Health Policy and Technology (2014) **3**, 3–12

Available online at www.sciencedirect.com

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journal homepage: www.elsevier.com/locate/hlpt

A general framework for interoperability with applications to healthcare

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Available online 10 October 2013

KEYWORDS
EMR;
Interoperability;
Data exchange;
Formal methods

Abstract
Purpose: The contribution of this paper is to provide a formalized methodology to define, specify or design a system of application modules that communicate information between the components. First this paper defines several types of interoperability. Second, it provides a framework for specifying and analyzing the interoperability of existing or proposed medical systems. Third, it provides a simple example of a provider ordering a prescription for a patient to illustrate the interoperability of the proposed healthcare application systems.
Methodology: Our theory-based methodology includes an extensive literature search on interoperability, practical experience in standardizing the Internet, and graph theory.
Results: Our results include a framework to specify, define, plan, and perform analysis on a set of applications that need to exchange information. Within this framework, an Interoperability Matrix and its associated Interoperability Flow Graph represent different types of interoperability between related applications. This formal representation is useful first to define the architecture and also provides the option of using graph algorithms that determine interoperability traits within a group of related applications.
Conclusion: In conclusion, this framework presents a formal methodology to define and classify interoperability within a set of related applications.

Introduction

The contribution of this paper is to provide a framework to define an existing system or specify and design the architecture of a new system of computer applications composed of many components that need to exchange data. It provides a formalized way to represent the interoperability of a group of related applications that share data. Interoperability is valuable for financial transactions, electronic commerce, and social networking. For example, today we use secure protocols to seamlessly transfer money across the globe, and we regularly shop online. The XML-based Open Financial Exchange (OFX) protocol is designed to exchange data among financial institutions, businesses and

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http://dx.doi.org/10.1016/j.hlpt.2013.09.004

consumers. We share many varieties of multi-media with our friends using networking sites such as Facebook and LinkedIn. In many industries, interoperability is a requirement, while in other industries such as healthcare; interoperability is far from fully realized. This is changing, in the US the concept of meaningful use of EHRs combined with government incentives are promoting interoperability. However this positive push is slow because of political and business reasons. What is missing in the general area of interoperability is a formal methodology to define current and design new systems that have interoperability as a core feature.

Even with meaningful use stage II interoperability and government incentive payments to adopt EHRs that meet meaningful use criteria the US is not capturing the value of interoperable EHRS because of lack of consensus in the healthcare industry. At the 2013 HIMSS conference McKesson, Cerner, Allscripts, Greenway, and Athenahealth announced the CommonWell Health Alliance designed to increase interoperability among their systems. Industry leader Epic Systems did not participate in the Alliance. From a technical point of view the industry understands interoperability and has frameworks and standards to promote it such as Health Information Exchanges (HIEs) [1], Health Level 7 (HL7) [2], and HL7 Clinical Document Architecture (CDA) [3]. In additional to the business and political reasons stiffing the exchange of medical information there are also technical issuers including (1) the systems are too complex, (2) it requires new skill sets to grasp the esoteric of these standards, and (3) the lack of practical implementation guidelines of these tools in the real-world settings. Semantic interoperability requires common reference models (i.e., HL7 RIM) as well as terminologies (SNOMED, LOINC, RxNorm); however, these are not in common use outside of the academic setting. It seems odd that we seamlessly exchange social and finance information electronically, but we cannot communicate even basic electronic medical records, since they are based on platforms using different standards for Electronic Medical Records (EMRs). Because of the compelling need for interoperability in the healthcare industry, we use this industry as an illustrative example for our design framework.

This paper discusses semantic interoperability and modularity because we are focused on the exchange of information. We update and clarify our definition from a previous paper [4] to define modularity, and semantic interoperability as follows:

S*emantic Interoperability and modularity*: Semantic Interoperability means that application components exchange structurally defined data with contextual meaning. Applications with modularity allow managers to craft systems with best of breed components. Monolithic architecture implies the many parts of the applications are intricately linked without the ability to replace one module with another module from a different vendor. This effectively inhibits the ability of vendors to create competing or even complementing products. For example consider a simple EHR system with a Computerized Physician Order Entry (CPOE) module used to order medications and a Clinical Documentation (CD) module used to record the current medications a patient is taking. The CPOE has semantic interoperability if it can order a prescription to be created for any local pharmacy; the system has modularity if the CPOE can be replaced by any CPOE that follows the correct standards. Semantic interoperability is a necessary condition for modularity, but semantic interoperability is not sufficient to ensure a system has modular architecture.

This paper introduces and defines an Interoperability Matrix (IM) and an associated Interoperability Flow Graph (IFG). The IM describes data flows among associated applications along with the standards used in data exchange between these applications. It also describes the modularity of each particular application. The IFG presents the same information in a visual map that highlights the connectivity and flow of information among the related applications. Together, the IM and IFG provide a visual representation of interoperability attributes in a single diagram.

The next section of this paper describes our motivation in developing an interoperability framework. After that, the section on Standards for Interoperability discusses Service-Oriented-Architecture (SOA) and some of the many standards used to build interoperability into EMR applications. After these definitions, the paper defines different types of interoperability. Finally, the IM and IFG are defined and applied to a simple medical application that creates an interoperable EMR.

Motivation

Formal methods in software development and engineering allow designers to specify the current design/implementation of an existing system as well as describe the next generation of applications and infrastructure. Traditional formal design methodologies such as flow charts, Entry Relation (ER) diagrams, Unified Modeling Language (UML), and Data Flow Diagrams (DFD) do not explicitly address interoperability. While studies such as Walker [5] illustrate the value of interoperable EMRs, there is no formal methodology to help designers achieve this goal. Our framework fills this gap by providing a formal methodology to define and specify the interoperability for any application composed of modules that need to exchange information.

Electronic medical records: The benefits of converting paper charts into electronic medical records (EMRs) are dependent upon the implementation of this conversion and the ability to electronically exchange the resulting medical data. At the most basic level, an EMR provides increased legibility and distributed access. Additional benefits can be achieved by structuring the data in a way that facilitates knowledge acquisition and data interoperability between applications. EMRs that follow the meaningful use criteria developed by the US Office of National Coordinator (ONC) will improve communication, enhance clinical decision-making, improve compliance with documentation and treatment standards, minimize redundancy, enable context-specific information presentation, integrate clinical documentation and billing functions, and facilitate quality improvement and clinical research. These benefits are more likely to be realized when clinical information is captured as structured data elements (i.e. HL7v3 CDA) encoded in a standardized way (i.e. XML) with an accepted terminology (i.e. SNOMED) rather than as free text, and stored in a way that allows the use of standardized retrieval methods. In the US, interoperability between heterogeneous medical IT infrastructures is lacking, despite the technical ability to provide for interoperability and the obvious advantages stemming from the ability to exchange data between applications that are cross-functional and cross organizational boundaries. The creation of CommonWell