AUTOMATING THE IMPORTATION OF MEDICATION DATA INTO PERSONAL HEALTH RECORDS

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Keywords: Medication data, e-Prescription, Personal health record, Business process management, XML, RDF.

Abstract: A personal health record (PHR) provides a summary of the health and medical history of a consumer. It includes data gathered from different sources such as from health care providers, pharmacies, insures, the consumer, and third parties such as gyms. Importing data into PHRs is problematic as different data sources use different representation formats. In addition, automating the importation is problematic as many of the sources are built based on proprietary solutions, and thereby are not able to interoperate with PHR systems. In this paper, we described how the importation of e-prescriptions into PHRs can be automated. In our solution e-prescriptions are produced by an electronic prescription writer (EPW) which functionality is specified by BPMN notation and then translated into executable WS-BPEL code. The EPW sends CCR-formatted data of e-prescriptions into PHR system, which first transforms (if needed) the data into the format of the used PHR system, and then stores them into PHRs. In particular, we consider how a PHR system can transform a CCR-formatted data into RDF/XML format. The gain of such transformation is that we can implement the PHR system as an application of a knowledge base system, and thereby we can capture the wide expression power of knowledge base system's query interface into the PHR system.

1 INTRODUCTION

E-prescription is the electronic transmission of prescriptions of pharmaceutical products from legally professionally qualified healthcare practitioners to registered pharmacies (Batenburg and Van den Broek, 2008). The information in an e-prescription includes for example, prescribed products, dosage, amount, frequency and the details of the prescriber.

The problems related to prescribing medication are discussed in many practitioner reports and public national plans, e.g., in (Hyppönen et al., 2005; Puustjärvi and Puustjärvi, 2006; Dwivedi et al, 2007; Batenburg and Broek, 2008; Ghani et al., 2008). These plans share several similar motivations and reasons for the implementation of electronic prescription systems (EPSs). These include: reduction of medication errors, speeding up the prescription ordering process, better statistical data for research purposes, and financial savings.

Physicians usually produce e-prescriptions by exploiting specific electronic prescription writers (EPWs), which also assist in storing e-prescriptions into prescription holding stores. As a result of recent interest in personal health records (PHRs) a relevant challenge is to extend EPWs in a way that they are also able to store e-prescriptions into PHRs.

A PHR is a record of a consumer that includes data gathered from different sources such as from health care providers, pharmacies, insures, the consumer, and third parties such as gyms (Agarwal et al., 2006; Kaelber et al, 2008). It typically includes information about medications, allergies, vaccinations, illnesses, laboratory and other test results, and surgeries and other procedures (Lewis et al., 2005; Tuil et al, 2006).

An ideal PHR provides a complete and accurate summary of the health and medical history of a consumer (Angst et al., 2008). It is accessible to the consumer and to those authorized by the consumer. It is not the same as electronic health record (EHR)

Puustjärvi J. and Puustjärvi L. (2010).
AUTOMATING THE IMPORTATION OF MEDICATION DATA INTO PERSONAL HEALTH RECORDS.
In *Proceedings of the Third International Conference on Health Informatics*, pages 135-141
DOI: 10.5220/0002335801350141

(EHR, 2009), which is designed for use by health care providers (Raisingha and Young, 2008).

PHRs can be classified according to the platform by which they are delivered. In internet-based PHRs health information is stored at a remote server, and so the information can be shared with health care providers. They also have the capacity to import data from other information sources such as a hospital laboratory and physician office. However, importing data to PHRs from other sources requires the standardization of PHR-formats.

Various standardization efforts on PHRs have been done. In particular, the use of the Continuity of Care Record (CCR standard) of ASTM and HL7's (Dolin et al., 2001) Continuity of Care Document (CCD standard) has been proposed. From technology point of view CCR (CCR, 2009) and CCD-standards (CCD, 2009) represent two different XML schemas designed to store patient clinical summaries. However, both schemas are identical in their scope in the sense that they contain the same data elements.

