SYSTEM ARCHITECTURE FOR AUTONOMOUS MAPPING OF HL7 RIM TO RELATIONAL DATABASE

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Presentation Scheme

1st
• Introduction
• Research Scope

2nd
• Problem Definition
• Proposed Solution

3rd
• System Architecture
• System Implementation

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• System Evaluation
• Research Outcomes

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• Conclusions & Future Work
• References

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Background and Introduction
Background

Role of Standardization

Air traffic control system

Postal Code System

eBanking

Healthcare Standardization?
Introduction
Introduction .....
Interoperability in Healthcare

- The ability of two or more systems or components to exchange information and to use the information that has been exchanged.
  
  (IEEE Standard Computer Dictionary)

- Healthcare systems require interoperability to share the information meaningfully
  - Real time and effective decisions.
Interoperability in Healthcare.

**Semantic Interoperability**
- Capable of automatically interpreting the information exchanged.
- Both sides must refer to a common information exchange reference model.

**HL7 v3.0**
- Provides semantic interoperability.
- Reference Information Model (RIM) collects and relates all the data that exists for HL7.
HL7 Reference Information Model

- HL7 RIM is the **foundation of healthcare interoperability**.

- Purpose is to share consistent meaning beyond a local context.

- A comprehensive source of all information subjects used in any HL7 specification.

- Expressed using a modified object notation similar to that used in UML.
Healthcare System Communication

Here we need RIM-to-Schema Mapping
Manual integration is less practical

Schemas can be quite large (tedious, error-prone, ..)

No documentation or meta data available sometimes

Poor design: exact semantics not known or fully captured in the schema

For a single element $s$ of schema $S$, one must examine all other elements of RIM
Motivation

- The vision is to automate RIM to clinical schema mappings to minimize the user intervention, thus saving time, reducing errors and providing ease & flexibility.

- Generate custom code to eliminate manual efforts in development.
RIM and Schema Mappings Challenges

- Heterogeneity issues because of:
  - Varying data models (ER, EAV, UML)
  - Differences in schemas
  - Query languages they support
  - Domain terminologies they recognize

- Same concept, different name.
  - Medicine: Drug, pills, Medicine etc.

- Same name, different concepts.
  - Doctor: Author, Performer, Verifier etc.
RIM and Schema Mappings Challenges

- RIM covers the whole healthcare arena, but complex to understand.
  - Complex Data types
  - Correct mappings to RIM attributes is complex problem.
  - IDs and sequence numbers are used for interoperability purpose, no such practical usage in clinical systems.
Currently, the RIM and schema mapping is largely performed manually, then it is a:

- tedious
- time consuming
- error prone, and
- expensive

To reduce the amount of manual effort as much as possible, semi automatic approaches are required.

It is not possible to determine all correspondences between RIM and schema automatically due to their semantic heterogeneity.
Problems in Existing Approaches

- No automation
- Time consuming task
- Error prone user intervention in identifying the appropriate mappings
- Lack of Code Generation, a development overhead
- Lack of Mapping Knowledge for HL7 Domain
Problem Statement

- Without automation, mapping requires human intervention for manually tracing out all attributes in RIM, which is laborious and time consuming task.

- Involve costly development efforts in enabling the output mappings with the working system.
Proposed Solution

- A process that can address the manual mapping by automating all possible mappings.

- And generate custom code to eliminate manual efforts in development.
Scope of the Work in HL7

Data Mappings
- Data model-to-Data model
  - Automatic Mappings
  - Manual Mappings

Object model-to-Data model

Healthcare Standards
- HL7
  - HL7 Version 3
  - HL7 Version 2.x
  - X12N
  - NCPDP SCRIPT

Health Care Domain
- Laboratory
- Patient Administration
- Billing and Accounting
- Pharmacy

HL7 RIM-to-Laboratory Schema Mapping Application
Automated Solution for Mapping of HL7 RIM to Relational Database
Proposed Methodology
Proposed Architecture

