Enhanced Semantic Interpretability by HealthCare Standards Profiling

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Abstract. Several current healthcare standards support semantic interoperability. These standards are far to be completely adopted in health information system development, however. The objective of this paper is to provide a method and necessary tooling for reusing healthcare standards by exploiting the extensibility mechanisms of UML, by that way supporting the development of semantically interoperable systems and components. The method identifies first the models and tasks in the software development process in which health care standards can be reused. Then, the selected standard is formalized as a UML profile. Finally that profile is applied to system models, annotating them with the standard semantics. The supporting tools are Eclipse-based UML modeling tools. The method is integrated into a comprehensive framework for health information systems development. The feasibility of the approach is exemplified by a scenario reusing HL7 RIM and DIMs specifications. The approach presented is also applicable for harmonizing different standard specifications.

Keywords: Standards, semantic interoperability, profiles, reusability, UML, HL7

Introduction

Especially in the context of long-term usable eHealth applications such as Electronic Health Record (EHR) systems, at least two basic requisites for semantic interoperability have to be met: i) agreement on a standardized set of domain-specific conceptual models, and ii) agreement on standardized terminologies associated with controlled vocabularies [1].

Several healthcare standards defining domain models currently exist, such as ISO HL7 21731 “Health informatics- HL7 version 3 Reference Information Model” (RIM), ISO EN 13606 “Health Informatics –EHR communication”, OpenEHR Archetypes, etc. These standards are far to be completely harmonized and adopted, however. Apart from political reasons, lack of tooling, methodologies, bridging between the domains involved, guidelines, completeness, conformance mechanisms, harmonization, etc., are principal barriers for their adoption.

Commonly, Standards Development Organizations (SDOs) use their own notation, and underlying development paradigm to describe their standards. UML, the de-facto industry standard for software modeling, has been used for many of them as language to formally represent the standards semantics. Using UML provides several advantages

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such as tooling support, widely spread use, graphical notation, exchangeability, extensibility, code generation, etc. Unfortunately, UML has not been consistently used in healthcare standards development and – without appropriate adaptation – presents some limitations to describe specific domain concepts.

The objective of this paper is to provide a method for reusing healthcare standards by exploiting the extensibility mechanisms of UML, by that way supporting the development of semantically interoperable systems and components. If systems were based on standard information models (e.g. specifying the platform independent model), this model would be easily transformed into different implementation platforms supported by the Model Driven Architecture (MDA) approach. The resulting systems and components implement the information structures and behavior described in the standard. As a result semantic interoperability at functional and services level is supported.

1. Definitions and Methodology

Profiling in software engineering is commonly defined as a mechanism for extending existing meta-models to adapt them for different purposes. In health informatics, the term profile has been extensively used in different ways. HL7 for example uses profiles to constrain and extend HL7 specifications such as the RIM, Domain Information Models (DIMs), services specifications, etc. The objective of profiling HL7 specifications is to use them in particular environments and/or defined community of users (e.g. specific requirements in some countries). The IHE (Integrating the Healthcare Enterprise) initiative defines Integration Profiles to describe the solution to a specific integration problem (use case) in different domains, e.g. IHE profiles for cardiology, radiology, IT infrastructure, etc., thereby reusing existing standards. OpenEHR defines the Archetype Profile which is a mechanism to specify custom Archetypes for certain kind of information models.

The concept of profiling deployed in this paper has been defined in the UML standard [2] as a formal mechanism to specialize a reference meta-model in such a way that it is possible to adapt that model to a specific platform or domain. Profiles are defined as UML packages which contain stereotypes representing the meta-classes of the meta-model that can be extended. The stereotype is represented as a UML class along with its attributes, and is represented adding the tag <<stereotype>> before the class name or using a customized shape (see class diagram in Figure 2). A profile is formally defined as a UML model enabling to interchange profiles between tools (using XMI), together with the models having been applied.

The method proposed to support the development of Health Information Systems (HIS) based on healthcare standards, is supported through the Health Information Systems Development Framework (HIS-DF) [3]. HIS-DF is a comprehensive and customizable methodology for the architectural analysis of HIS based on the Generic Component Model (GCM) and deployed as a specialization of the Rational Unified Process. An instance of the HIS-DF for the specification of integration between public health and clinical information systems has been previously discussed by the authors [4].