It is widely anticipated that in the near future PHRs have the potential to dramatically change healthcare. However, our argument is that a critical aspect of current PHRs' use is their consistency. In particular the recall (the fraction of the relevant documents, which have been stored in PHRs) is crucial: making healthcare decision on inadequate data may be a strong risk.

It is evident that the recall of PHRs is highly dependent on the way the data is imported to PHRs. Our argument is that in order to ensure that a PHR includes an accurate medical history of the patient the importation of source data into PHRs should be done automatically. Re-entering data into PHRs would cause additional manual operations, and the importation of all the relevant data cannot be ensured.

In this paper, we describe our work on automatic importation of e-prescriptions' data into PHRs. We will illustrate the extension of WS-BPEL based EPW in a way that it can automatically send prescriptions' data into relevant PHRs. The format of the data follows the CCR standard. However, we do not assume that all PHR-systems are based on CCR standard since the format can be transformed by a stylesheet engine into PHR system's used format. As an example, we present how a CCR-file can be transformed into RDF/XML-format (RDF, 2004). The gain of using RDF/XML-format is that we can store the data in a knowledge base which provides powerful querying facilities on PHRs. This in turn increases the efficient and reliable use of the PHRs.

The rest of the paper is organized as follows. First, in Section 2, we give an overview of an electronic prescription process in which prescription writer application interacts with other health care applications. Then we illustrate how BPMN can be used in modelling the coordination of electronic prescription processes. In Section 3 we present the service oriented architecture where EPW takes place. In Section 4 we consider the representation formats of the delivered medicinal and give an example of transforming a CCR-file into RDF. The gains of using RDF-formatted PHRs are analyzed in Section 5. Finally Section 6 concludes the paper by discussing the weaknesses and advantages of our developed solutions.

2 e-PRESCRIPTION PROCESS

2.1 Constructing e-Prescriptions

In our used model, in prescribing medication the physician uses an EPW. The prescribing process goes as follows: First the physician request from the patient whether the patient have a PHR, and whether the data of the new prescription should be stored in patient's PHR. In the case positive attitude the physician delivers that information to EPW. If the EPW do not have information about patient's PHR then such information is requested from the patient and then delivered to the EPW.

In prescribing the actual medication the EPW used by the physician may interact with many other health care systems in constructing the prescription. For example, the EPW may query previous prescriptions of the patient from the prescription holding store and from patients PHR (in the case of authorized by the patient). The EPW may also query patient's records from other health care systems.

Once the physician has constructed the prescription the EPW sends the prescription to the medical expert system which checks (in the case of multi drug treatment) whether the prescribed drugs have mutual negative effects, and whether they have negative effects with other ongoing medical treatment of the patient. Then the EPW sends the prescription to a medical database system, which checks whether the dose is appropriate. The medical database may also provide drug-specific patient education in multiple languages. It may include information about proper usage of the drug, warnings and precautions, and it can be printed to the patient. Then the EPW sends the prescription to a pricing system, which checks whether some of the drugs can be changed to a cheaper drug.

Once the checks and possible changes have been done the physician signs the prescription electronically. Then the prescription is encrypted and sent to an electronic prescription holding store.

The patient is usually allowed to take the prescription from any pharmacy in the country. At the pharmacy the patient gives the prescription to the pharmacist. The pharmacist will then request the electronic prescription from the electronic prescription holding store. After this the pharmacist will dispense the drugs to the patient and generates an electronic dispensation note. Finally they electronically sign the dispensation note and send it back to the electronic prescription holding store. Hence the dispensation of the e-prescription is also stored in the prescription holding store.

2.2 Modelling e-Prescription Processes

Now we illustrate how the coordination of the interoperability required by electronic prescription systems can be automated by utilizing XML-based languages. In particular we show how the Business Process Modeling Notation (BPMN) (BPMN, 2005) and Web Services Business Process Execution Language (WS-BPEL) (WS-BPEL, 2007) can be used for automating the coordination of electronic prescription processes.