**Schema Loader:** Loads the schema

**Schema Mapper:** Finds the most appropriate match.

Loading corresponding RMIM Object Model.
Key Functions

1. Schema Loading
2. RMIM Loading
3. Perform Mappings
   - 3a. Constraint Handler
4. Mapping Knowledge Repository (MKR)
   - 4a. Integrated Browsing and Searching Interface
   - 4b. Integrated Updating Interface
5. User Mapping
7. Code Generator
   - Generate Custom Classes
   - Generate Hibernate Mapping Files (.hbm)
**Schema Loading:**

- **Purpose:**
  - Extract the basic schema details from a relational database
  - View and manipulate the schema details during performing mappings
**Schemaspy**

- Open source tool that extracts schema details in html files.
- Customized it according to this work.
- Supports more than 15 RDs
  - E.g. mssql, derby, db2, mysql etc.
Key Functions Cont.....

1. Schema Loading Cont...

Fig. Schema Loading
RMIM Loading

- XML Reader
  - Scans the RMIM Schemas and extract the detailed information

- Class Name, corresponding attributes.

Fig. Partial Schema Snapshot
Key Functions Cont.....

RMIM Loading Cont...

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Key Functions Cont.....

3. Mapping Controller

Fig. Perform Mappings
Mapping Strategies

- **Exact Match Rule:**
  - Finds the exact pattern in the Mapping Knowledge Repository.
  - For example,:
    - name, pname, patname etc. - pname, patname then this will be the exact match.

- **Pattern Match Rule:**
  - Traces pattern in the database element.
  - For example
    - name, pname, patname etc. - patientname, which contains the pattern ‘name’ as a sub-pattern.
Mapping Strategies

- **Synonyms Match Rule:**
  - Find synonym match with the database element.
  - For example:
    - `description` as `desc, description, comments` etc.

- **Sub-Pattern Match Rule:**
  - Find a sub-pattern of the stored mappings in the database element.
  - E.g.
    - `name, pname, patname` etc.
    - `p_nam` than this will be the sub-pattern match.
Key Functions Cont.....
Mapping Controller Cont...
Constraint Handler

Delete Mappings
Database of the possible mappings found in the clinical laboratory databases.

This is done by the analysis of functioning laboratory databases

To be extended with more mapping knowledge by community involvement.
MKR provides two essential features,

- Store mapping knowledge
- Accommodate various input/output features
  - View and create new mappings.

- Repository is designed in XML.
<Class name="Patient" Mappings="Patient,tblPatient" Description="Holds Patient Information">
    <attribute name="id" Datatype="II"RegularExpression="" Mappings="id">Identifier: This carries the patient identifier.</attribute>
    <attribute name="addr" Datatype="AD"RegularExpression="((Home|Office|residential)\(_\)Address)|(Address)" Mappings="Address,Addr,Location,ResidentialAddress,OfficeAddress">Holds address of the patient.</attribute>
    <attribute name="telecom" Datatype="TEL"RegularExpression="((tele|cell|mobile)\(_\)phone)|(fax|mobile|phone)(no|number|no.)?" Mappings="phone,telephone,email,fax,mobile">holds telecommunication address</attribute>
    <attribute name="statusCode" Datatype="CS"RegularExpression="" Mappings="statuscode_status_code">Definition:A code specifying the state of the Act.</attribute>
    <attribute name="effectiveTime" Datatype="SXCM_TS"RegularExpression="" Mappings="tstPerformTime">A time expression specifying the focal or operative time of the Act</attribute>
    <attribute name="priorityCode" Datatype="CE"RegularExpression="" Mappings="priority">the primary time for which the Act holds</attribute>
    <attribute name="confidentialityCode" Datatype="CE"RegularExpression="" Mappings="confidentiality_code">the time of interest from the perspective of the Act's intention.</attribute>
    <attribute name="veryImportantPersonCode" Datatype="CE"RegularExpression="" Mappings="veryImportantPersonCode,VIP">is happening</attribute>
</Class>

