A Framework for Semantic Interoperability in Healthcare: A Service Oriented Architecture based on Health Informatics Standards

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Abstract. Healthcare information is composed of many types of varying and heterogeneous data. Semantic interoperability in healthcare is especially important when all these different types of data need to interact. Presented in this paper is a solution to interoperability in healthcare based on a standards-based middleware software architecture used in enterprise solutions. This architecture has been translated into the healthcare domain using a messaging and modeling standard which upholds the ideals of the Semantic Web (HL7 V3) combined with a well-known standard terminology of clinical terms (SNOMED CT).

Keywords. Distributed systems, Modeling, Standards, Terminology-vocabulary

Introduction

Each year avoidable deaths and injuries occur because of poor communication between healthcare practitioners [1]. The Systemized Nomenclature of Medicine - Clinical Terms (SNOMED CT) is a universal health care terminology, the aim of which is “to improve patient care through the development of systems to accurately record health care encounters” [1]. Terminology is an important tool toward achieving semantic interoperability and thus improving communication in healthcare, and ultimately benefiting patients.

Terminology on its own only provides a standardised set of terms, but this model is strengthened by providing a standard structure for information and rules about where terms may be used in this structure. To this end, the Health Level 7 (HL7) V3 messaging and modeling standard is used. HL7 is chosen because it is consistent with the Semantic Web vision of providing a universal and computer-interpretable medium for the exchange of data (specialised within the health care domain) [2].

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In previous work [3], a strategy for achieving semantic interoperability in healthcare by basing HL7 message models on SNOMED CT concepts and relationships was outlined. It was demonstrated that this methodology could be applied to a basic set of clinical observations successfully. Since then, a full PDA application has been developed for collecting clinical observations data which utilises these message models for communication with a PC. This work was done as part of the ePOC project, which has now concluded.

In this paper, the authors go on to describe an expansion of the basic message model construction method used in the ePOC project, and to outline their overall goal of creating a middleware infrastructure called the Health Service Bus (HSB), a service oriented architecture for effective communication in healthcare.

1. Methods

1.1. Health Service Bus

Enterprise Service Bus (ESB) is a term used to describe a middleware software architecture with a standards-based messaging engine, which is event-driven and provides foundational services for more complex software systems [4].

ESB is both operating system and programming language independent and provides interoperability between different platforms; for example, between Java and .NET applications. ESB is not necessarily Web-Services based (although this is often the case) and uses XML as a standard communications language.

A middleware infrastructure for health systems has been based on the ESB ideology, called the Health Service Bus (HSB). An overview diagram of the HSB architecture is shown in Figure 1. The HSB provides communication between disparate health systems which can all connect to it regardless of the type of software or hardware used. The HSB is also envisaged to provide services such as a terminology server and translation services for legacy systems.

In [3] a small subset of SNOMED CT Observable Entities with corresponding Procedures was concentrated on, in accordance to the clinical requirements of the ePOC project. Since then the focus of this research has been extended as demonstrator of the Health Service Bus. This involved taking a workable-sized subset of SNOMED CT2 revolving around ‘Vital Signs’ terms and concepts, converting the subset to XML and then storing them in a native XML database.

The HSB is built on Jini technology, a service oriented architecture for the construction of secure, scalable distributed systems [5]. A Jini service for querying the SNOMED CT XML database has been created and is one of the core services of the HSB. Applications attached to the HSB communicate via JavaSpaces (part of the Jini Technology), using HL7 V3 in the actual content of the messages, in the format described later in this paper.

Figure 1 shows the ultimate goal of the HSB: the goal of PCs and mobile computing devices all accessing the HSB in order to communicate and access services such as terminology servers and patient databases.

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2 A subset is used because the entire SNOMED CT terminology is extremely large and not practical for research and testing purposes.
1.2. Previous Work

SNOMED CT concepts corresponding to a set of clinical observations were aligned with HL7 message models for use in the ePOC (electronic Point of Care) project. The ePOC project was a multi-phase, iterative R&D project with a research focus involving the development of a prototype PDA based point-of-care information delivery system [6]. A PDA application for clinical observations was developed for this purpose and these message models used and tested within this application [3].

The alignment of these message models is based on mapping SNOMED CT Observable Entities to HL7 Observations (a specialisation of the Act class) by populating the code field of the HL7 Observation with the code corresponding to the SNOMED CT Observable Entity concept. The relationships between the SNOMED CT concepts are upheld in the HL7 model by mapping them to ActRelationships between the Observations. At the same time, the HL7 methodCode field was populated with a SNOMED CT concept from the Procedures subset and the relationships between these concepts also upheld with the same ActRelationships. Table 1 shows a summary of the mapping between HL7 and SNOMED CT.
1.3. Extended Alignment Strategy

The work described in the previous section (2.1), while being sufficient for its application, is a preliminary step toward a greater goal to create a complete framework for health communication and has formed the basis for the messaging models and use of terminology in this framework. To this end, the messaging focus has been expanded more generally to include all types of SNOMED CT concepts (not just Observable Entities and Procedures) by taking a subset of SNOMED CT based on the concept of ‘Vital Signs’. In this new strategy, HL7 models and messages are automatically generated based around the HL7 PatientCareProvisionEvent and ObservationEvent specialisations of Act using these terminological concepts.