The reason for using BPMN is that the BPMN notation is readily understandable for the employees of the health care sector. It is also readily understandable for the business analyst that create the drafts of health care processes as well as for the technical developers responsible for implementing the technology that will perform those processes. In addition, a notable gain of BPMN specification is that it can be used for generating executable WS-BPEL code.

BPMN provides a graphical notation for specifying business processes in a Business Process Diagram (BPD), based on a flowcharting technique very similar to activity diagrams from Unified Modeling Language (UML).

In BPD there are tree Flow Objects: Event, Activity and Gateway: An *Event* is represented by a circle and it represents something that happens during the business process, and usually has a cause or impact. An *Activity* is represented by a rounded corner rectangle and it is a generic term for a work that is performed in companies. A *Gateway* is represented by a diamond shape, and it is used for controlling the divergence and convergence of sequence flow. In BPD a *Sequence Flow* is represented by a solid line with a solid arrowhead.

In Figure 1 we have presented how the process of producing electronic prescription (described in Section 2.1) can be represented by a BPD.

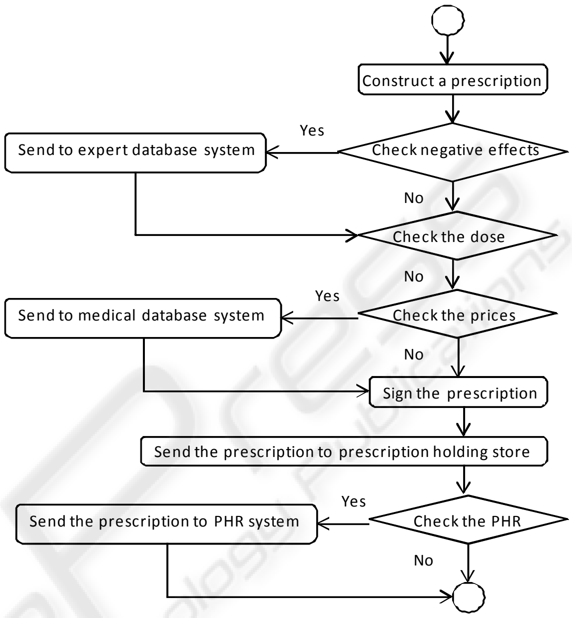

Figure 1: A prescription process presented by a BPD.

3 EXECUTING e-PRESCRIPTION PROCESS

Web Services Business Process Execution Language (WS-BPEL) is an XML based programming language to describe high level business processes (WS-BPEL, 2007). A 'business process' is a term used to describe the interaction between two businesses or two elements in some business. An example of this might be an EPW system requesting from the expert database system whether two drugs have negative mutual effects. WS-BPEL allows this interaction to be described easily and thoroughly such that the expert database system can provide a Web Service and the EPW can use it.

In terms of WS-BPEL, the term 'Web Service' means something with which one can interact (Singh and Huhns, 2005). For example, in our prescribed e-prescription process there are web services that are interacted to get information whether there are substitutable drugs having lower prices.

The interactions of web services are described from architectural point of view in Figure 2.

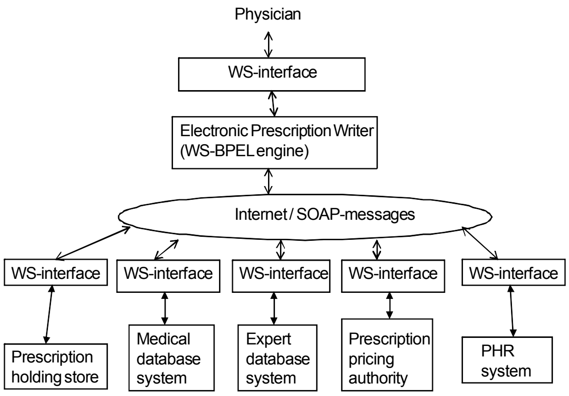

Figure 2: The interoperation of the EPW.

