Quality of Life through Quality of Information
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Standardizing Intensive Care Device Data to Enable Secondary Usages

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Abstract. To represent medical device observations in a format that is consumable by clinical software, standards like HL7v3 and ISO/IEEE 11073 should be used jointly. This is demonstrated in a project with Dräger Medical GmbH focusing on their Patient Data Management System (PDMS) in intensive care, called Integrated Care Manager (ICM). Patient and device data of interest should be mapped to suitable formats to enable data exchange and decision support. Instead of mapping device data to target formats bilaterally we use a generic HL7v3 Refined Message Information Model (RMIM) with device specific parts adapted to ISO/IEEE 11073 DIM. The generality of the underlying model (based on Yuksel et al. [1]) allows the flexible inclusion of IEEE 11073 conformant device models of interest on the one hand and the generation of needed artifacts for secondary usages on the other hand, e.g. HL7 V2 messages, HL7 CDA documents like the Personal Health Monitoring Report (PHMR) or web services. Hence, once the medical device data are obtained in the RMIM format, it can quite easily be transformed into HL7-based standard interfaces through XSL transformations because these interfaces all have their building blocks from the same RIM. From there data can be accessed uniformly, e.g. as needed by Dräger´s decision support system SmartCare [2] for automated control and optimization of weaning from mechanical ventilation.

Keywords. ISO/IEEE 11073, HL7 Version 3, PDMS, HL7 CDA, PHMR

Introduction

In order to represent medical device observations in a format that is consumable by clinical applications, standards like HL7v3 and ISO/IEEE 11073 should be used jointly.

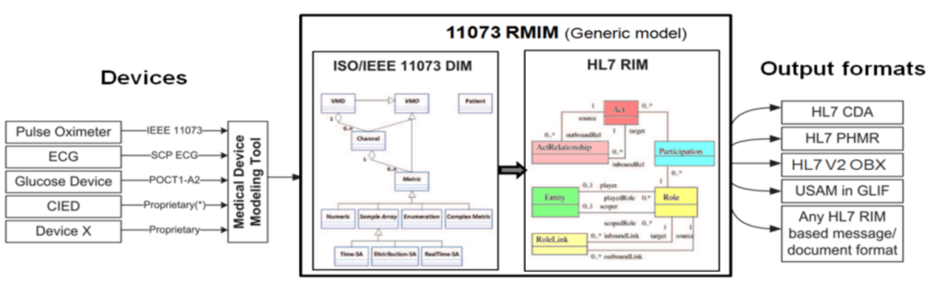

Figure 1. Generic approach for medical device data integration; based on [1]

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This is also true in our project with Dräger Medical GmbH that wants to reuse intensive care device data stored proprietarily in their Patient Data Management System (PDMS), called Integrated Care Manager (ICM) [1] for secondary purposes. As an example, we improved the integration of the decision support system SmartCare for automated control and optimization of weaning from mechanical ventilation [2] and intensive care software for accessing device data uniformly. Otherwise the interface has to be adapted for every customer according to data structures and device terminology used by them.

Instead of bilateral mappings from device data to target formats (e.g. [3]) we use the approach from Yuksel et al. [1] shown in figure 1. The generality of the underlying integrated model *11073 RMIM* allows the flexible inclusion of IEEE 11073 conformant device models of interest on the one hand and the generation of needed representation formats for secondary usages on the other hand, e.g. HL7v2 messages, HL7 CDA documents like Personal Health Monitoring Report (PHMR) or qualified web services.

Depending on devices (Figure 1, left) and message or document formats (Figure 1, right) of interest, mainly XML transformations and code mappings are left to do. As this paper focuses on device data already available within the ICM system, we exclude the aspect of device interactions based on the IEEE 11073 exchange protocol as well as corresponding wrappings of proprietary devices. In the following it is shown

- that migrating proprietary device data to HL7v3 compliant output formats based on the approach from Yuksel et al. [1] is achievable and beneficial; and
- what are the necessary steps for adapting the *11073 RMIM* for devices of interest and for instantiating output formats for intensive care systems of interest.

1. Methods

After the corresponding data types in HL7v3 and IEEE 11073 DIM were studied, we adapted the *11073 RMIM* mentioned in figure 1. It was necessary to extend the RMIM for multiple devices and additional PDMS data. Figure 2 gives an idea of the relevant classes in both models mapped to each other.

