HL7 and DICOM based integration of radiology departments with healthcare enterprise information systems

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ABSTRACT
Purpose: Integration based on open standards, in order to achieve communication and information interoperability, is one of the key aspects of modern health care information systems. However, this requirement represents one of the major challenges for the Information and Communication Technology (ICT) solutions, as systems today use diverse technologies, proprietary protocols and communication standards which are often not interoperable. One of the main producers of clinical information in healthcare settings represent Radiology Information Systems (RIS) that communicate using widely adopted DICOM (Digital Imaging and Communications in Medicine) standard, but in very few cases can efficiently integrate information of interest with other systems. In this context we identified HL7 standard as the world’s leading medical ICT standard that is envisioned to provide the umbrella for medical data semantic interoperability, which amongst other things represents the cornerstone for the Croatia’s National Integrated Healthcare Information System (IHCIS). The aim was to explore the ability to integrate and exchange RIS originated data with Hospital Information Systems based on HL7’s CDA (Clinical Document Architecture) standard.

Methods: We explored the ability of HL7 CDA specifications and methodology to address the need of RIS integration HL7 based healthcare information systems.

Results: We introduced the use of WADO service interconnection to IHCIS and finally CDA rendering in widely used Internet explorers. The outcome of our pilot work proves our original assumption of HL7 standard being able to adopt radiology data into the integrated healthcare systems.

Conclusion: Uniform DICOM to CDA translation scripts and business processes within IHCIS is desired and cost effective regarding to use of supporting IHCIS services aligned to SOA.

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1. Introduction
Healthcare delivery environments are under constant pressure to rationalize the cost of care provisioning while at the same time having to preserve or even increase the quality of care pathways and clinical processes. In the process of evaluation how to address this stringent set of requirements, integration and integrated personalized care based on the well-founded Information and Communication Technology (ICT) solutions are recognized as the major quality component [1]. In that sense, Hospital Information Systems (HIS) and integrated healthcare information infrastructures need to address these issues by defining business processes in care delivery settings, and identify the integration mechanisms that include business scenarios and use cases, semantics and communication technology.

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In the process of integration, high quality data management based on open standards represents the stepping stone in achieving the goals of integrated care. Electronic patient record represents the heart of any healthcare services delivery settings, where the ICT systems that support clinical delivery processes need to “pump” the blood into the heart of these systems in an efficient and interoperable manner. In that context, we have recognized radiology systems as one of the major medical data generators that produce a large quantity of important clinical information, which needs to be efficiently integrated in patients’ medical records. Having that fact in the focus of our work, in this paper we evaluate a pilot approach to develop a generic framework for the integration of DICOM (Digital Imaging and COmmunications in Medicine) based Radiology Information Systems (RIS) to the integrated HL7v3 (Health Level 7 ver. 3) enabled Healthcare Information Systems (HIS). The goal of this research was to define and implement a reliable and efficient transformation service that will bridge DICOM and HL7 standards differences, and enable the integration of radiology data to the HL7 founded clinical settings.

The paper will elaborate in detail developed DCM-CDA (DICOM-CDA) service that provides efficient transformation of DICOM objects to CDA (Clinical Document Architecture) conformant XML (Extensible Markup Language) documents. The access to DICOM images has been implemented and accomplished using the emerging WADO (Web Access to DICOM Persistent Objects) definition.

It is also important to note that we align all of our work with the strategy for the next generation Croatian healthcare delivery system officially accepted by the Croatian Government. The foundation for all future care processes in Croatia represent the recently officially released national healthcare ICT infrastructure that is based on Ericsson Nikola Tesla’s Integrated Healthcare Information System solution. Among other features, this solution implements state of the art healthcare standards such as HL7v3 and CEN ENV 13606 which are important from the perspective of this work. The details of the strategy as well as components of the IHCIS solution can be found in referenced literature [2].

