User Centred Networked Health Care
A. Moen et al. (Eds.)
IOS Press, 2011

doi:10.3233/978-1-60750-806-9-804

Using a Logical Information Model-Driven Design Process in Healthcare

Yu Chye CHEONG[a1], Linda BIRD[a], Nwe Ni TUN[a], Colleen BROOKS[a]
[a]*MOH Holdings Pte Ltd, Singapore*

Abstract. A hybrid standards-based approach has been adopted in Singapore to develop a Logical Information Model (LIM) for healthcare information exchange. The Singapore LIM uses a combination of international standards, including ISO13606-1 (a reference model for electronic health record communication), ISO21090 (healthcare datatypes), SNOMED CT (healthcare terminology) and HL7 v2 (healthcare messaging). This logic-based design approach also incorporates mechanisms for achieving bi-directional semantic interoperability.

Keywords. Logical Information Model, Semantic Interoperability, Healthcare Standards, Messaging

1. Introduction

Most clinical applications can send or receive point-to-point messages using standards, such as HL7 version 2. However, for two or more clinical systems to share healthcare data unambiguously, the structure, the (reference) terminology and the semantics must all be agreed upon. This is a requirement for truly shareable Electronics Health Records (EHRs) and downstream functionality such as clinical decision support and care planning that relies on semantic interoperability.

The current lack of message standardisation in Singapore is hindering information sharing between healthcare clusters, sectors and facilities. HL7 v2 is the current de facto standard for healthcare messaging in Singapore – however, there are numerous different HL7 v2 message profiles being used, and widespread use of local extensions and locally defined Z-segments. As a result, national information exchange, querying and conformance quality testing has been difficult. These challenges are further exacerbated by disconnected terminology sets, which differ in their degree of precoordination due to differing local interfaces and information structures.

To achieve bi-directional semantic interoperability [1] within this multi-profile environment, each clinical system must be able to produce and consume every message variation. Each system may therefore need to support dozens of interfaces to other systems. To address these interoperability issues, a logical information model is needed to harmonize (reference) terminology, semantics and structure. The Singapore Logical Information Model is a critical enabler for national initiatives such as the National Electronic Health Record (NEHR) system [2], which aims to consolidate distributed information from various institutions into a single electronic health record for each patient.

[1] Corresponding Author: {yuchye.cheong, linda.bird, nweni.tun, colleen.brooks}@mohh.com.sg

2. Method

The Singapore Logical Information Model (LIM) is an implementation-independent information model for healthcare data exchange. The LIM is based on a standards-based Logical Reference Model (LRM) and includes a set of 'archetypes', or reusable building blocks of clinical information. These archetypes can be further constrained into 'templates' to meet specific use cases. The LIM defines the structure, reference terminology and clinical content of healthcare data exchanges. The LIM can be expressed in a machine-readable format that can be used to generate a variety of artefacts such as exchange format specifications, conformance validation software, user interfaces and human readable documentation. The LIM's novel use of 'design pattern' constructs support a diversity of pre-coordination approaches used by clinical systems to populate their messages using native interface terms.

The process of developing the LIM and resulting artefacts is shown below in Figure 1.

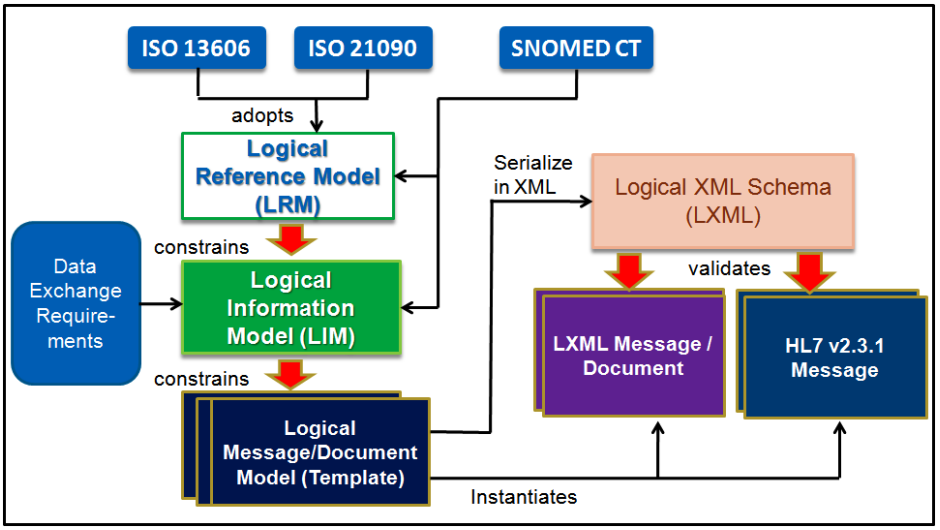

Figure 1: LIM Design Process

Firstly, a **Logical Reference Model (LRM)** was developed to provide both modelling integrity and flexibility. It incorporates the following international standards:

- ISO 13606-1 [3]: A profile of the ISO 13606 reference model is used, in which certain attributes were removed due to a lack of a tangible use case in our local context and to reduce modelling complexity. Some ISO 13606-1 constraints were also relaxed in the LRM - for example, some mandatory constraints were changed to optional, where existing clinical systems could not support ISO 13606's record-keeping metadata requirements, (e.g. AUDIT_INFO.committer [0..1]), or where a standard default value has been defined for Singapore (e.g. RECORD_COMPONENT.synthesised: default="FALSE"). Other changes made to ISO13606-1 include the extension of FUNCTIONAL_ROLE to allow a Participation_Type and Participation_Time, and the extension of IDENTIFIED_ENTITY to support Singapore-specific demographic requirements.

- ISO 21090 data types [4]: A profile of the ISO 21090 data types is used, in which some datatypes (e.g. MO) were excluded, and the HXIT attributes were removed (except for validTimeLow and validTimeHigh required for II).

Besides ISO 13606, Singapore also evaluated the HL7 Reference Information Model (RIM) as the basis for the LRM. The HL7 v3 RIM artefacts (e.g. DIMs, CIMs and CMETs) require a high level of technical skill to interpret, thereby inhibiting widespread and effective clinician validation. There is also an overlap in the semantics of the RIM and SNOMED CT, which can lead to ambiguities. In view of these issues, it was decided that the RIM should not form the basis for the LRM.

Secondly, a **Logical Information Model (LIM)**, conforming to the LRM, was developed for Singapore's healthcare information exchange. The requirements analysis for the LIM was based on two main approaches:

- An evidence-based approach involved the analysis of existing healthcare information exchange. All relevant message profiles (primarily HL7 v2) in Singapore were fully documented in a consistent format, and validated against several million messages in conjunction with local implementation groups. Message types such as ADT (Admission/Discharge/ Transfer), Pharmacy Order and Laboratory Results were covered. A number of local message profiles exist for each of these message types, each using a surprising diversity of representations for the same or similar semantics.
- A clinician-driven approach to gathering requirements for the NEHR and Discharge Summary documents.

The LIM was developed as a set of reusable, clinical 'archetypes' for each ENTRY that needed to be exchanged (e.g. 'Problem/Diagnosis', 'Pharmacy Order'). Archetypes were initially developed based on modelling the clinical semantics of the data that was currently being exchanged, rather than modelling the 'intended' meaning of the HL7 v2 message. In many cases, this resulted in a single HL7 v2 field being mapped to two different LIM elements (where the meaning of data included in this field differed between existing profiles), and two different HL7 v2 fields being mapped to the same LIM element (where the meaning of data used in a field of one profile was actually the same as that used in a different field of another profile).

For each LIM element, mappings to the relevant local message profiles were developed to provide traceability back to the source requirement. The constraints defined on each LIM element were the lowest-common-denominator of all existing message profiles. For example, if the cardinality of a particular element was mandatory in one local profile, but optional in another, then the LIM element cardinality was set to optional, to cater for all existing information requirements. Record-keeping metadata was mapped to, and supported by, the LRM attributes.

The LIM supports the binding of elements to both the national 'reference terminology' and various 'interface terminologies' used within local clinical systems. To support the diversity of pre-coordination allowed in clinical interface terms, 'design patterns' (DP) were introduced, based on the SNOMED CT concept model [5][6]. These design patterns allow more than one split between the information model and the terminology model to be represented, and then normalised for consistent, national querying. The approach used to normalise the interface terms is shown in Figure 2. A reverse process is also being developed to take the normalised terms and convert them back into a system-specific structure to enable bi-directional semantic interoperability.