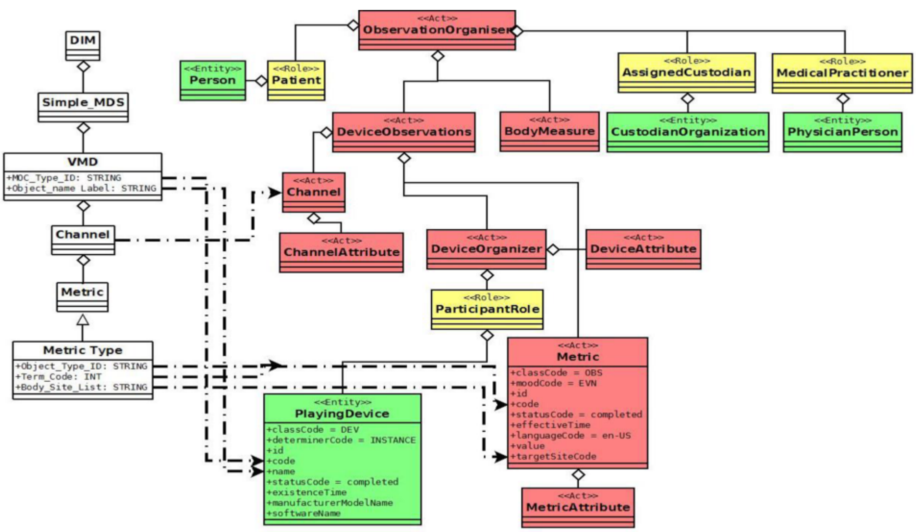

Figure 2. Mapping of IEEE 11073 refined DIM and HL7 RMIM.

The medical devices are specified in the DeviceOrganizer class of the *11073 RMIM*. More details can be represented in the PlayingDevice class. It is simplified to the device name and MDC code attribute, due to specification in the VMD. The measured values, detected by the medical device, are grouped into channels in both models. Numeric and Real-Time-Sample-Array classes of the IEEE 11073 DIM were mapped to the HL7v3 Metric class. This is a suitable starting point for deriving XML schemes and Java classes, enabling the migration of most proprietary device data to standard formats.

We then developed a mapping tool “V3Map” that is applied to Drägers´s ICM system but can be adapted to other systems. This tool is structured according to the following steps; three steps for initialization and one for actual data transformations at runtime:

a) Provision resp. addition of IEEE 11073 DIM schemata for devices of interest
b) Provision resp. adaption of a “simple” XML based intermediate format for extracting the data of interest out of the ICM system. In addition, there is a mapping table to relate codes and units for device data from the ICM system to IEEE 11073
c) Provision resp. adaption of XSL-transformation rules for mapping an instantiated *11073 RMIM* to target output formats of interest
x) <u>V3Map Core</u>: Instantiation of the *11073 RMIM* with exported data from the ICM system (based on a) - b)) and generation of instantiated target formats (based on c).

a) For all relevant types of devices parts of their corresponding 11073 DIM are extracted, containing all necessary classes and attributes for generating informative HL7v3 instances. For our use case “Enabling decision support by SmartCare based on ICM data”, we modeled two intensive care devices including ventilators by using the ICSGenerator [4]. By adding MDC codes from the IEEE 11073-10101 nomenclature [5] to our refined DIM, we created standard compliant device descriptions.

b) To access patient and device data at runtime, we utilized the integrated ICM export module filtering patient data with treatments, e.g. device observations like heart rate. The chosen intermediate XML-format is already oriented partially to the HL7v3 standard such that further processing can easily be done:

<Case id="7009"> <Order id="5">
<Treatment id="2799"> <Name>etCO2 mmHg</Name> …
… <SubstanceUnit>mm[Hg]</SubstanceUnit> </Treatment>
… … <Mode id="23"> … <Measurement id="430"> … <Timestamp>
…

Before the exported data can be used to instantiate the adapted 11073 RMIM we need to prepare a mapping table with mappings between codes and units used in the ICM system and within IEEE 11073. For example, the ICM treatment ID "20498" is mapped to the metric code MDC_AWAY_RESP_RATE for finding the according metric to each value extracted from the ICM system. Fortunately, a provisionally completed Rosetta Terminology Mapping (RTM) table is provided by Dräger (figure 3).

REFID	CODE10	Description	DisplayName	Vendor_UOM	UOM_UCUM	Vendor_ID
MDC_ATTR_PT_WEIGHT	2527	weight	Wt	g oz	g [oz_av]	Draeger
MDC_AWAY_CO2_ET	20656	End-tidal Carbon Dioxide	etCO2	mmHg kPa	mm[Hg] kPa	Draeger
MDC_AWAY_CO2_ET	20656	End-tidal Carbon Dioxide	etCO2*	mmHg kPa	mm[Hg] kPa	Draeger
MDC_AWAY_CO2_EXP	20660	Mixed-Expired CO2	mib PECO2	mmHg kPa	mm[Hg] kPa	Draeger
MDC_AWAY_RESP_RATE	20498	Respiratory Rate spontaneous	mib RR s	/min	{breath}/min	Draeger
MDC_BLD_PULS_RATE_INV	18450	Arterial Pressure - Pulse Rate	PPR	/min	/min	Draeger
MDC_CO2_RESP_RATE	20522	Respiratory Rate	RRc	/min	{breath}/min	Draeger

Figure 3. Extract of Draeger´s contribution to the Rosetta Terminology (IEEE 11073 nomenclature)

c) As one of several possible output formats (figure 1, right) we decided to transform the instantiated *11073 RMIM* to the CDA document PHMR [6], which serves for storing and processing monitoring data. As the *11073 RMIM* instance is available as an XML file compliant to HL7 RIM, we decided to use XSL transformations to accomplish this task. Besides PHMR, other HL7v3 RIM based message or document standards can be derived alternatively.