2. Radiology and hospital systems interoperability needs

The DICOM standard represents the evolution of the historical ACR-NEMA (The American College of Radiology—National Electrical Manufacturers Association) sets of recommendations [3]. DICOM specifies the network communication rules and the physical data format to enable communication between modalities and humans through developed software solutions. In this context we are focusing on the DICOM supported datasets exchange, which requires specific connectors and communication enablers that use other widely accepted standards like HTTP (HyperText Transfer Protocol). This requirement has been identified as one of the key integration components, and has resulted in new additions to the DICOM standard known as WADO [4]. WADO enables the HTTP communication of DICOM objects by defining the GET parameters of the HTTP request with pre-defined types of returning context e.g. image/jpeg and text/xml.

The HL7 standard today represents the foundation of many healthcare information management systems [5]. It specifies structures and mechanisms to describe and communicate administrative and clinical data without focusing on a specific healthcare domain or communication technology. HL7 standard in its third version (HL7v3) focuses on the methodology how do the clinical and ICT experts specify the final data sets that are exchanged between systems, and does so by founding all its’ artifacts on HL7 Reference Information Model. HL7 RIM represents one of the major qualities of HL7v3 standard, which has been recently accepted by ISO as the global standard on the international level (The official title: ISO/HL7 21731:2006 - Health Informatics - HL7 Version 3 - Reference Information Model (RIM) - Release 1).

One of the HL7 standard packages that we refer to in our work is CDA. CDA introduces document-based specifications to exchange various clinical data in healthcare delivery environments, e.g. laboratory reports, discharge letters etc. Based on the fact that HL7 CDA is widely used as the information layer integration solution for heterogeneous healthcare delivery environments, we have identified the CDA specifications as the bridge of connectivity between RIS systems based on DICOM standard where we consider only WADO as access point, and HL7 enabled HIS systems. However, today there are no generic data transformation mechanisms and most of the transformations are done on a case-by-case basis, which makes this research even more challenging and interesting.

Having identified this state, the starting point to this work represents the development of the architectural framework for DICOM/HL7 CDA integration [6], which is clearly separated of the development and final implementation of the service itself. The idea behind this approach is to introduce a Platform Independent Model (PIM) that will identify the information model mappings, and serve as the input to the service development that can be then implemented in any preferred technology.

2.1. DICOM and HL7 information models

The DICOM to CDA transformation consists of semantic mapping textual and multimedia contexts. We consider the textual data mappings according to the semantic meaning, and multimedia data linking to the defined WADO services. Direct linking to WADO services enables acquiring multimedia sub context information from DICOM datasets directly from distant radiology departments.

The DICOM information model consists of IOD (Information Object Definition) elements. Each IOD saves data relevant to the IOD global context. For example, the patient’s name, sex and ID are encapsulated in the Patient IOD. In HL7 CDA the patient relevant data is saved under the patient element, and formatted using XSD (XML Schema Definition) specifications and rules. Similarities in both information models are evident from the semantic meaning according to mapping relevant information from the DICOM dataset to the CDA header.

The DICOM and CDA information models have slightly different base models (Fig. 1). The DICOM tag and the CDA
element pair define the mapping of information relevant to the CDA header. The CDA header should provide administrative information about included clinical data. In our approach we define mappings according to the pairs DICOM tag—CDA element place.

The CDA body element saves clinical data, which can contain textual and multimedia data. All multimedia data should be linked according to CDA external data definition. Linking presents a hyperlink to the multimedia data, and is available with simple HTTP transfer protocol.

The DICOM datasets must be divided into parts presenting separate multimedia content, providing support for multiple images management. Separate multimedia content is then available using the DICOM WADO specification. WADO specifies HTTP GET parameters to query and retrieve modalities of underlying DICOM solutions to retrieve whole data sets or separate elements (e.g. images) according to the slice number.