The EPW (WS-BPEL engine) loads WS-BPEL specifications and then runs the prescription process. A nice feature of WS-BPEL engines is that they itself are also web services. Hence the physician interacts with the web service interface of the EPW.

The EPW communicates with other systems by using the SOAP protocol (SOAP, 2009), which was originally intended to provide networked computers with remote-procedure call services written in XML. It has since become a simple protocol for exchanging XML-messages over the Web.

A SOAP-message is comprised of a SOAP header, SOAP envelope and SOAP body (Singh and Huhns, 2005). In particular, the SOAP body contains the application-specific message that the backend application will understand. As illustrated in Figure 3, we incorporate our used CCR-formatted medicinal documents in the SOAP body.

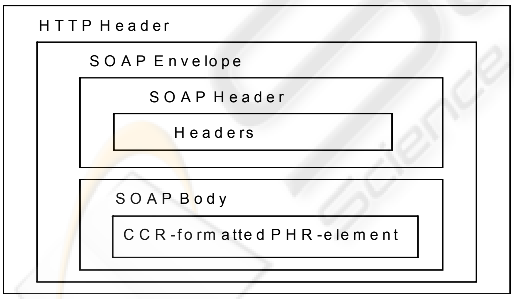

Figure 3: A CCR-formatted PHR-element in a SOAP-message.

4 REPRESENTATION FORMATS

4.1 Transforming PHR-formats

In order that the medicinal information systems are able to handle the XML-elements of the SOAP-messages they have to use the DOM-parser and the Stylesheet engine. The DOM parser (Daconta et al., 2003) transforms input text (i.e., CCR-elements) into a tree, which is suitable for the Stylesheet engine to process.

The term DOM (Document Object Model) (Daconta et al., 2003) refers to a language-neutral data model and application programming interface (API) for programmatic access and manipulation of XML-coded data. Generally, parsing (also called syntactic analysis) is the process of analyzing a sequence of tokens to determine its grammatical structure with respect to a given formal grammar.

As illustrated in Figure 4, the Stylesheet engine takes the CCR-formatted XML-document from the DOM-parser, loads it into a DOM source tree, and picks out the needed information in transforming the XML-document with the instructions given in the local (PHR-specific) stylesheet.

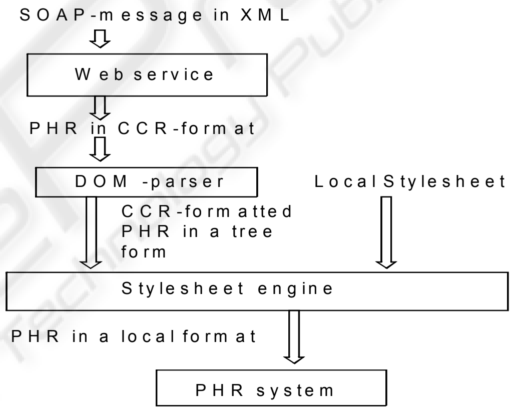

Figure 4: Transforming the representation format of a CCR file.

4.2 Transforming a CCR-file into RDF

The CCR standard is an ANSI-accredited health information technology standard, which is published in 2006. Though it is proposed for PHRs its original purpose is to enable the creation, storing and exchange (between computer systems) of digital summaries of individuals' administrative and clinical health information.

A CCR-file is comprised of seventeen sections. It is not intended to capture individuals' all past medical history but instead to summarize information that will be most useful in individual's medical encounter with a new or unfamiliar provider.

The sections of the CCR standard include for example patient demographics, insurance information, immunizations, allergies, diagnoses, procedures and medication list. Each section contains elements that can represent free text or structured XML-coded text. The content of each CCR file is captured from various sources such as from hospital information system, a clinical laboratory, from a pharmacy or from the patient him or herself. In order to know who or what organization is the source of each element in a CCR file each data element is time and source stamped.