2. Formally Profiling HealthCare Standards

The paper describes a method and necessary tooling for identifying and creating UML profiles to health care standards, and applying them to existing UML models. The
method is integrated as guidance artifact into the HIS-DF Eclipse configuration. The method is summarized in the following subsections.

2.1. Identify Standard Models and Tasks in the Software Development Process

HIS-DF is the proposed framework for using profiles in an HIS development project. The task within the HIS-DF process is called standards harmonization. It can be defined within any of the three RM-ODP viewpoints described in the process. In the Enterprise Viewpoint, the task Business Use Cases can for example extend the HL7 profiles defined for the use case models, activity diagrams, business rules, storyboards, and other artifacts of the HL7 Development Framework (HDF). In the information viewpoint, profiles can be defined to formally describe the system analysis model based on HL7 RIM, DIMs, Refined Message Information Models (R-MIMs), Common Message Element Types (CMETs) or Templates. Finally in the computational viewpoint, profiles can be defined for HL7 services specifications, application roles, trigger events, interactions, and messages specifications.

2.2. Implement the Standard as a UML Profile

After having identified the models and the processes in the HIS-DF methodology where a standard can be reused, it is represented as a UML profile. The classes and properties of the information model of the standard are described as stereotypes and tagged values respectively. The Object Constraint Language (OCL) can be also used to constraint the profile. In this stage, UML tools are necessary to build the UML profile.

2.3. Apply the profile to System Models

The previously defined UML system models are annotated with the standard models by applying the profile. Conformance to the standard is assured because the UML profiles impose certain restrictions on how the UML model can be modified, excluding further changes to the profile. These restrictions should be supported by the UML tooling, however. A mapping (applying rules manually or tool-assisted) describes which classes from the original model corresponds to the base classes in the profile. Using model transformations it is possible to automate the mapping process.

2.4. An Example using HL7 Profiles

In order to exemplify how the previously described method is applied to an HIS development project, a public health information system example is used. A similar scenario has been described in a previous paper [4], but especially focusing on the use of the HIS-DF methodology. In that work, the information models were manually extended using HL7 Visio tools. That approach didn’t follow the UML profiling mechanism, resulting in HL7 models incompatible with the UML 2.0 standard.

2.4.1. Identify Standard Models and Tasks in the Software Development Process

The method in this example supports the informational viewpoint described in the HIS-DF, concretely the system analysis model. The main diagram in the model is a UML class diagram describing the system information entities, its properties and relation-
ships. Figure 1 describes the analysis model for the public health surveillance system as a UML class diagram. The main classes in the domain are represented: Citizen, Event-Place, Public Health Authority and the Health Service Provider, all being associated to a Public Health Event.

Following the harmonization process defined in the HIS-DF methodology, each one of the classes in Figure 1 are mapped to classes, attributes and data types defined in HL7 information models. Table 1 summarizes the mapping to classes in the HL7 RIM and successive refinement to classes in the Notifiable Condition Report R-MIM (PORR_RM100001UV01) as part of the HL7 v3 Normative Edition 2006.

2.4.2. Implement the Standard as a UML Profile

According to the mappings found in Table 1, UML profiles for the HL7 RIM and the Notifiable Condition Report R-MIM are necessary. The UML profile for the HL7 RIM is imported from the HyperModel tool [5], whereas the R-MIM profile is created using the IBM Rational Software Architect tool. The structure of the R-MIM profile is shown in the “Project Explorer” view in the left frame in Figure 2. A UML stereotype is created for each entity, act and role of the R-MIM, along with its attributes. The profile is made available for reuse as an Eclipse plug-in and an XMI file.