Fig. Mapping Knowledge Repository Structure
Mapping Knowledge Repository

<table>
<thead>
<tr>
<th>Attribute Name</th>
<th>Datatype</th>
<th>Description</th>
<th>Mappings</th>
</tr>
</thead>
<tbody>
<tr>
<td>targetSiteCode</td>
<td>CD</td>
<td>is happening</td>
<td>targetsite,target_site,targetsite_code</td>
</tr>
<tr>
<td>methodCode</td>
<td>CE</td>
<td>can happen</td>
<td>Method,method_code</td>
</tr>
<tr>
<td>reasonCode</td>
<td>CE</td>
<td>specifying the urgency under which the...</td>
<td>reason_code</td>
</tr>
<tr>
<td>independentInd</td>
<td>BL</td>
<td>emergency</td>
<td>Independent_ind</td>
</tr>
<tr>
<td>interruptibleInd</td>
<td>BL</td>
<td>for routine</td>
<td>interruptible_ind</td>
</tr>
<tr>
<td>repeatNumber</td>
<td>IVL_INT</td>
<td>A code or set of codes (e.g., repeat_no</td>
<td>repeat_no</td>
</tr>
<tr>
<td>confidentialityCode</td>
<td>CE</td>
<td>the time of interest from the perspective...</td>
<td>confidentiality_code</td>
</tr>
<tr>
<td>priorityCode</td>
<td>CE</td>
<td>the primary time for which the Act holds...</td>
<td>priority</td>
</tr>
<tr>
<td>effectiveTime</td>
<td>SXCM_TS</td>
<td>A time expression specifying the focal...</td>
<td>timestartTime</td>
</tr>
<tr>
<td>statusCode</td>
<td>CS</td>
<td>Definition: A code specifying the state...</td>
<td>statuscode_status_code</td>
</tr>
<tr>
<td>text</td>
<td>ED</td>
<td>A renderable textual or multimedia de...</td>
<td>Description,casc,comments,heading,n...</td>
</tr>
<tr>
<td>code</td>
<td>CD</td>
<td>Definition: A code specifying the partic...</td>
<td>code</td>
</tr>
<tr>
<td>id</td>
<td>II</td>
<td>Identifier: This carries the Placer Num...</td>
<td>id,test_id,testid</td>
</tr>
</tbody>
</table>

Fig. Integrated Searching Interface
Select the Class from MKR

Details of the class selected

Fig. Integrated Searching Interface
Fig. Adding Mappings to MKR
Fig. Adding Mappings to MKR
Key Functions Cont.....
MKR Cont.....
Integrated Updating Interface

Fig. Adding Mappings to MKR
Key Functions Cont.....
MKR Cont.....
Integrated Updating Interface

Fig. Adding Mappings to MKR

Mapping Knowledge Repository

Class Name: Patient
Class Description: Information, e.g. address, telephone etc
Attribute Name: telecom
Attribute Description: Holds contact details like phone no, email
Mappings: Phone, Mobile, Email,

Next Attribute  Add
Key Functions Cont.....  
MKR Cont.....
Integrated Updating Interface

Fig. Mapping Knowledge Repository
Evolution Process of MKR

- Involves the community through a registration process.

- Update MKR by adding new matching columns and the tables found in their clinical databases.

- MKR automatically gets updated while the tool is performing mappings i.e. when the user edits or re-maps

- Conduct a clinical survey about the medical terminologies most frequently used.
Manual Mappings

- Allows user to manually perform the mappings
- Select attribute from RMIM panel,
- Select column from Schema panel
- Click <<Map>> Button
- The mappings are added.
Key Functions Cont.....
User Mappings Cont....

Fig. User Mapping Interface
Key Functions Cont.....

Generate Output Mapping File

Output Mapping File

- Contains the output mappings
- .xml format
Key Functions Cont.....

Generate Output Mapping File Cont...

Fig. Perform Mappings
Key Functions Cont.

Generate Output Mapping File Cont...

Fig. Output Mapping File

```xml
<?xml version="1.0" encoding="UTF-8"?>
<root>
  <Map>
    <Class name="COC_HD050000UV.Patient" attribute="id">
      <Table Table="tblPatient" Column="id" DataType='int identity'/>
    </Class>
  </Map>
  <Map>
    <Class name="COC_HD050000UV.Patient" attribute="telecom">
      <Table Table="tblPatient" Column="PhoneNo" DataType='varchar'/>
    </Class>
  </Map>
  <Map>
    <Class name="COC_HD050000UV.Person" attribute="name">
      <Table Table="tblPatient" Column="Name" DataType='varchar'/>
    </Class>
  </Map>
</root>
```
Key Functions Cont.....

