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Reference Architecture Model Enabling Standards Interoperability

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Abstract. Advanced health and social services paradigms are supported by a comprehensive set of domains managed by different scientific disciplines. Interoperability has to evolve beyond information and communication technology (ICT) concerns, including the real world business domains and their processes, but also the individual context of all actors involved. So, the system must properly reflect the environment in front and around the computer as essential and even defining part of the health system. This paper introduces an ICT-independent system-theoretical, ontology-driven reference architecture model allowing the representation and harmonization of all domains involved including the transformation into an appropriate ICT design and implementation. The entire process is completely formalized and can therefore be fully automated.

Keywords. Interoperability; system; ontology harmonization; interoperability reference architecture; framework

1. Introduction

1.1 Interoperability Issues

Interoperability as defined by IEEE as "ability of two or more systems or components to exchange information and to use the information that has been exchanged" must be able to interconnect those in the business case involved systems technically by guaranteeing signal and protocol compatibility (technical interop.). With growing knowledge about the business case shared among the involved components in advance or at runtime, information systems interoperability evolves in following steps:

1. Sharing data about the business case at different level via simple electronic data interchange (EDI) (syntactic interop.) or structured messaging like HL7v2 (syntactic interop.);
2. Information sharing enabling the understanding of underlying concepts of the business case represented in openEHR Archetypes, EN/ISO 13940 ContSys concepts, HL7v3 artifacts, or HL7 FHIR® resources (semantic interop.);
3. Taking the information and communication technology (ICT) part related actions for realizing the business objectives (service interop.).

All the aforementioned interoperability levels happen between ICT components supporting the business case, while the business case is usually a non-ICT but real

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world scenario. According to the Good Modeling Practice, the relevant stakeholders define the provided view of the model as well as the way of structuring and naming the concepts of the problem space. First capturing key concepts and key relations at a high level of abstraction, different abstraction levels should be used iteratively, where the first iteration is performed in a top-down manner to guarantee the conceptual integrity of the model. This requires meeting design principles such as orthogonality, generality, parsimony, and propriety [1]. Therefore, the IEEE interoperability definition has to be extended to include the domains involved in the business case resulting in cross-domain cooperation, which requires sharing and harmonizing those domains' knowledge represented by related ontologies and policies. As the domain experts do not share equal levels of experiences, training, knowledge, etc., shortly summarized in skills, the final interoperability level is skills-based interoperability resulting in moderated individualized end-user collaboration based on individual ontologies. In other words, interoperability turns from technical aspects of ICT and data sharing to domain-specific aspects of policy, knowledge and skills harmonization. In the lack of administrative power as well as a priori shared and enforced knowledge and policies, missing interoperability pre-requisites must be distributed and harmonized at runtime by advanced interoperability solutions.

The advancement of medicine from an empirical, phenomenological approach towards systems medicine enabling personalized, preventive, predictive, participative precision medicine for individually tailored care requires the cross-disciplinary understanding of the status of the individual and its context as well as its correct, consistent and formal representation for integration in the ICT system as part of the business system. Harmonizing and sharing all instances of individual cases and their informational representations in advance is impossible, as a) nobody can pre-define what will happen, and b) sharing all thinkable instances will lead to a representation system's complexity which is un-determined and not manageable.

The non-ICT interoperability is not just defining the ICT interoperability solution, but is the real challenge in the game. In most interop-standards specifications, both facts are ignored.

1.2 Standards and Specification Issues

Meanwhile, many standards and specifications have been developed by different Standards Development Organizations (SDOs) to enable cooperation between actors in health business cases. Thereby, specifications usually address different aspects of the business from a specific domain's perspective, considered by domain experts using their specific methodologies as well as their specific terminologies, at best based on related domain ontologies. In real world business systems, usually different domains are involved, so requiring an integration of those different specifications, thereby growing regarding the complexity and multi-disciplinary characteristics when moving to more advanced healthcare paradigms.

For harmonizing domain or use case specific specifications when adding a new specification or changing/extending the business case, especially when including another domain, currently a mutual adaptation and harmonization is performed, resulting in a revision process of the impacted standards and specifications. With increasing complexity and variability of the system and the diversity of its subsystems and components, the lifetime of domain specific specifications goes down.

The alternative way of a priori harmonizing the aforementioned highly complex, highly dynamic, multi-disciplinary/multi-domain advanced healthcare system by representing it by one domain‘s terminology/ontology or - even worse - by using ICT ontologies fails. The same holds when using one domain’s representational style and models or standards as reference or master that all other domains and their experts must adhere to, e.g., by enforcing biologists, physicians, philosophers and artists to think and represent in UML and the 78 concepts of the ICT base ontology [2].

Therefore, an adaptive approach is required to sharing and harmonizing ICT, domain, and personal ontologies and conditions at runtime.

2. Methods

For meeting the non-ICT interoperability challenges, an abstract domain-independent representation of systems is deployed, based on a system-theoretical, architecture-centric, ontology-driven approach [3, 4]. The mathematical concept representation using the universal type theory in combination with systems engineering methodologies allows representing any system architecturally (i.e. the system’s components, their functions and internal as well as external relations) by generically describing its composition/decomposition as well as the aspects (domains) of the system relevant in a specific context (e.g. business case), instantiated using those domains’ ontologies. The reference architecture model - here focus on the business domain - can be used recursively, so representing, e.g., the real-world systems’ continuum from elementary particles to the universe (Figure 1).