2.2. DICOM context management for HL7 enabled communication

Corresponding to the HL7 protocol, a "plug-in" DCM-CDA web service upgrade is required to enable HL7 interfaces communication to DICOM enabled systems. We determine that this service should be mediator to enable HL7v3 communication to the DICOM WADO service as illustrated on Fig. 2. Operations for query and translation within DICOM-CDA service should be made on the HL7v3 messaging protocol. Our pilot solution use direct SOAP communication as request to DCM-CDA service, but final output is HL7v3 CDA document. Note that authentication and authorization services for this framework are usually implemented by a third party service provider. In the Croatian case, directory services and access manager implemented by the national healthcare infrastructure provide these features.

2.3. Radiology report in HL7 healthcare delivery environment, activity scenario

Acquisition modality is starting point for radiology report generation. All images are saved within Picture Archiving and Communication Systems (PACS) in accordance to DICOM standard. The business processes usually include radiology specialists contacting PACS systems, and after examining captured images they generate report in the textual form, also usually accompanied with snippets of diagnostic images (see Fig. 3). Report is saved according to the DICOM specifications to the RIS system as Structured Report (SR) referencing Service Object Pairs (SOP) instances (images, waveforms, etc.), which would make this system highly important to the integrated care processes and patient care pathways. As the next
step patients are usually referred back to his family doctor, where the assigned physician would access RIS repositories in order to acquire radiologists’ reports or original radiology images to identify next steps in the patient care processes. With this interaction a centralized translation service, in this case DCM-CDA would be used to provide necessary RIS repository connection, querying and standard translation to HL7. Once the data is available to the assigned physician, he is authorized to update patient healthcare record, and define further actions to be instantiated (e.g. prepare new prescription or referral for the patient, etc.).

There are many benefits why the ability of accessing radiology reports and DICOM original content outside the RIS or even HIS bring benefits to the care delivery systems. The most significant ones can be listed as follows:

- Direct access to latest radiology reports for patients independent of place and time of access, which enables physicians to make efficient and correct decisions based on valid and accurate data.
- Improving the importance and empowering family physicians in the patient care processes, which is proved to bring quality improvements and cost savings to the system.
- Patient’s choice of the hospital or private stakeholders to take radiology examination is improved, as the data would be available in an efficient, location and time independent manner.
- Simple reuse of cost expensive acquisition modalities and radiology specialists allowing patient guide to earliest free acquisition modality.
- RIS to RIS integration and sharing of resources, which provides the foundation of knowledge sharing and opinions exchange between radiology specialists.
- Telemedicine consultations within or outside RIS, HIS, region or other country, which is proven to bring extreme quality improvements during the health services provisioning, both on the cost and quality aspects.

3. Results

The presented integration framework with the DCM-CDA service upgrade has been implemented in a testing environment as illustrated in Fig. 4. The testing environment consisted of a DCM-CDA integration component, a web based WADO implementation and a HIS portal web application, which simulated the services provided by the Croatian national healthcare infrastructure. Additional extension to WADO has been implemented to enable querying DICOM objects by unique Patient Identifier, where XML file with resulting DICOM ObjectID’s is returned as the response to the query. HL7 communication with DCM-CDA was facilitated using the Web Service’s implementation (Fig. 5).
3.1. **DCM-CDA service configuration and implementation**

The main responsibility of the DCM-CDA service is to reliably translate DICOM objects to a CDA conformant document. DICOM transformation to CDA and the final HTML (HyperText Markup Language) presentation goes through the DICOM parser (our own implementation) transforming the DICOM binary dataset to a DICOM xml presentation (DICOM.xml file on Fig. 6 and it’s schema visualized on Fig. 7). MSXSL (Microsoft’s Extensible Stylesheet Language) transformations processor transforms the DICOM xml presentation to a CDA document according to the DCMtoCDA.xsl transformation definition. The final presentation is then generated in the...
3.2. **DICOM to CDA transformation flow**

The DICOM datasets are first transferred to a simple XML format, as annotated in the previous chapter. The XML representation of the DICOM object represents the input for DICOMtoCDA.xsl transformation. The DCM-CDA service then generates the final DICOM CDA presentation based on this input. The DICOM to CDA transformation consists of several transformations, where each transformation element handles a different CDA sub domain (Fig. 8). That makes the service modular and easy to maintain.