7 Code Generator

RSM Interface

Output Mapping File (.xml)

1

2

3

Hibernate (O/R) Mapping files (.hbm)

RIM Based Custom Classes (.java)

JavaSIG

Healthcare Database

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Hibernate Framework

- Persists objects in relational database
- Open source
- Transparent solution – underlying tables are hidden from classes
- Very well matured and adopted by a large developer community
• Reads output mapping file
• Scans the file and generates
  • custom classes
  • .hbm files

• Code generator is supporting to generate code with different IDE project types
Provide the path of the output mapping file generated in the previous step

Fig. Get path Dialog Box
Key Functions Cont.....

Code Generator Cont..

**Fig. Setting the Filepath**
Fig. Output custom classes & hbm files
import java.io.Serializable;

public class tblPatient implements Serializable {

    private int address;
    private int Phone;
    private int telephone;
    private int Mobile;
    private int Email;
    private int Sex;
    private int Name;

    public void setPhone(int Phone) {
        this.Phone = Phone;
    }

    public int getPhone() {
        return Phone;
    }

    public void setEmail(int Email) {
        this.Email = Email;
    }

    public int getEmail() {
        return Email;
    }

    public void setMobile(int Mobile) {
        this.Mobile = Mobile;
    }

    public int getMobile() {
        return Mobile;
    }

    public void setSex(int Sex) {
        this.Sex = Sex;
    }

    public int getSex() {
        return Sex;
    }

    public void setName(int Name) {
        this.Name = Name;
    }

    public int getName() {
        return Name;
    }
}

Fig. Custom Classes
Key Functions Cont....

Fig. Output hibernate mapping files

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Key Functions Cont.

Code Generator Cont.

Fig. Output hibernate mapping files
End to end experience

- HL7 Message parsing into CITILab Database
Working with JavaSIG.....

Fig. JavaSIG
Working with JavaSIG ……

Fig. HL7 Message
Working with JavaSIG.....

Fig. hbm File for Patient
Working with JavaSIG …..

Fig. JavaSIG to CITILab Database
Adapter Package – Data types Conversion

Fig. Adapter Package for Data types Conversion
System Evaluation
caAdapter provides graphical user interface for mapping without automation.

caAdapter mapping service requires human intervention for manually tracing out all attributes in RIM.

Laborious and time consuming efforts.
- Schema and ontology matching tool
- Not open source tool
- Showed unsatisfactory results for HL7 message mapping
- Lack of Code Generation

Fig. COMA ++ Mapping GUI
## Feature-based Comparison with existing Systems

<table>
<thead>
<tr>
<th>Tools / Features</th>
<th>Database Mapping</th>
<th>Open Source</th>
<th>Code Generation</th>
</tr>
</thead>
<tbody>
<tr>
<td>caAdapter</td>
<td>Yes (Manual)</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>HAPI</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>MIRTH</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Chameleon</td>
<td>Yes semi-automatic (HL7 V2.x)</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>RSM</td>
<td>Yes (semi-automatic)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Research Outcomes
Research Outcomes

Bleffioere  RSM
Where is RIMBAA?

**User Interface**

- **Database**
- **Message**

**Persistent Representation**
- MP
- RP
- AP

**Object Representation**
- MO
- RO
- AO

**Serialized Representation**
- MS
- RS
- AS

**RIM (generic)**
- Model

**RIM (specialized)**
- Message

**Message (RIM)**
First Approach

Persistent Representation
- MP
- RP
- AP

Object Representation
- MO
- RO
- AO

Serialized Representation
- MS
- RS
- AS

User Interface

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Second Approach

Persistent Representation
- MP
- RP
- AP

Object Representation
- MO
- RO
- AO

Serialized Representation
- MS
- RS
- AS

User Interface

Database

Message
Conclusion

- Addressed the problem of identifying corresponding elements in different healthcare schemas and HL7 RMIM.

- A challenging problem, very active area of research with various market applications.

- Provides fast and simple integration.

- Enriched with extensive knowledge of HL7 RIM

- A generalized framework that can be extended to other domains.

- This tool will help in bridging the existing relational databases with the HL7 messaging.
Thanks