A simplified example of a CCR file is presented in Figure 5. It represents a CCR file that has a medication list (element Medications) which is comprised of one medication (element Medication) that is source stamped by the Pharmacy of Kaivopuisto.

```
<ContinityOfCareRecord>
  <Patient><ActorID>Person.12345></ActorID></Patient>
  <Medications>
    <Medication>
      <CCRDataObjectID>
        Medication567
      </CCRDataObjectID>
      <DateTime>
        <ExactDateTine>
          2009-03-01TO12:00
        </ExactDateTime>
      </DateTime>
      <Source>
        <Actor>
          <ActorID>Pharmacy of Kaivopuisto</ActorID>
          <ActorRole>Pharmacy</ActorRole>
        </Actor>
      </Source>
      <Description>
        <Text>One tablet three times a day</Text>
      </Description>
      <Product>
        <ProductName>Voltaren</ProductName>
        <BrandName>Diclofenac</BrandName>
      </Product>
      <Strenght>
        <Value>50</Value>
        <Unit>milligram</Unit>
      </Strenght>
      <Quantity>
        <Value>30</Value>
        <Unit>Tabs</Unit>
      </Quantity>
    </Medication>
  </Medications>
</ContinityOfCareRecord>
```

Figure 5: An element of a CCR file.

In order to illustrate the transformation of CCR files into RDF, the CCR file of Figure 5 is presented in RDF/XML format in Figure 6.

```
<rdf:RDF
    xmlns : rdf=
        "http://www.w3.org/1999/02/22-rdf-syntax-ns#"
    xmlns : xsd="http://www.w3.org/2001/XMLSchema#"
    xmlns : po=http://www.lut.fi/ontologies/p-ontology#>
    <rdf:Description rdf:about="120962-K3">
      <rdf:type rdf:resource="&po;Patient"/>
      <po : PatientName>Lisa Smith</po : PatientName>
          <po : Uses>MO-5481</po:Uses>
      <po : Performed>H-257L</po : Performed>
    </rdf : Description>
    <rdf:Description rdf:about=" MO-5481">
       <rdf:type rdf:resource="&po;Medication"/>
       <po : Contains>Voltaren</po : Contains>
       <po : StrenghtValue rdf:datatype=
           "&xsd;integer">30</po : StrenghtValue>
       <po : StrenghtUnit>Tabs</po : StrenghtUnit>
    </rdf : Description>
    <rdf:Description rdf:about=" 211708-8">
       <rdf:type rdf:resource="&po;Source/>
       <po : ActorRole>Pharmacy</po : ActorRole>
    </rdf : Description>
    <rdf:Description rdf:about=" Voltaren">
       <rdf:type rdf:resource="&po;ProductName"/>
       <po : BrandName>Diclofenac</po : Contains>
    </rdf : Description>
 </rdf:RDF>
```

Figure 6: A PHR in RDF/XML format.

5 THE GAINS OF USING RDF IN PERSONAL HEALTH RECORD

We have investigated the use cases of PHRs. It is turned out that patients are not only interested about single documents such as the content of the previous prescription but most of the searches or queries require computing over many documents. For example, a patient may be interested to know the average blood pressure and/or blood sugar concentration (glucose level) during the time periods he or she was using Diovan (a drug for blood pressure), or the patient may be interested to know the cholesterol values when he or she was on a diet.

Unfortunately the computation required by such data centric queries is not supported by the query languages (e.g., XPath (XPath, 2008) and XQuery (Xquery, 2008) that are designed to address XML-documents. The problem here is that the CCR- (as well as the CCD-based) PHRs are XML-documents that can only be accessed by the query languages developed for XML-documents.

