Improving Systems Interoperability with Model-Driven Software Development for HealthCare

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Abstract:

An aging population and an increase in chronically ill patients demand teamwork treatment models. To support these with information systems, interoperability is a prerequisite. Model-driven software development (MDSD) with special healthcare extensions can enable reuse of components and improve conformance to international standards. In this paper, a MDSD HealthCare Framework is proposed and demonstrated for homecare services. Using the framework, information systems will improve their conformance to international standards and the interoperability with other systems.

Keywords:

Medical Informatics, Home Care Services, Information Systems, Systems Integration

Introduction

In healthcare, the disease burden is changing from acute to chronic care, 35000000 people died from chronic diseases in 2005, and 60% of all deaths are due to chronic diseases [1]. New ways of providing care are being evaluated, based on teamwork treatment – demanding support from interoperable information systems. Interoperability in healthcare has been identified as an important area of research and development by many organizations, including the European Union (EU)[1], the Object Management Group (OMG)[2] and other national organizations [2]. The ability to exchange information and share services across departmental, organizational and national borders can reduce the administrative overhead and costs [3], and as a result improve the effectiveness of healthcare provided. Consequently, more patients can be treated faster with the same amount of (care) resources. A sustainable healthcare infrastructure depends upon interoperable health information services [4, 5].

The treatment and management of homecare consumers, typically elderly, chronically ill and cognitive disabled, require a coordinated effort from healthcare and social welfare services.

To effectively support these care services with information systems, interoperability of core information such as patient careplan calendar and medication-list is a prerequisite.

To improve interoperability between systems, the leading standardization bodies in healthcare information, HL7, CEN TC251 and OpenEHR, have specified standards that address systems architecture and information exchange. Although these standards have been available to the Health Information Systems (HIS) vendors for some time, they have not fully adopted them into their products. Thus, the different HIS are not interoperable, requiring the development of software adapters to be able to exchange information about the patients. There is an urgent need for a standardized interface and method to realize this information exchange.

The standardization bodies provide limited tool support to the developers of health information systems. To incorporate standard healthcare concepts in the systems' design, an operational software engineering artefact that provides both semantic and syntactic interoperability functionality [6, 7] should be available for the system architects and developers [8-10].

In 2002, the Object Management Group (OMG) introduced the Model-Driven Architecture (MDA) [11], an approach focusing on using models (e.g., UML models [12]) as first-class entities in the development of software systems. In practice, this means that the models are used directly in the implementation of an information system, either as system blueprints or as input to code generation engines that produce executable code. MDA is the most known model-driven software development (MDSD) approach, and the overall idea is to separate business functions (in Platform Independent Models - PIM) from its technological implementations (in Platform Specific Models – PSM), enabling code generation and reuse of components. The overall benefit is improved interoperability and reduced development time and cost.

Using a MDSD approach in the development of healthcare information system services could facilitate the use of standards through specification of reusable standards-based PIMs. Advanced UML mechanisms such as Profiles and Patterns could be used to further extend the expressiveness of the modeling language and force the use of standardized healthcare concepts. As a result, the developed systems will increase the

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[1] EU Life sciences, genomics and biotechnology for health website: http://cordis.europa.eu/lifescihealth/home.html
[2] Object Management Group (OMG) website: http://www.omg.org

level of interoperability, and at the same time development and maintenance costs will decrease.

With an aging population and a rapidly increasing number of chronically ill patients [1], the need for teamwork treatment is crucial. Healthcare Information Systems (HIS) can no longer be seen as standalone systems, but need to interoperate in a health network [10]. This leads to the problem statement: *How can health information systems development be improved to ensure that systems involved in a homecare teamwork treatment infrastructure can share information in an effective and sustainable manner?*

This paper proposes a model-driven software development framework with standards-based healthcare extensions as a tool to achieve interoperability between HIS. The healthcare focus is on homecare services although the healthcare standards discussed have general applicability. The paper concludes that MDSD with the appropriate healthcare information extensions can improve software's conformance to standards and thus also the ability for caregivers to share information in teamwork treatment.