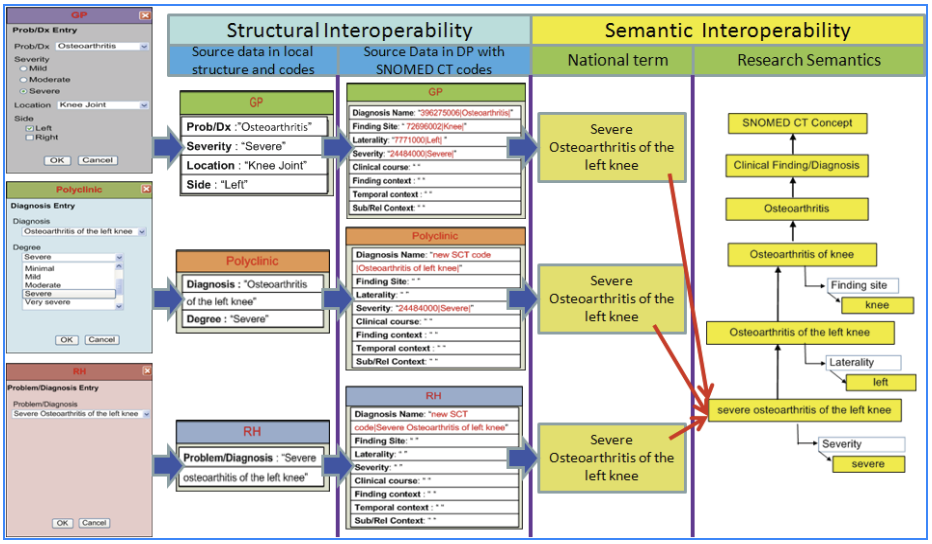

Figure 2. Use of Design Patterns

Thirdly, a series of use case-specific **Templates** were developed for each message or document type, as a set of constraints on the LIM. Templates have been developed for two main purposes:

- To represent the mapping from an existing messaging profile to the LIM
- To represent the set of elements and constraints that forms the national standard for a given message type – referred to as the **National Data Definition Specification (NDDS)**. Each NDDS accommodates all data currently being exchanged for a given message type, and all anticipated future requirements.

Lastly, from each NDDS one or more format-specific **National Data Exchange Specifications (NXDS)** are generated. These NXDSs include guidance on how each LIM element in the associated NDDS is mapped into the specific exchange format. NXDSs for two exchange formats have been developed – namely:

- **Logical XML (LXML)**: This exchange format has been developed as a direct XML serialisation of each LIM-based NDDS (called NXDS-LXML). This enables the exchange specification and conformance testing software to be generated in a completely automated way from the clinician-validated requirements, represented in the LIM. Use case-specific XML tag names have been used to make implementation easier, and enable simple conformance compliance testing to be achieved using XML schema. However, to minimise the maintenance costs arising from changing business requirements, and provide a future-proof capability, the LXML is developed by extending the record-keeping components of the ISO 13606 reference model XML schema. This enables a pair of simple XSLT transforms to be written which takes any LXML instance and converts it to/from a generic ISO 13606-1 XML schema.
- **HL7 v2**: An HL7 v2.3.1 [7] NXDS specification (called NXDS-HL7 V2) has been developed for each NDDS. These national HL7 v2 profiles include Singapore-specific cardinalities, constraints and value domains. The HL7 v2 NXDSs minimise information loss from the NDDSs by including those entries

that do not fully map to standard HL7 v2 segments, into additional structured OBX and NTE segments (also referred to as 'archetyped v2'). This approach allows additional information to be included in the HL7 v2 messages, while still maintaining conformance to the standard message segment tables.

3. Results and Discussion

The LIM currently supports the generation of 6 main NDDSs – ADT, Pharmacy Order, Pharmacy Dispense, Laboratory Results, Radiology Results and ACIDS (Acute Care Inpatient Discharge Summary) – and 12 NXDSs (HL7 v2.3.1 and LXML for each NDDS). Variations to these message types (including smaller, constrained versions tailored to the NEHR requirements) can be achieved with little additional effort.

The above LIM-based design approach has initially been implemented on an extremely small tooling budget. The LIM has been documented in the form of a spreadsheet, in which each 'archetype' is represented on a separate worksheet (using a predefined definitional format), and each 'template' is represented using a column of this worksheet (to document each template constraint against the associated data components). NDDSs are generated by auto-filtering the rows of the spreadsheets, based on the appropriate template constraints, HL7 v2 NXDSs are generated through manual mappings, and LXML NXDSs are generated by manually serialising the NDDSs into XML schema. The intention, however, is to transition to a comprehensive and highly automated tooling suite to fully realise the benefits of the above approach. We plan to implement terminology normalisation and denormalisation algorithms over the LIM's design patterns, and a query language over the LIM semantics, which can be transformed to system-specific queries over multiple heterogeneous data sources.

In conclusion, we believe that the establishment of the LIM is a critical step in achieving bi-directional semantic interoperability in Singapore, and ultimately achieving greater clinical safety in the interchange of healthcare information.

References

[1] Stroetmann VN, (Ed.), Kalra D, Lewalle P, Rector A, et al. *Semantic Interoperability for Better Health and Safer Healthcare, SemanticHEALTH Report*, European Communities, 2009.
[2] Singapore National Electronic Health Record System
[3] ISO 13606-1. *Electronic Health Record Communication - Part 1: Reference Model*, 2008.
[4] ISO 21090. *Harmonized Datatypes for Information Interchange*, 2009.
[5] IHTSDO. *SNOMED Clinical Terms User Guide: January 2010 International Release*, 2010.
[6] Spackman KA. *Expressions and Context Patterns, IHTSDO, 2008.*
[7] Quinn J, (Tech. Chair). *HL7 v2.3.1 Final Standard*, 1999.