This is the reason why we have developed PHRs, which content is structured according to an ontology, and which thereby allow a wide variety of data centric searches and queries. In particular, we have used OWL (Web Ontology Language) (OWL, 2006) in designing the PHR-ontology. The instances of the ontology are presented in RDF. Hence, for example the RDF-formatted PHR element of Figure 6 can be stored in an ontology based PHR system.

Fundamentally, the purpose of the PHR-ontology is to describe the concepts of the domain in which PHRs take place. Hence, a PHR-ontology describes the concepts (as well as their relationships) such as demographics, insurance information, immunizations, allergies, diagnoses, procedures and medication.

In developing the PHR-ontology we have exploited the XML-schema of the CCR file. In transforming the XML schema to OWL-ontology we have used on the whole the following rules:

- Complex elements are transformed to OWL classes.
- Simple elements are transformed to OWL data properties.
- Element-attribute relationships are transformed to OWL data properties.
- The relationships between complex elements are transformed to class-to-class relationships (object properties).

To illustrate this kind of transformation, a simple PHR-ontology is presented in Figure 7. In this graphical representation ellipses represent classes, and rectangles represent data and object properties.

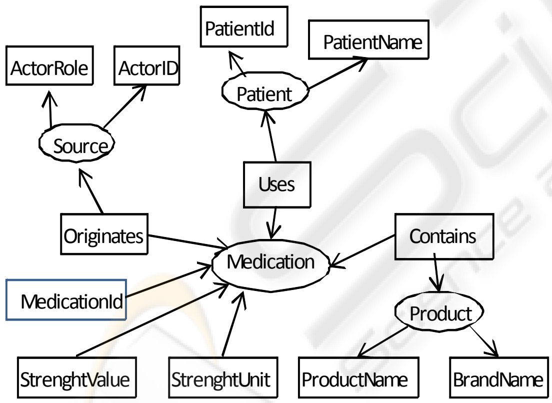

Figure 7: A simple PHR-ontology in a graphical form.

6 CONCLUSIONS

It is obvious that in the near future PHRs have the potential to dramatically change healthcare. They will enable consumer to become more involved and engaged in their care, and allow other authorized stakeholders to access information about consumer that has not been previously been available or difficult to access electronically. The change that can be caused by the deployment of PHR systems could have a significant impact on the efficiency of administrative and clinical process within healthcare sector, and thus will give rise for considerable cost savings.

However, the extensive exploitation of PHRs requires that (i) PHRs are exhaustive in the sense that they contain all the relevant documents, and that (ii) PHR systems support appropriate use cases such as data centric queries.

Our argument is that the exhaustive medicinal history can be captured in PHRs only if we can automate the importation of relevant documents into PHRs. As we have presented, one way of doing that with respect to e-prescriptions is to extend the EPWs by exporting the prescriptions into PHRs. Further, in order to support appropriate use cases, we can implement the PHR system as an application of a knowledge base or a database system.

The importation of e-prescriptions into PHRs is rather straightforward if the EPW exploits service oriented architecture. In particular, if the EPW is based WS-BPEL then the required modifications can be done by just inserting appropriate operations in the WS-BPEL code.

In order to support a wide variety of queries on PHRs we have analyzed PHRs, which data is structured according to an PHR ontology. Importing data from XML-based data sources (e.g., HL7 CDA compliant systems) to such PHR system requires that the XML documents are first transformed by a style sheet engine to RDF/XML format and then inserted to the PHR.

We will emphasize that using a PHR should not be an end in itself: if the PHR captures information that is imported at random, then the use of the PHR in healthcare may be a risk. Developing and maintaining a reliable and exhaustive PHR requires considerable efforts in developing health care systems interoperability.

The deployment of a reliable PHR system is also an investment. The investment includes a variety of costs including software, hardware and training costs. Introducing and training the staff on new technology is a notable investment, and hence many organizations like to cut on this cost as much as possible. However, the incorrect usage and implementation of a new technology, due to lack of proper training, might turn out to be a risk of healthcare.

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