Structuring and Combining domain-specific Standards for Interoperability in Health Care

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Abstract. Cooperation of health care providers is required to enable shared care. By means of efficient and effective communication, costs for health care shall be lowered and, at the same time, the quality of care shall increase. Well-known problems for interoperability with respect to correct communication among heterogeneous software systems of dissimilar health care providers emerge. A large amount of patient data has to be exchanged among the health care institutions to enable efficient shared care. In the past, various application systems for the different sectors in health care have been developed and deployed independently. To achieve effective communication, not only technical interfaces are required, but also common semantics for exchanged data. This paper focuses on problems of interoperability on the level of the application architecture, viz. Enterprise Application Integration [1]. Various health care standards are analysed, uniformly structured and put into a software architecture that enables interoperability based on domain-specific standards.
After a short overview of some relevant standards for communication and documentation in healthcare, we introduce our mediator-based architecture, which supports a top-down integration starting with standard-based integrated schemas [5, 6]. The proposed architecture is evaluated in the context of the Epidemiological Cancer Registry Lower Saxony.

1 Standards for Interoperability in Health Care

The IEEE defines interoperability as the ability of two or more systems or components to exchange information and to use the information that has been exchanged [2, 3]. Connecting heterogeneous information sources in health care usually implies problems of semantic interoperability [3]. Concerns of technical interoperability are not discussed in this paper.

A typical problem of semantic interoperability is that the same terms are often used for different concepts (homonyms) and that the same concepts are denoted by different terms (synonyms). Many standardization efforts aim at solving these problems [4]. Standards play an important role for ensuring a common understanding of transferred data among heterogeneous application systems [5]. Top-down integration, based on domain-specific standards, can result in scalable

and flexible software architectures for federated information systems [6]. In the domain of health care there exist various standards for communication and documentation, which are introduced below. Later we will integrate these standards into a common metamodel.

1.1 Communication Standards

HL-7 (Health Level Seven) is a standard, which is used mainly for communication within hospitals [8, 9]. An accepted standard for exchanging digital images is DICOM (Digital Imaging and Communications in Medicine) [10]. Communication among general practitioners in Germany is supported by the BDT (Behandlungsdatenträger) standard [7]. We modelled the relationships among these standards by means of the standardized modeling language UML (Unified Modeling Language) [17]. Figure 1 illustrates the resulting structure of communication standards in health care as UML class diagram. The syntax of message structures defines multiple levels of partitions (hierarchical composition). This UML model defines a nomenclature resp. ontology for communication standards.

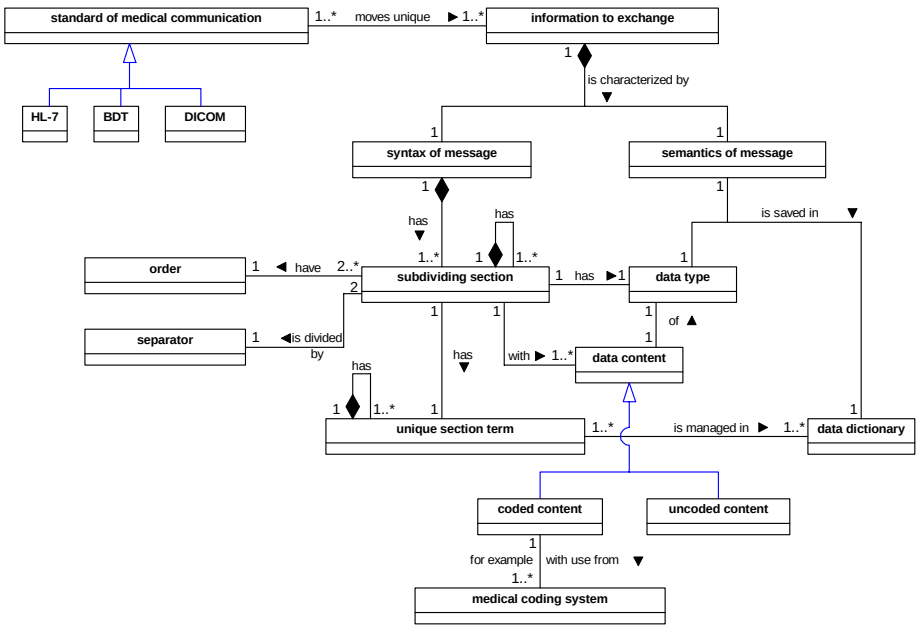

Fig. 1. Extract of the metamodel for communication standards in health care.