Additionally to agreeing on one or more, and at best standards-based, ICT ontologies, the agreed domains’ knowledge, but also individual (language, education, skills, experiences, social and psychological aspects, etc.) and environmental context must be represented, harmonized and communicated by instantiating the system’s architectural components and behavior through the domain-specific ontologies and policies.

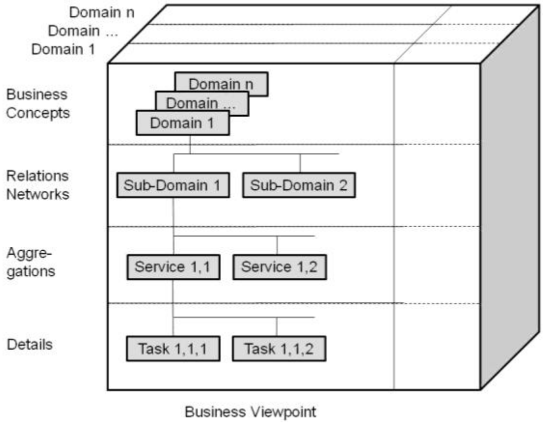


Figure 1. Granularity Levels of the Interoperability Reference Architecture Model

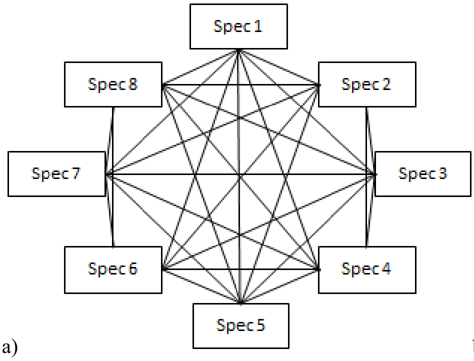
By combining that model with ISO/IEC 10746 RM-ODP, the Interoperability Reference Architecture Model (introduced in the nineties as Generic Component Model

- GCM) as well as the applicable rules - the Interoperability Reference Architecture Model Framework - (also known as GCM Framework) is completed [4, 5].

3. Results

This reference architecture model allows consistently describing any complex real world system's structure and behavior by representing concepts and relationships of the domain-specific sub-system at the real world system component's level of granularity using the specific domain ontologies. In other words, the domain-specific subsystem (e.g. a domain-specific standard or specification) is not harmonized any more by peer-to-peer and case-by-case revisions (Figure 2a), but is re-engineered using the Interoperability Reference Architecture Model (Figure 2b). Bound to the GCM Framework, inter-domain relationships must happen at the same level of granularity [5]. To get there, intra-domain specializations/generalizations have to be performed. In summary, the Interoperability Reference Architecture Model supports ontology harmonization or knowledge harmonization to enable interoperability between existing systems, standards and solutions of any level of complexity without the demand for continuously adapting/revising those specifications.

The described process can be automated. The same holds for transforming the cross-domain, harmonized, consistent informational representation of the complex business system into the different ISO/IEC 10746 views for analyzing, designing, implementing and maintaining the related ICT solution.

a)


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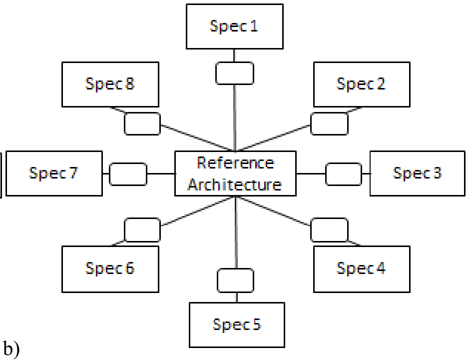

Figure 2. Standards Harmonization and Integration Approaches

Examples for re-engineering existing standards to provide cross-specification or even inter-disciplinary interoperability can be found in [5] regarding interoperability between HL7v2 and HL7v3 or in [6, 7] enabling use case and domain-crossing interoperability in the context of ISO 13972 Health informatics - Detailed clinical models. The approach has also been adopted for ISO and CEN standards such as ISO 13606-1 Health informatics – EHR communication – Reference Model, where the reference model used for all parts has been re-engineered. The feasibility of the Reference Architecture Model and Framework has also been practically demonstrated for automatically designing inter-domain Web services to facilitate multi-disciplinary approaches to Type 2 Diabetes Care management [8].

4. Discussion and Conclusions

Domain experts involved describe specific aspects of business systems in a specific context, using their specific terminologies and ontologies, methodologies and frameworks. Normally not bound to a specific framework, resulting informational representations are therefore quite inconsistent. This as well as evolving contexts or the inclusion of further domains require the adaption of existing (standardized) informational representations of domain-specific use cases, resulting in permanent revisions of specifications. Migrating to a domain-independent reference architecture developed from an abstract mathematical representation of the universe and combined with system-theoretical engineering, enables the consistent formal representation, harmonization and interrelation of any discipline to complex systems' interoperability.

The presented approach has been successfully introduced in several cross-domain ISO specifications, such as ISO 22600 Privilege management and access control, ISO 21298 Functional and structural roles, HL7 Composite Security and Privacy Domain Analysis Model. A simplification of the model is the basis of the open architectures for national health information systems in developing African countries [9]. The approach also allows a comparative analysis and evaluation of ICT Enterprise Architectures [4]. Recently, ISO TC 215 decided to include the Interoperability Reference Architecture Model in all specifications crucial for health systems interoperability such as ISO 13606, ISO 13972 or ISO 21298 Health informatics – Health systems architecture, managed by ISO TC 215 Working Group 1 "Architecture, Frameworks and Models", but also including related specification work of the other WGs.

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