Following next is an overview of the challenges that are associated with developing such a MDSD Healthcare framework, both from a software engineering and healthcare viewpoint. Then the framework is presented along with an example from the homecare domain, before the paper concludes with a discussion of the validity of our results and directions for future work.

Immature MDSD tools and need for evaluations

In a keynote talk at the 2006 ECMDA-FA conference in Bilbao (Spain), Bran Selic (IBM) advertised for rigorous scientific studies that investigate how MDSD can improve the development process[3]. Recently, the ModelWare project[4] conducted five different scientific MDSD evaluations. A summary of the evaluations is presented in [13] and concludes that by applying MDSD, a productivity gain of 20% can be expected and the quality of the software produced would increase.

Despite these and other reports, there is a considerable skepticism in the software engineering community about the performance and usability of MDSD. The skepticism is based on three main points: 1) the UML is too generic and is conceptually too far from implementation languages making it difficult to generate efficient and fully executable code [14, 15], 2) The maturity of MDSD tools: transformation tools are not complete enough to provide return of the investment put into developing reusable UML models. E.g., the Query/View/Transformation (QVT) standard [16] by OMG does not have good tool support and 3) standards are used in different versions, some of which are not interoperable.

Many Systems, Many Standards

The use of information standards to improve interoperability between information systems in the healthcare domain is not straight-forward. In a single healthcare organization, there is a plethora of information systems, each based on one or more information standards. In the context of systems development, sharing of information and services between these systems need to address the following issues: 1) Many systems (such as patient administrative systems) are dated back to the late eighties, long before the specification of today's information standards, 2) Department specific systems developed to serve one specific purpose do often not use international standards nor follow best-practice in systems architecture, 3) The information systems themselves and the information standards used are continuously being upgraded [7].

A MDSD Framework for HealthCare

The work presented in this paper build upon three assertions presented in the following.

Assertion 1: Model-Driven Software Development with healthcare information standards support will improve interoperability between health information systems (compared to the traditional way of developing systems)

UML allows for extensions through the use of UML Profiles. A profile defines stereotypes, tagged values and constraints that can be assigned to modeling elements in the design process. The main purpose of a profile is to extend UML's expressiveness for a certain domain, e.g. healthcare. By providing healthcare specific UML profiles and patterns as a part of a MDSD framework for healthcare, concepts defined in international healthcare information standards can be automatically built into the information systems. A healthcare profile can be used by transformation templates and code generators to explicitly implement attributes, relationships, operations and objects that provide interoperability services.

Assertion 2: Healthcare Information Standards are appropriate as reusable model-driven development artefacts.

Standards from HL7, CEN TC251 and OpenEHR make use of UML class diagrams to specify concepts and relationships. However, parts of the semantics are described textually as constraints-comments to the formal UML models. To be able to correctly incorporate these standards into model-driven development artefacts such as UML Profiles, the complete semantics of the standards must be possible to represent formally. The correctness and reusability of the models created with the UML profile will depend on the mapping between the standard and the UML profile artefacts.

Assertion 3: Healthcare information services in the homecare domain can be reused across organizations.

The usefulness of a MDSD Healthcare framework for the development of interoperable homecare services will depend on the ability to define functional and coherent information services in the domain. The services need to be reusable beyond departmental and organizational borders, preferably also na-

tional borders as some healthcare institutions have rehabilitation and treatment centers abroad, often collaborating with the local healthcare services.

Results

Using a model-driven approach such as the MDSD Healthcare Framework enables rapid development of interoperable healthcare information systems. The framework includes a set of UML profiles, models and experience reports from the homecare domain, but with generic healthcare service applicability.

Example of MDSD Healthcare Framework in Homecare

A trivial example is provided to demonstrate how a UML Profile for healthcare can be used in the development process to achieve interoperability between information systems.