1.2 Documentation Standards

For medical documentation it is important to have standardized structures for documents and standardized coding systems for fields in the documents (terminologies, taxonomies, ontologies, nomenclatures, etc.).

Electronic Healthcare Records

It can be expected that electronic healthcare records (EHCR), based on medical terminology, will be at the center of future health care information systems. Important standardisation projects in this field are EHCR of CEN (Comit Europen de Normalisation) and the CDA (Clinical Document Architecture) of the HL-7 Group [9, 11]. The three different levels of CDA for example offer a way to incrementally add (semantical) markup, based on the HL-7 RIM (Reference Information Model). Currently, only CDA Level One has been defined, CDA Level Two is under work.

The goal of the SCIPHOX project (Standardisation of Communication between Information Systems in Physician Offices and Hospitals using XML) is to define a standardised report (e.g. referral, discharge letter) based on the standards CDA and XML to exchange reports between BDT and HL-7 domain [18]. SCIPHOX defines six semantical units to describe and structure diagnoses, therapies etc. to a greater detail than CDA Level One. The results of SCIPHOX will influence the definition of CDA Level Two.

Again, we modelled the relationships among the relevant documentation standards in the UML to later combine them on a metalevel with the communication standards. Figure 2 displays our nomenclature for documentation standards.

Medical Coding Systems

Medical coding systems are used within documents to code measurements, diagnoses etc. They standardize terminology. Examples are the ICD (International Statistical Classification of Diseases and Related Health Problems) and SNOMED (Systematized Nomenclature of Human and Veterinary Medicine). In [4] we introduce a nomenclature of coding systems, which specifies in the UML the connections among several relevant medical coding systems. Figure 3 displays an extract. At the heart of this model, you can see the semiotic triad. On a meta level, we combine this nomenclature with the standards of communication in Section 1.3.

1.3 Combining the Healthcare Standards

Metadata is important for federated information systems to achieve flexibility for evolution and means for overcoming heterogeneity [14]. Figure 4 displays the relationships among the communication and documentation standards that were introduced in the previous subsections. For example the nomenclature for communication standards contains metadata for the relevant communication standards HL-7, BDT and DICOM. Standards for documentation such as electronic

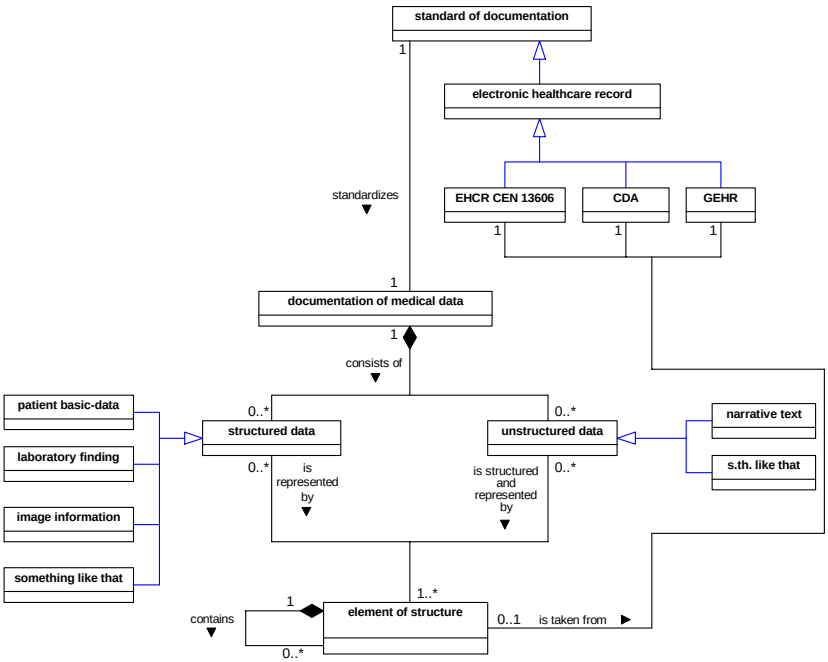

Fig. 2. Extract of the metamodel for documentation standards in health care.

