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A development framework for semantically interoperable health information systems

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ABSTRACT

Background: Semantic interoperability is a basic challenge to be met for new generations of distributed, communicating and co-operating health information systems (HIS) enabling shared care and e-Health. Analysis, design, implementation and maintenance of such systems and intrinsic architectures have to follow a unified development methodology.

Methods: The Generic Component Model (GCM) is used as a framework for modeling any system to evaluate and harmonize state of the art architecture development approaches and standards for health information systems as well as to derive a coherent architecture development framework for sustainable, semantically interoperable HIS and their components. The proposed methodology is based on the Rational Unified Process (RUP), taking advantage of its flexibility to be configured for integrating other architectural approaches such as Service-Oriented Architecture (SOA), Model-Driven Architecture (MDA), ISO 10746, and HL7 Development Framework (HDF).

Results: Existing architectural approaches have been analyzed, compared and finally harmonized towards an architecture development framework for advanced health information systems.

Conclusion: Starting with the requirements for semantic interoperability derived from paradigm changes for health information systems, and supported in formal software process engineering methods, an appropriate development framework for semantically interoperable HIS has been provided. The usability of the framework has been exemplified in a public health scenario.

Abbreviations: NET, The Microsoft .NET Framework; ACME ADL, Generic Software Architecture Description Language; ADD, SEI Attribute-Driven Design; ADM, Architecture Development Method; ATAM, Architecture Tradeoff Analysis Method; CDA, HL7 Clinical Document Architecture; CEN, European Committee for Standardization; CMMI, Capability Maturity Model® Integration; COM, Component Object Model; CORBA, Common Object Request Broker Architecture; DODAF, Department of Defense Architecture Framework; FEAF, Federal Enterprise Architecture Framework; HDTF, Health Domain Taskforce; HTML, HyperText Markup Language; IBM, International Business Machines Corporation; ICD-10, International Classification of Diseases; IEEE 1471-2000, IEEE Recommended Practice for Architectural Description; ISO/IEC, International Organization for Standardization/International Electrotechnical Commission; J2EE, Java 2 Enterprise Edition; OMG, Object Management Group; OpenEHR ADL, OpenEHR Archetype Definition Language; RIM, Reference Information Model; RM-ODP, Reference Model for Open Distributed Processing; RUP, Rational Unified Process; SAAM, Architecture Analysis Method; SEI, Software Engineering Institute; SPEM, Software Process Engineering Meta-Model; TOGAF, Open Group's Architecture Framework; UML, Unified Modeling Language; XML, Extensible Markup Language.

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1. Introduction

For meeting the challenge for efficient, high quality and sustainable care, increasingly specialized and distributed health systems in developed, and more in developing countries require extended communication and cooperation between all principals involved in patient's care. Principals are all actors within the information management chain such as persons, organizations, systems, devices, applications, components or even single objects [1].

Characterizing a system by its inherent technical, environmental, or policy conditions, communication between different actors requires open, flexible, scalable, service-oriented, intelligent, semantically interoperable, and trustworthy information systems. Requirement analysis, design, implementation, evaluation, use, and maintenance of such complex systems have to follow an agreed process. A formal health information systemS (HIS) development process covering domain perspectives, the views on systems, the composition and decomposition (generalization and specialization) of systems components, comprising not only the architecture development, but also the tooling to be deployed, needs to be provided.

In this paper, a development framework as a set of principles and guidelines as well as methodologies and techniques to be deployed within a unified development process for realizing semantic interoperability in health information systems is proposed, and its usability is exemplified in a public health scenario. For achieving this objective, state of the art approaches for information system's architecture are analyzed and then harmonized towards the framework. As a result, the approach realizes architectural principles by defining an architecture development process in a standard way, documenting, as no other methodology does: tasks, responsible persons, artifacts, products, guidance, phases, and workflows. Particularly important is the use of formal software processes engineering methods and the use of the newest version of the Rational Unified Process (RUP) framework, defined as the facto standard for software systems development. RUP facilitates the flexibility, scalability and reusability of the methodology by providing tooling for delivering the methodology through exportable Web pages and XML Metadata Interchange (XMI) documents. The advantage using the RUP tooling is that the development process's documentation can be viewed (as HTML pages) and shared (as XML files) among software development teams, enforcing them to design consistent models and use of the same guidelines, therefore supporting the design of semantically interoperable models and finally systems.

The paper is organized as follows: In Section 2, business needs and interoperability requirements for health information systems have been defined. Because of its fundamental importance for the approach offered in the paper, systems, systems architecture and systems modeling are systematically and carefully considered in Section 3, thereby introducing the Generic Component Model (GCM). Analyzing and evaluating existing architectural approaches to information systems especially focusing to health-related environments in Section 4, a comprehensive development framework for semantically interoperable health information systems has been derived in Section 5. The Generic Component Model has been used for adapting the Rational Unified Process and harmonizing the outcome with the aforementioned existing approaches. In Section 6, the use of the health information system development framework is exemplified by describing the system architecture of a public health information system, before concluding the paper in Section 7.

In the paper's context, the architecture development framework considers Architecture Vision, Business Architecture, Information System Architecture, and partially Technology Architecture, all expressed by formal models. Other architectural issues such as maintenance, adaptation, governance, etc., are out of scope of the current research paper.

2. Interoperability requirements

The shift in care paradigm towards highly distributed, labor-sharing care settings also concerns the supporting information and communication technology (ICT). Information systems are forced to support communication and co-operation (interoperability) at different levels: technical interoperability at plug, signal and protocol level; structural interoperability realized as simple data exchange; syntactic interoperability as meaningful data exchange with agreed vocabulary; semantic interoperability with common information models and agreed communicating applications' behavior; organization/service interoperability based on common business models and chained services.

Especially in the context of long-term usable e-Health applications such as Electronic Health Record (EHR) systems, several crucial requirements for semantic interoperability reflecting basic business needs have to be met. According to ISO/TR 20514 [2], there are four prerequisites for EHR semantic interoperability: (i) agreement on a standardized reference model, (ii) standardized service interface models to provide interoperability between health services and other services such as demographics, terminology, access control and security (iii) a standardized set of domain-specific concept models, e.g., archetypes and templates for clinical, demographic, and other domain-specific concepts, and (iv) standardized terminologies associated with controlled vocabularies. These requirements only concern informational aspects of HIS, however. From a more comprehensive perspective also including organizational, Technology Architecture as well as other aspects, communication and co-operation between different health information systems and their components in a complex and highly dynamic environment also requires [3]:

- openness, scalability, flexibility, portability;
- distribution at internet level;
- standard conformance;
- business process orientation;
- consideration of timing aspects of data and information exchanged;