The example service is a CarePlan service where a HomeCare Center System and a General Practitioner (GP) EHR HomeCare extension can access and update the homecare patient's careplan. Both systems will need to provide a defined interface for information exchange based on the same standard. A small subset of the "CarePlan" concept in the Continuity of Care (CONTSYS) [17] standard is used for demonstration (Figure 1). A "CarePlan" is applied by one or more HealthCare Professional and addresses one or more health issues that the Subject of Care has (relation not shown).
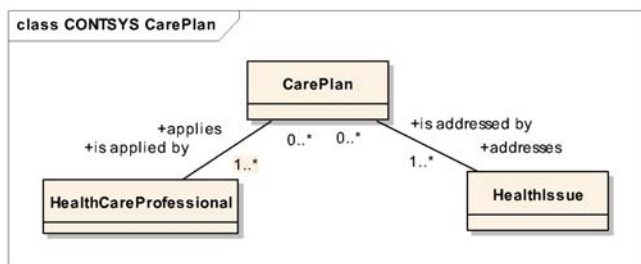

Figure 1: A subset of the CONTSYS CarePlan concept

The goal is to develop Java based (sub-) systems that allow exchange of careplan information for the homecare patient according to the CONTSYS standard.

A Simple UML Profile for HomeCare

Based on the CONTSYS standard, the following UML extensions are specified: 1) UML Class Stereotype: SubjectOfCare: The person receiving treatment, 2) UML Class Stereotype: CarePlan: The treatment plan for one or more health issues (problem), 3)UML Class Stereotype: HealthCareProfessional: A caregiver entitled to provide care, 4) UML Association Stereotype: HealthCareProfessional_isResponsible: The healthcare professional (source element) is responsible for the target element and 5) UML Association Stereotype: SubjecfOfCare_Owns: Subject of Care (source) has owner right of the target element.

Two *tagged values* are defined: 1) Boolean: isShared: when used with a CarePlan, stating whether the careplan is shared or not and 2) Boolean: isOrganDonor: used with a SubjectOfCare to state if the person is organ donor or not.

The Healthcare Information Systems

The two systems are being developed independently by different vendors using the same CONTSYS-based UML profile. The Care Center system platform independent model (PIM) shown in Figure 2 shows that the HomeCarePlan (stereotyped CarePlan) is related to the HomeCarePatient (owned by), the Doctor (under responsibility of) and the Visiting Nurse. All classes are stereotyped according to CONTSYS. As a result, the HomeCarePatient has a tagged value for "isOrganDonor" and the HomeCarePlan has an "isShared" tag.
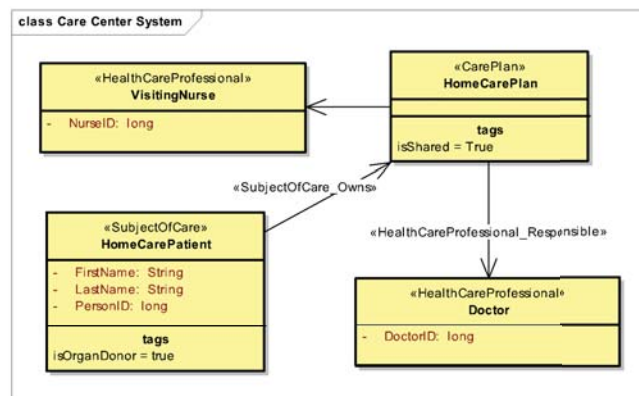