3.3. **User-end presentation of the CDA document**

The HTML presentation of the CDA translated DICOM dataset is generated according to the pre-defined XSLT (Extensible Stylesheet Language Transformations) transfor-
mation scheme used by the client’s web browser (Fig. 9) and browsers internal XSL processor like MSXML for Internet Explorer. To meet with the performance and bandwidth utilization requirement, all images are retrieved directly from the WADO web application, according to the generated external resource elements in the CDA document. External resources are transformed to a HTTP request with GET method required attributes according to WADO specification.

3.4. Simple web access to DCM-CDA service

Service for standard transformation (like DCM-CDA) is simply adopted in HIS system or exposed to physician systems by giving a simple access to radiology reports through HL7 standard and Web Services. Fig. 10 shows login to HIS portal, with credentials (in production site this is provided through token or smartcard).

Physician is uniquely identified according to his/her credentials and he/she can start Radiology report query for specific patients radiology report according to patients unique ID. After some time service respond with all radiology reports for patient from all locations for which DCM-CDA service have access.

4. Conclusion

The primary target of this research has been the evaluation of the standard based methodology and tools to enable cross-communication of patient information between radiology systems and general sense hospital information networks. Based on the results provided we can conclude that the developed DCM-CDA represents an easy to use, configurable and modular component which facilitates the main integration bridge from the medical imaging management solutions to the healthcare information networks. This bridge is envisioned as one of the major quality components when it comes to patient care delivery, which improves overall patient safety and decreases the cost of the care processes and services. Our solution starts with the detailed analysis of information models, and facilitates WADO definitions to provide access mechanisms from patient clinical data to diagnostic images. XSLT based transformation gives the advantage of upgrades in accordance with most recent specific standard changes. Our results also prove the technical correctness of this component to be fully aligned with the needs of RIS/HIS integration based in the DICOM and HL7 standards.

It is also important to note that the decision to use HL7 standard has been heavily influenced by the wide adoption of HL7 recommendation, including the national healthcare infrastructure in Croatia. Although at this stage IHCIS facilitates the support for primary care processes only, Croatia has over the years had many successful telemedicine pilots that have proved a high value of the concept for a country with over 1000 islands and other areas that are not so easily reachable. IHCIS is envisioned to represent the healthcare highway in the future that includes telemedicine applications as well. In that context we see the importance of this work as being a fully feasible technical bridge between radiology sessions supported by the patient medical history contained in IHCIS.

<table>
<thead>
<tr>
<th>Main conclusion</th>
<th>Lessons learned from project</th>
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<tbody>
<tr>
<td>Well defined service interface for exchange of radiology reports through HL7 enabled information systems makes the care provisioning more efficient, timely and accurate.</td>
<td>Web services provide reasonable choice for this service implementation since WS-* standards give desired level of upgradeability and full SOA integration.</td>
</tr>
<tr>
<td>DCM-CDA service fits well with the business processes for image query, translation and retrieval, which is important from the overall adoption perspective.</td>
<td>The simplest business process up to the DCM-CDA service and between DCM-CDA service and whole RIS, prepare this service for full SOA adoption within IHCIS.</td>
</tr>
<tr>
<td>Division of the DCM-CDA translation script to IOD MODULES and DICOM Dictionary simple database and other translation subscripts.</td>
<td>Cost effective solution regarding to maintenance and use of supporting services which affects final cost (e.g. security).</td>
</tr>
<tr>
<td>Readiness for full integration within Croatian national infrastructure as one of our major goals.</td>
<td>Ease of use, upgradeable, easy maintainable and full versioning solution for further standard upgrades.</td>
</tr>
<tr>
<td>Proof of concept system developed in test environment.</td>
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**REFERENCES**


[2] M. Končar, D. Gvozdanović, Primary healthcare information system—the cornerstone for the next generation healthcare