x) V3Map Core: At runtime for every case of interest data is exported by the ICM system. Starting from the intermediate format (b) the *11073 RMIM* - XML schema is instantiated. If concrete devices are mentioned, the abstract metric classes from the *11073 RMIM* are used as templates for adding complete metrics prepared in step a). Parsed measurement values of the ICM output are included regarding the mapping of codes and units in step b). We chose Java to implement our algorithm. RMIM compliant Java classes are achieved by converting our HL7v3 based schema via XMLBeans. Once a fully instantiated *11073 RMIM* is available, a PHMR document is generated by XSL transformations (c). The correctness is validated with NIST online validator [7].

2. Results

Using our approach, available patient and device data are provided initially in a simple intermediate XML-based format and as long as there is no change regarding the involved medical device types the transformation to the target format of interest is done automatically. Our approach is flexible in three dimensions:

- First, one can add, change or delete types of medical devices at the schema level, i.e. adding an 11073 conformant DIM for an ECG device (a).
- Second, the PDMS is replaceable if its data export conforms to our simple intermediate XML format and code and unit mappings are provided (b).
- Third, a variety of standard output formats can be reached (c).

Every exported ICM case data is available in a standard format to be accesses uniformly, e.g. by a decision support system like SmartCare [2]. Figure 4 demonstrate the access to PHMR data of interest by using XPath commands.

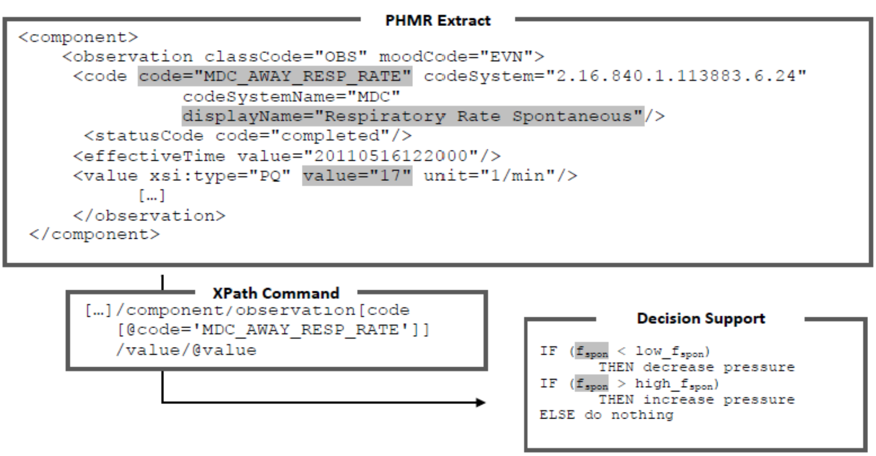

Figure 4. Accessing decision support system relevant data out of the generated PHMR document.

Besides using XMLBeans for processing HL7v3 objects in Java we tested the RIM Based Application Architecture (RIMBAA) [8]. It provides an API to develop RIM-based documents in Java. Since RIMBAA supports the whole RIM, it is very complex and therefore caused many problems. From our point of view, it introduces an unnecessary burden on the implementation. In contrast, XMLBeans translated only the *11073 RMIM* into Java classes. Therefore, the produced library is not as complex as the one provided by RIMBAA. XMLBeans also supports validation of instances and values contained therein. Therefore, we preferred XMLBeans to construct Java objects.

3. Discussion

The mapping of the 11073 MDC codes to the UCUM units was often difficult as most RTM entries are improperly specified. Especially, UCUM units and the corresponding MDC codes are frequently omitted or mentioned several times. An improvement could be the inclusion of the Rosetta table in the Unified Medical Language System (UMLS) to access RTM codes and units through terminology services.

Opposed to initiatives like Continua (IEEE 11073 DIM => HL7 V3 PHMR) and IHE (IEEE 11073 DIM => HL7 V2 OBX) we enable different clinical applications to extract device data from a generic model (*11073 RMIM*) rather than using bilateral mappings to different target standards (figure 1) [1]. If the target standard format (for instance the PHMR) is known, it seems easier to realize the mapping from the PDMS data directly into that format. However, once a suitable generic model reflecting necessary devices for a given use case has been created, several standard formats can be generated by quite simple XSL transformations. This argument becomes even stronger, as not only HL7v2 message formats or HL7v3 document formats are of interest. Dräger as a medical device developing company is interested very much in improving device interoperability based on SOA (Service Oriented Architecture). For that, HL7 provides a suitable Web Services Profile. Regio [9] demonstrates the feasibility of that approach by using appropriate wrappers enclosing the data and passing it to web service adapters for transmitting HL7v3 content via SOAP messages. The improvement of SOA-based integration of medical devices at the semantic level is on the agenda of future work.

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