Figure 2: The Care Center System PIM

The PIM for the GP EHR Homecare extension system (Figure 3) shows that the TreatmentPlan ("CarePlan") elements are related to one or more patient problems ("HealthIssue") according to a problem-oriented EHR [18]. This can be used to filter out treatment activities that are not related to the coordinated care of a homecare patient.
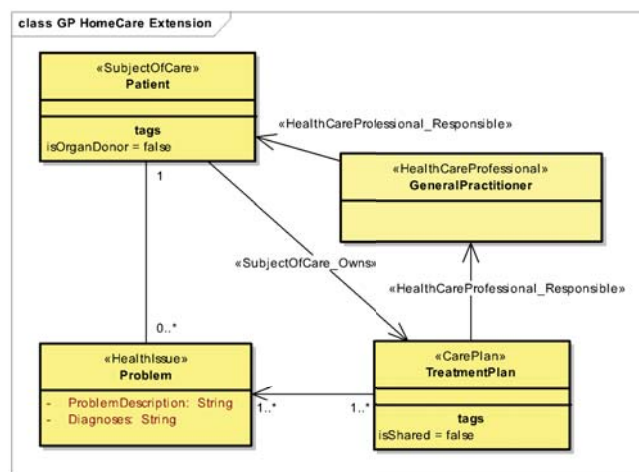

Figure 3: The GP EHR Homecare Extension PIM

The two PIMs can be transformed to Java Platform Specific Models (PSM) using a CONTSYS-based transformation script for Java. This script utilizes the stereotypes and tagged values in the transformation process to add attributes and operations to ensure that the required interoperability mechanisms are implemented. In this trivial example, only set and get opera-

tions for the tagged values and careplan elements are created. The Java Model for the Care Center system (Figure 4) and the GP EHR Homecare extension (Figure 5) show that during the transformation process, three operations have been created on the CarePlan-stereotyped classes. These operations, stereotyped with "CarePlan", enables exchange of CarePlan elements and retrieval of all HealthCare Professionals that are related to the CarePlan.
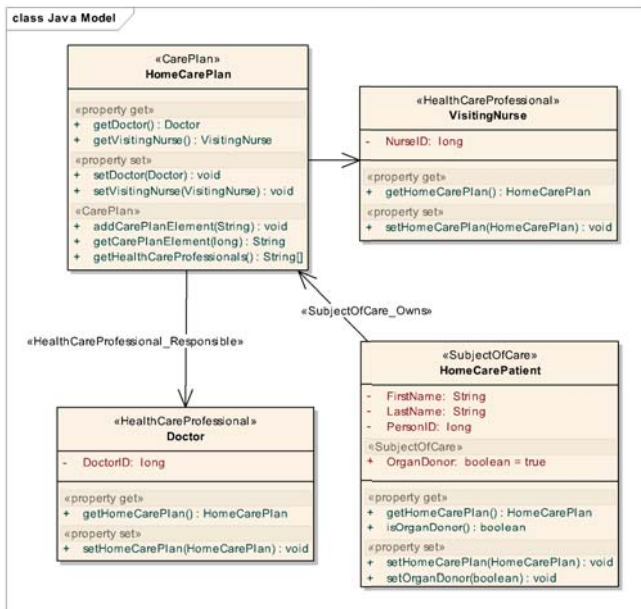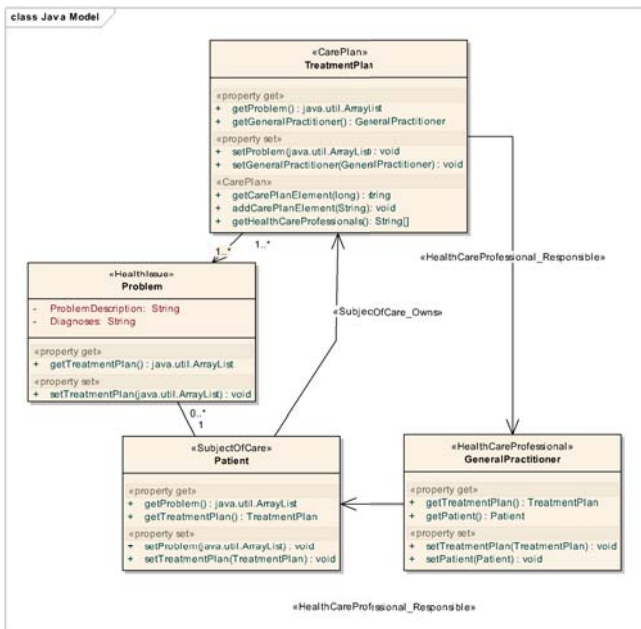

Figure 4: Java PSM for the Care Center System

Figure 5: Java PSM for the GP EHR HomeCare Extension

From these Java PSMs, code can be generated using a standard code generation tool based on e.g. QVT [16].