Along with the mappings used in the ePOC project shown in Table 1, SNOMED CT Body Structures have been mapped to the HL7 targetSiteCode field, and Clinical Findings mapped to the HL7 interpretationCode field. This field is automatically populated based on the code combined with the value field, to assist with decision support.

As an example, if the code is blood pressure and the value is ‘120/80 mmHg’, the decision support system will automatically populate the interpretationCode field with the concept normal blood pressure, as the normal blood pressure concept has the relationship ‘interprets’ with blood pressure, and the blood pressure value is in a healthy range. The targetSiteCode field is then restricted to the systemic arterial structure and its subconcepts, based on the fact that the normal blood pressure concept has the relationship ‘finding site’ with systemic arterial structure.

Business rules (or constraints) have also been implemented to uphold restrictions between these fields so that all code values in the one instance of a HL7 Observation class must have existing relationships in SNOMED CT, or must not have contradicting relationships in SNOMED CT. These rules facilitate automatic message generation in the HSB.

The SNOMED CT Is a relationship is mapped to the HL7 componentOf ActRelationship, just as in Table 1. Other SNOMED CT relationships, such as Finding Site, are mapped by the two concepts belonging to the same HL7 Observation instance, as described in the example above. A summary of all mappings between HL7 and SNOMED CT is shown in Table 2. The new mappings are shown in bold.
Table 2. Mappings of concepts and relationships between HL7 and SNOMED CT.

<table>
<thead>
<tr>
<th>Concepts</th>
<th>HL7 Observation Field</th>
<th>SNOMED CT Subset</th>
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<tr>
<td>code</td>
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</tr>
<tr>
<td>methodCode</td>
<td>Procedures</td>
<td></td>
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<tr>
<td>targetSiteCode</td>
<td>Body Structures</td>
<td></td>
</tr>
<tr>
<td>interpretationCode</td>
<td>Clinical Findings</td>
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<td>Subtype</td>
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<tr>
<td>componentOf</td>
<td>Is a</td>
<td></td>
</tr>
<tr>
<td>code fields in a single Act</td>
<td>Finding Site, etc</td>
<td></td>
</tr>
</tbody>
</table>

2. Results

2.1. Messaging in the Health Service Bus

HL7 classes have been modeled and implemented in software and can be generated based on a user’s selection of SNOMED CT Observable Entity concepts and entering of associated data. The clinician (as the user) can enter in patient details and clinical notes for an entire episode of care into a front-end application. These notes are stored in the HL7 PatientCare Provision text field, and are optional. The clinician can then add any number of ObservationEvents to the care episode. For each ObservationEvent, the clinician chooses a corresponding SNOMED CT concept from a list and can enter a value and text. The value can be of any type, and will be interpreted based on the SNOMED CT concept chosen.

A dynamic message model will then be created, which can be traversed recursively and an XML message output. These messages are then communicated between applications along the HSB using JavaSpaces. Synthetic message generation allows the scalability of the HSB architecture to be tested.

2.2. Terminology Server in the Health Service Bus

The SNOMED CT ‘Vital Signs’ subset has been converted into XML (SNOMED CT is distributed as a tab delimited text file) for the purposes of using it in the Health Service Bus. This is stored in an eXist [7] XML database and allows for great querying power against the terminology. A Jini service acts as a front end to the terminology server, allowing other applications to communicate with it using the HSB.

2.3. Summary of Results

Figure 1 shows the HSB architecture. Large steps have been made towards this goal, namely the communication (the ‘bus’ in the middle of Figure 1) has been implemented in JavaSpaces and allows any PC (regardless of operating system) to communicate with any other using HL7 messages, and the Terminology Server has been implemented as a SNOMED CT XML database with a Jini Service front end. A translation service
between HL7 V2.3.1 (the most popular version of HL7 2 currently in use) and HL7 V3 is currently being worked on, to allow legacy systems to communicate on the HSB.

3. Conclusion

The information modeling strategies outlined in this paper, combined with Jini technologies, and in particular JavaSpaces, form the basis for communication in the Health Service Bus, and pave the way for semantic interoperability in healthcare.

Synthetic message generation allows the scalability of the HSB architecture to be tested and the plan is to simulate the messaging environment of a large hospital or regional health service.

An XML terminology server and a user-interface for entering patients’ vital signs, which generates and sends HL7 messages, have been implemented.

The next step is to create translation services so that legacy applications and computers connected to the HSB can also communicate with each other. This is an important step towards seamless communication, and will be a further step towards the goal of total semantic interoperability in healthcare.

Acknowledgments

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References