Table 1. Mapping the Surveillance System model to HL7 Information Models

<table>
<thead>
<tr>
<th>Sivigila Classes</th>
<th>RIM Core-Classes</th>
<th>HL7 RIM Classes</th>
<th>R-MIM Classes</th>
</tr>
</thead>
<tbody>
<tr>
<td>SivigilaEvent</td>
<td>Act</td>
<td>PublicHealthCase</td>
<td>PublicHealthCaseEvent</td>
</tr>
<tr>
<td>Health Service Provider</td>
<td>Role</td>
<td>RoleHeir</td>
<td>AssignedEntity</td>
</tr>
<tr>
<td>Citizen</td>
<td>Entity</td>
<td>Person</td>
<td>InvestigatedPerson</td>
</tr>
<tr>
<td>EventPlace</td>
<td>Entity</td>
<td>Place</td>
<td>EventPlace</td>
</tr>
<tr>
<td>Public Health Authority</td>
<td>Role</td>
<td>RoleHeir</td>
<td>TerritorialAuthority</td>
</tr>
<tr>
<td>Address</td>
<td>Attribute</td>
<td>Person.addr</td>
<td>InvestigatedPerson.addr</td>
</tr>
<tr>
<td>Age</td>
<td>Attribute</td>
<td>Person.birthTime</td>
<td>InvestigatedPerson.birthTime</td>
</tr>
</tbody>
</table>

2.4.3. Applying the Profile to System Models

Figure 2 (main frame) shows the analysis model for the public health system, after having applied the HL7 profiles. For each class in the model, the applied stereotype is represented, along with the HL7 attributes and data types extended from the HL7 RIM and R-MIM information models. For example the SivigilaEvent class extends the <<PublicHealthCase>> and <<PublicHealthCaseEvent>> stereotypes defined in the RIM and
R-MIM profiles, respectively. The classes are colored using the HL7 functionality provided by the HyperModel tool.

Figure 2. The Public Health System Information Model using the HL7 Profiles

3. Discussion

Few approaches suggest the use of UML profiles to support the development of semantically interoperable systems. In [6], a method for profiling healthcare standards using UML is proposed. The method is not integrated into a development process, and the creation of ad-hoc profiles is enforced. Carlson [7] developed a tool for MIF to UML transformation. While UML profiles for HL7 HDF and RIM have been developed, they have not been used for HIS modeling. CaCORE [8] provides an infrastructure to semantically annotate UML information models with specific domain standards and vocabulary, but not exploiting UML profiling mechanisms.

The proposed method for identifying and creating UML profiles to healthcare standards provides the following advantages:

- Support for Semantic Interoperability. System models are annotated, extending standard information models and intrinsic vocabulary. HL7 information models are at the moment the recommended set of standards to be reused because they cover a wide spectrum of clinical information, along with business processes, and services partially covering the business, informational and computational viewpoints defined in the HIS-DF methodology.

- Formal Mechanism for Models Specialization. An UML profile provides mechanisms for specializing healthcare standards in such a way that the specialized semantics does not contradict the semantics of the generalized standard. The profile establishes restrictions on how the standard should be specialized; avoiding changes in the meta-class definitions.

- Standard and Shareable Models. UML is the standard de-facto language for software systems modeling. UML models and profiles can be created and shared using the XMI standard. Most UML tools support the implementation of profiles.
Support of Model-Driven Development. The UML system models described are platform independent information models. They can be transformed into platform specific models and code (Web Services, J2EE, and CORBA) using UML transformations. Profiles can also support transformations (mapping) between standards.

The major limitation of using existent UML modeling tools (even using the IBM Rational family) is that functionalities to specialize reference information models are not completely supported. Visio R-MIM Designer provides such functionality, but the resulting models can not be processed by conventional UML tools, however. Further limitation results from incompatibility between existing tools. For example, in the tools used for this study despite being Eclipse based tools, incompatibility between the latest versions of the HyperModel and the IBM Software Architect occurred due to incompatibilities between the Eclipse SDK distributions. It can be expected that with HL7’s tooling migration towards the Eclipse platform, the R-MIM Designer will be extended by functionalities to process UML models and profiles.

4. Conclusion

Analysis and design of health information systems, especially the underlying business and informational models describing basic concepts, business and relation networks, have to be based on standards. The paper describes a method and necessary tooling for reusing standard healthcare information models, by that way supporting the development of semantically interoperable systems and components. The approach is based on the UML extensibility mechanisms by defining profiles. Using UML provides several advantages such as tooling support, graphical notation, exchangeability, extensibility, code generation, etc., deployable in the next generation of HL7 tools.

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References