To summarize: using the CONTSYS UML Profile in the design and development of the careplan service in the Care Cen-

ter and GP EHR systems ensured that the services are conform to the standard and thus can exchange information correctly.

Discussion

The MDSD Healthcare framework proposed in this paper addresses the need to make information systems in the healthcare domain interoperable and sustainable. To achieve this, the framework provides tools and reusable components that incorporate international information standards into the information system design.

The effect this will have for the future healthcare information systems relies on the three assertions described in the first part: 1) the quality of artefacts produced from the framework, 2) the ability to map information standards to useful UML profiles and 3) the identification of reusable services.

The quality of the software produced by the framework will depend on the tool support and the developer. The main improvement compared to traditional software development lies in the built-in healthcare tool support, where use of healthcare UML profiles, reuse of existing platform independent models and use of code generation will reduce roundtrip time and improve the quality of the code.

The example showed a simple careplan service where a concept from CONTSYS was applied. More complex services will need more concepts, maybe from more than one standard. The MDSD framework will provide UML Profile support for the most used healthcare standards and patterns for the most recurring concepts. A modular design, in line with Beale's *archetype* concept (7), provides scalability and maintainability of the models as the standards are updated or extended. The *Archetypes* being specified in both CEN TC251 EN13606 [19] and OpenEHR, can be used by the MDSD framework as reusable models and patterns. An archetype is a model of a healthcare concept, and is represented formally using UML.

The specification of reusable services in the healthcare domain is in accordance with Service-Oriented Architecture (SOA) [20]. Many healthcare organizations are adapting SOA as the core enterprise architecture, using a message-oriented middleware with HL7 to exchange information between systems. The process of transitioning to a SOA architecture is expensive, but a fully interoperable healthcare infrastructure would reduce coordination expenses dramatically [3]. Homecare services are likely to be a part of this enterprise service architecture connected through a health network [5]. SOA-based homecare system services can enable independent development and deployment of new patient monitoring and surveillance services in the health network. A SOA based infrastructure will allow sustainable development of healthcare services.

A critical aspect when introducing new development tools and techniques is to evaluate its effect. Proper scientific methods must be applied to achieve rigor. A complete medical informatics solution should not only evaluate the artefacts isolated, but also study their effect in a real environment [21]. The

MDSD HealthCare Framework will be subject for two scientific experiments with real users in the M-Power project[5].

Future work

The framework proposed in this paper is a part of the work being done within the M-Power and Linkcare projects[6]. These projects will identify and develop reusable homecare services for the provision and coordination of homecare services. Using the first version of the HealthCare MDSD framework, some of these services will be evaluated in 2007 and 2008.

Conclusion

With an aging population and dramatic increase in chronic diseases [1], systems interoperability in the healthcare domain is of utmost importance in order to maintain the service level of today and support teamwork treatment. One way to improve interoperability is to ensure the healthcare information systems' conformance to international standards.

The Healthcare MDSD framework will incorporate standards into the development process of information systems, and as a result improve interoperability. The MDSD framework will be evaluated in two experiments in 2007 and 2008 as a part of the LinkCare and M-Power projects. These projects have a strong focus on treatment and management services for chronically ill, elderly and cognitive disabled. This will ensure the framework's relevance for the domain.

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5 MPOWER homepage: http://www.mpower-project.eu
6 LinkCare homepage: http://www.linkcare-bcn.org