healthcare records use medical coding systems. CDA, the electronic healthcare record defined by the HL-7 group, is formulated in HL-7.

2 Mediator-based Software Architecture

Our goal is to develop a flexible and scalable software architecture, which enables interoperability among the various institutions providing health care. This architecture uses the meta models for health care standards which were introduced in Section 1. Figure 5 illustrates our mediator-based architecture, which follows the mediator metaphor [12, 13] with facilitators and component mediators.

The mediation layer, which enables interoperability based on domain-specific standards, consists of wrappers, component mediators, facilitators, optional application mediators and various metadata stores. For each domain-specific standard for documentation there exits a component mediator, for example the CDA component mediator. The documentation component mediator uses the metadata from the nomenclature for documentation standards (Section 1.2). This model illustrates the correspondences (mappings) among the specific component mediators. Metadata from the nomenclature for coding systems helps to mediate among the different medical coding systems, which are used in medical documentation. Several facilitators manage the specific domain models, for example an HL-7 facilitator for the HL-7 reference information model (RIM).

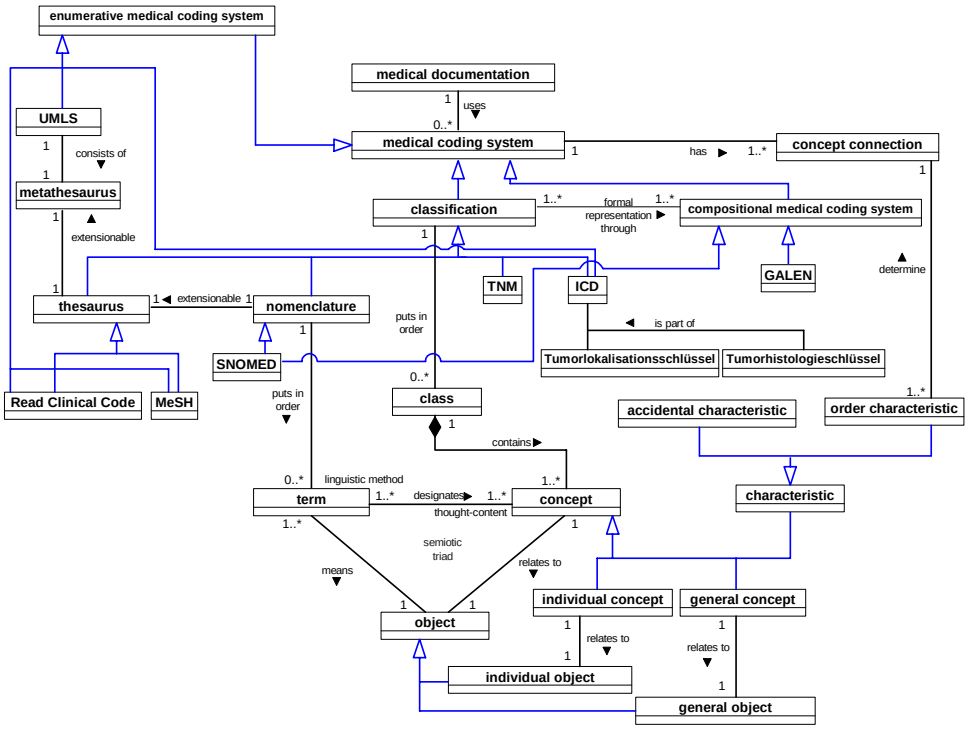

Fig. 3. Extract of the metamodel for coding standards in health care.

