysics, molecular biology, microbiology, medical disciplines, social sciences, but also mathematics and statistics, engineering disciplines and even process excellence and business sciences are inevitable when tackling the aforementioned continuum. However, the problem is not just the presented structural complexity, but also the functional diversity of the cells as building blocks, such as metabolic cells, supporting cell, reproduction cells, moving cells, secretion cells, information processing cells and energy transformation cells [3]. Finally, those basic elements additionally demonstrate specific flexibility realized by metabolism, reproduction and evolution [3]. Directly and indirectly supporting the health and social care business, health informatics acts a mediator and moderator between those disciplines involved, enabling mutual communication and cooperation based on knowledge and skills shared between the actors involved. Those actors can be any type of principals such as organizations, persons, devices, applications, components or even single objects [5]. The paper highlights the problem and offers solutions for managing the multi-disciplinary approach to health informatics.

1. Methods

For analyzing and representing advanced health informatics business cases, first we have to manage the complexity and diversity problem of the domain in question using modeling approaches and system theory. Second, we have to harmonize the representation of knowledge and skills in the different subdomains involved in the health and social care arena by ontology harmonization to enable intelligent interoperability [6, 7].

2. Results

2.1. The Modelling Paradigm

To meet the first challenge, we provide a model, i.e. a partial representation, of reality by abstracting from differences and just focusing on attributes of interest in the business case context. The pragmatic aspect of a model, i.e. the intended use of the models depends on the target group, their business aims and the business process needed to meet those objectives. The resulting model may be deployed for a certain purpose and for a certain time as substitute of the original [7].

2.2. The System-Theoretical Paradigm

The real world health and social care system will be represented as a system model where the involved disciplines consider specific perspectives on, or aspects of, that system. In its black-box-approach, the system is described by its input-output-relationships, simulating the system’s behavior. Systems can be composed (aggregated) to super-systems or decomposed (specialized) to sub-systems. For understanding the
system’s behavior, the system’s architecture, i.e. the system’s components, their functions and interrelations are considered, represented by a white-box-approach, which is also called an architectural approach. A system groups structurally and/or functionally interrelated components. System boundaries separate the system components from the environment components. The system-theoretical approach complements the general features of models by abstracting and formalizing the representation of reality. Furthermore, the definition of the system in question against the environment allows for selecting a granularity/complexity level of that system which is optimal for the specific business case. The recursive application of those principles enables the coverage of the entire health domain continuum.

### 2.3. Domain and their Ontologies

Different aspects of the system are modelled as subsystem or system domain, managed by domain experts using their domain-specific terminology to name the related components as well as using domain-specific ontologies to describe the underlying, domain-specific concepts of those components, their functions and relationships. So, the concepts and relations of the domain-specific subsystems are defined by the knowledge and methodologies, but also by the representation style developed by the related aforementioned multiple disciplines (domains). Interrelations between domain-specific subsystems representing the multidisciplinary nature of the real world can only happen between domain-specific components at the same architectural granularity level. Structuring concepts and relations of a discipline results in a domain-specific ontology. For guaranteeing shared understanding of the concepts and relations of a domain-specific subsystem, the modelled architectural components must be represented using the domain-specific terminologies and their underlying domain-specific ontologies. While this approach supports communication and cooperation between experts from one domain, interoperability between experts from different domain (inter-domain interoperability) must be facilitated. Here, the ontology harmonization challenge comes into play.

At the first glance, it seems to be favorable to look for an overarching ontology. There are several ways of performing this task such as merging ontologies, thereby watching consistency problem, or harmonizing them by alignment. The process of ontology harmonization is supported by developing a hierarchical system of ontologies from general ontology through top level/upper level ontologies, domain ontologies up to application ontologies. The latter represents specialization of domain ontologies for specific use cases. For interrelating the concepts of two components, matching (in the case of equivalence) or mapping (in the case of existing, formally expressed and provable relationships) can be performed. Similar to real world systems, also the system of ontologies easily runs into the complexity problem. For overcoming this problem and for avoiding inconsistencies with real world systems, the system-theoretical, architecture-centric approach proposed in this paper has to be applied to the system of ontologies as well [8] – especially in the context of the multi-disciplinary nature of health informatics.

### 2.4. The Language Problem of Health Informatics Interoperability

Ontology concepts can be expressed using formal or natural languages, while ontology relations are represented by taxonomies (is_a relations), partonomies (part_of relations),
predefined relations such as synonymies, homonymies, ononymies, hyponymies, etc., or by domain-specific or user-defined associations [9]. Regarding the functional, or in general inter-relational, aspects of the advanced care paradigm system, the relations comprise quantum-mechanical effects in the nano-world, biochemical processes, interrelations based on classical physics, and finally social interrelations in the macro-world [3]. For bridging between the knowledge spaces of different domains, the concepts must be also described (explained) in a way understandable for stakeholders not being domain experts. Natural languages, characterized by implicitly represented knowledge, are consistent and complete, but suffer from a lack of sufficient abstraction and expressivity. Formal languages represent knowledge explicitly, have sufficient abstraction and expressivity, but are not consistent and complete, running into the complexity problem again. Therefore, the level of abstraction and expressivity for realizing semantic interoperability according to Figure 1 should be limited to the necessary level [10, 11].

Figure 1. Types of Ontologies

3. Discussion and Conclusions

The system represented by the subject of care and the processes analyzing and managing his/her health according to the advanced paradigm of personalized, predictive, preventive and participative care comprises all levels of granularity from atoms through molecules, cell components, cells, tissues, organs, bodies, communities, up to population. It arranges mobile technologies, nano- and molecular technologies,

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Of course, for each business case, the appropriate level of granularity must be selected for managing analysis and design of the system of interest.
knowledge representation & management, KI, big data & business analytics, cloud computing, social business, bioinformatics, genomics, social sciences, public health, etc., so enabling the individualization of diagnosis and therapy. Such services require cooperation of many different and sovereign stakeholders from different policy domains in a multi-disciplinary approach including medicine, natural sciences, engineering, but also social, legal and political sciences and the entire systems sciences world (systems medicine, systems biology, systems pathology, etc.), performed through any type of principals (person, organization, device, application, component, object). There are two challenges to be met: a) reduction of complexity of the resulting system, and b) cross-domain and cross-community sharing of knowledge and skills between all actors involved. Comprehensive, intelligent interoperability requires the explicit and formalized representation and implementation of involved knowledge and skills by integration and not just cooperation of medicine/telemedicine, medical informatics, biomedical engineering and bioinformatics and omics disciplines, but also public health and social care, etc., as well as the application of pervasive and autonomous computing technologies for healthcare. Multidisciplinary approaches to interoperability require the consideration of the system in question and its domain-specific representation by architecturally modeling the real world system to guarantee that interrelations are described at the same granularity level. Most interdisciplinary approaches ignore this fact completely or reflect it insufficiently. Meanwhile, the term “architecture” is widely misused by pretending the deployment of the aforementioned principles. Mostly however, just the involved ICT facilities are really considered, and systems are only represented using poor ICT ontologies.

Research and development, but also education for flexible, scalable, business-controlled, adaptive, knowledge-based, intelligent health information systems interoperability must follow a systems-oriented, architecture-centric, ontology-based and policy-driven approach. Such approach is required for research and development, but also for education in advanced health informatics with an strong multi-disciplinary educational focus (mathematics, physics, chemistry, biology, etc.).

References