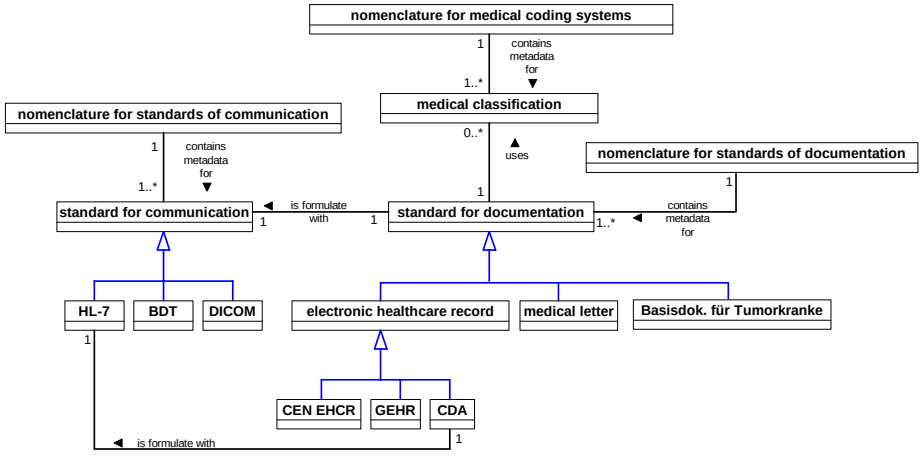

Fig. 4. Relationships among the communication and documentation standards.

A communication facilitator coordinates as facilitator by means of a nomenclature for communication standards. This way, we support a top-down integration starting with the domain-specific standards [5, 6]. Complete mappings are not always possible. When application structures and standard structures harmonize the quality of the mappings increases. This also means that an evolution of standards themselves is useful and required.

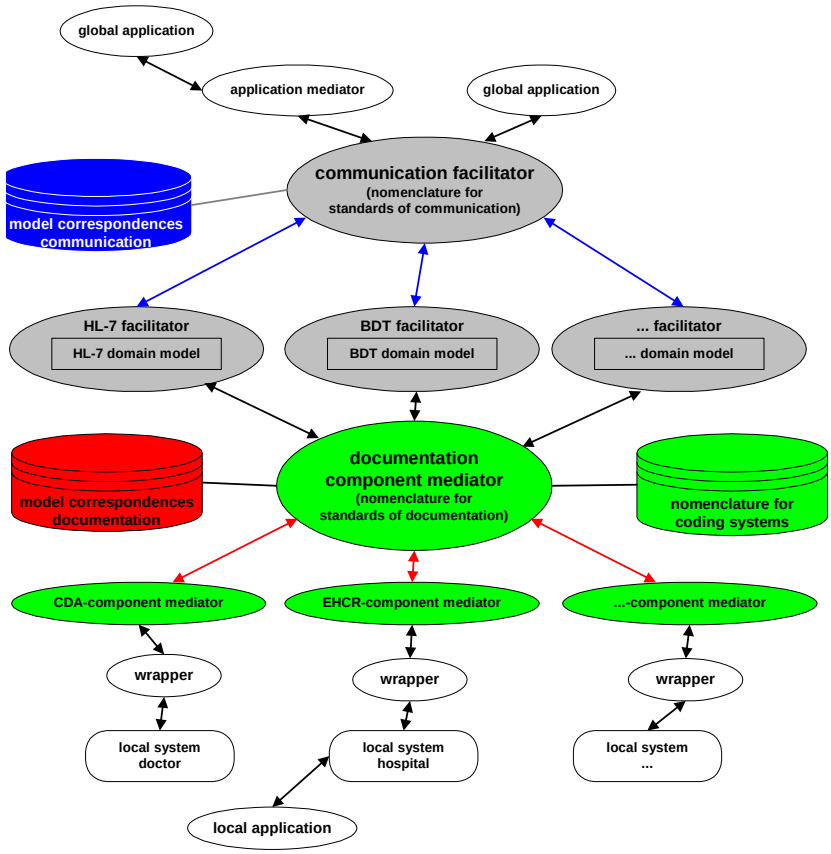

Fig. 5. Architecture for interoperability among institutions in health care.

3 Case Study

Our approach to structuring communication and documentation standards in health care for managing interoperability in federated information systems is

currently under practical evaluation, whereby the Epidemiological Cancer Registry Lower Saxony (EKN) [15] serves as a case study. With the procedure suggested in [16], we selected for this case study HL-7 and BDT as standards for communication, and ICD-O (International Statistical Classification of Diseases and Related Health Problems - Oncology) as the coding standard. The "Basisdokumentation für Tumorkranke" (base documentation for tumour diseases) from the "Deutsche Krebsgesellschaft e.V." (German cancer association) and the "Arbeitsgemeinschaft Deutscher Tumorzentren" (working group of German tumour centres) was selected as the appropriate documentation standard as a basis for an integrated model. The heterogeneous documents corresponding to the epidemiological cancer registries from the different reporter groups are integrated in a top-down manner starting with the selected domain-specific standards.

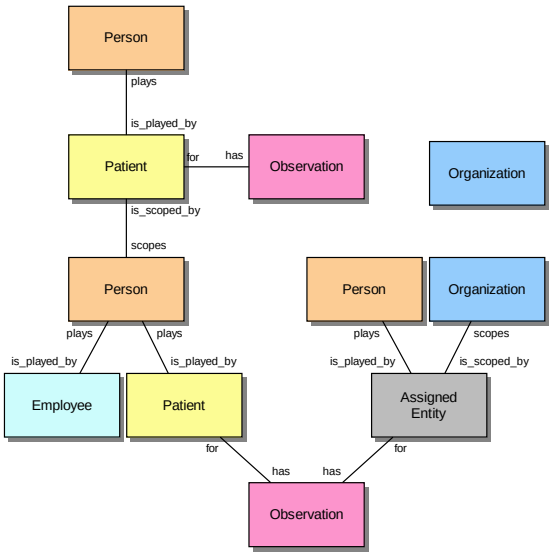

Fig. 6. Corresponding classes of the HL-7 RIM to the EKN from [19].

Figure 6 shows those classes derived from the HL-7 RIM, which correspond to the structure of the EKN. The generic HL-7 RIM has a high degree of abstraction and therefore varied possibilities for its mapping to the base documentation for tumour diseases [19]. On the other hand it was not possible in this case study to get a complete mapping from HL-7 RIM to the base documentation. Some relations, e.g. information from death certificates could not be modeled in HL-7 RIM. So there is a need for evolution of standards in health care [5]. As mapping language an extended version of BRIITY (Bridging Heterogeneity) [20] was used.

Figure 7 illustrates the instantiation of our more general architecture in Figure 5 to the specific requirements of the EKN. The mappings among the heterogeneous data models are coordinated by a control component.

Fig. 7. Architecture of our EKN case study.

4 Summary

Domain-specific standards play an important role for achieving semantic interoperability among federated information systems. Both, standards for communication formats and standards for documents with an appropriate standardized coding system (nomenclature) are required for a holistic solution.

In the present paper, we presented our efforts for uniform structuring of these relevant standards. The proposed mediator-based architecture offers a flexible

and scalable approach for sustainable evolution. This approach is based on a separation of concerns for managing the global, integrated models and the individual mappings from local component models into the integrated domain-specific models. This way scalability is enabled. The proposed architecture is evaluated within the context of an epidimiologic cancer registry system. Our goal is to develop a flexible and scalable software architecture, which enables interoperability among the various institutions in health care. This architecture is based on the presented meta models for health care standards. Because of our uniform specification of relevant standards for communication and documentation by means of the standardised UML, appropriate metadata for a transformation among heterogeneous models is provided for achieving interoperability among federated information systems of the various institutions in health care.

There is a need for evolution of standards themselves. Current standards often do not fit properly to application areas, which not in the medical main stream, such as epidemiological cancer registries.

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