MANAGING MEDICINAL INSTRUCTIONS

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Abstract: The number of new medications increases every year. As a result also the amount of new instructions concerning new medication increases rapidly. A problem is how to ensure that the employers of the medicinal organizations are aware of the relevant medicinal instructions. In this paper, we restrict ourselves on this problem. In particular, we consider three complementary ways for the dissemination of medicinal instructions: (i) by providing keyword-based searching of instructions (ii), by providing ontology-based searching of instructions, and (iii) by integrating the instructions to employers´ day-to-day work tasks. Our argument is that integration is most preferable as medicinal instructions are provided just-in-time, tailored to their specific needs, and integrated into day-to-day work patterns. However, automating the integration of instructions to day-to-day work pattern is not an easy task. In our solution, day-to-day work patterns are described by BPMN (Business Process Modeling Notation) and BPMN's association- notation is used for integrating the instructions to BPMN-processes. The integration of the tasks and instructions is based either on a medicinal ontology or a taxonomy. The ontology specifies the relationships of the day-to-day tasks and the medicinal instructions. The taxonomy is used for attaching metadata items for the tasks and instructions, and so the integration of the tasks and instructions can be done based on the similarity of their metadata descriptions.

1 INTRODUCTION

Healthcare is a field where the fast development of drug treatment and technologies requires specialized skills and knowledge that need to be renewed frequently (Puustjärvi and Puustjärvi, 2006). Furthermore, the number of new medications increases every year. As each drug has its unique indications, cross-reactivity, complications and costs also the prescribing medication as well as the distribution of medicinal products becomes still more complex (Jung, 2005). As a result also the amount of new instructions concerning new medication increases rapidly. An interesting question arising from this reality is how medicinal instructions should be organized and retrieved in order to ensure that the employees are aware of the relevant medicinal instructions.

In principle, the (medicinal) information retrieval system should be able to retrieve all the medicinal instructions, which are relevant while retrieving as few non-relevant instructions as possible. This kind of quality of information retrieval system is usually measured by two fractions, called recall and precision (Baeza-Yates and Ribeiro-Neto, 1999). Recall is the fraction of the relevant documents (e.g., medicinal instructions), which has been retrieved. Precision is the fraction of the retrieved documents, which is relevant. The values of these fractions are highly dependent on the way the query and the content of medicinal documents are presented.

In this article, we will first illustrate that by replacing taxonomy–based searching by ontology-based searching we can significantly improve both the recall and precision fractions in searching medicinal instructions.

On the other, minimizing the extra time required for retrieving the instructions is turned out to be crucial. Therefore, in many cases integrating medicinal instructions to day-to-day work patterns is

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more preferable. Moreover, in this approach, medicinal instructions are provided just-in-time, and tailored to their specific needs.

However, automating the integration of instructions to day-to-day work pattern is not an easy task. As we will show, in our solution day-to-day work patterns are described by BPMN (Business Process Modeling Notation) (White, 2006) and BPMN's association- notation is used for integrating the instructions to BPMN-processes. The integration of the tasks and instructions is based either on a medicinal ontology or a taxonomy. The ontology specifies the relationships of the day-to-day tasks and the medicinal instructions. The taxonomy is used for attaching metadata items for the tasks and instructions, and so the integration of the tasks and instructions can be done based on the similarity of their metadata descriptions.

The rest of the paper is organized as follows. First, in Section 2, we give a motivating example of the restrictions that we will encounter in using keyword-based search in retrieving medicinal instructions. Then, in Section 3, we illustrate the use of medicinal ontologies in retrieving medicinal instructions. How such ontologies can be specified by the Web Ontology Language (OWL) is illustrated in Section 4. Then, in Section 5, we illustrate how day-to-day work patterns can be modeled by business process modeling language BPMN. In particular, we present how the modeling primitives of BPMN can be used in attaching medicinal instructions to business process tasks which model the day-to-day work patterns. Finally, Section 6 concludes the paper by discussing the advantages and disadvantages of our approach.

2 TAXONOMY-BASED SEARCHING

Documents' content is traditionally represented through keywords, which are extracted directly from the document (Baeza-Yates and Ribeiro-Neto, 1999). However, a reason for missing many relevant documents is that the keywords used with queries and documents descriptions are not standardized (Puustjärvi and Pöyry, 2006). In order to standardize semantic metadata specific taxonomies are introduced in many disciplines. To illustrate this, a simple drug taxonomy is presented in Figure 1. The idea behind this classification is that the medicinal instructions can be annotated by the metadata items (the branching points and the leaves) represented in the tree.

A user can then query medicinal instructions by Boolean expressions (Baeza-Yates and Ribeiro-Neto, 1999) comprising of operands and operations. The operands are the used keywords (which are taken from the taxonomy) and the operands are typically "and", "or", and "not". For example, by using the taxonomy of Figure 1 the keywords attached to the medicinal instruction "*New warnings of using pain drugs in topical use with children"* could be *"Pain drugs for topical use*" and "*Prescription based pain drug*".

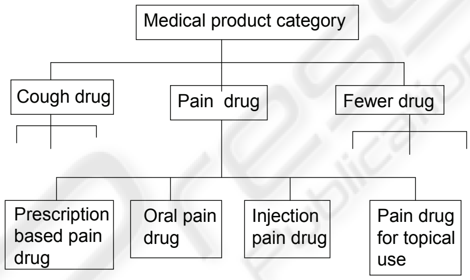

Figure 1: Medicinal product categories in a taxomomy.

Now assume that a pharmacist has to check the instructions concerning pain drugs, and so she enters the Boolean expression: *Prescription based pain drug* and *Pain drug for topical use*. In our example the result includes at least the instructions "*New warnings of using pain drugs in topical use with children"*. After reading the instruction the pharmacist is interested to read the previous medicinal instruction of the same topic. The pharmacist may also be interested to know the medicinal products that are under this new warning. Unfortunately by using keyword based searching (i.e., Boolean expressions) the pharmacist has no hope for finding the answers for such queries.

In the next section we will consider an ontology-based (Gruber, 1993; Antoniou and Harmelen, 2004) searching that supports such queries as well as the queries based on taxonomies.

3 ONTOLOGY-BASED SEARCHING

In order that the information retrieval system could answer for the queries presented in previous section we have to extend the search functionalities by querying features. This requires the deployment of an ontology.

Our developed medicinal ontology models the medicinal instructions as well as their relationships to other relevant medicinal concepts such as patient, physician, patient record, drug, and e-prescriptions. In addition the ontology models the associations of medicinal instructions to the tasks of the day-to-day work tasks. Part of this ontology is graphically presented in Figure 2. In the figure ellipses represent classes and boxes represent properties. The ontology includes for example the following information:

- Medicinal product category is a class and each instance of the category may have a parent, which is also an instance of medicinal product category, i.e., among other things, the ontology models the taxonomy presented in Figure 1.
- Each medicinal instruction relates to zero or more medicinal products (e.g., *Aspirin*), and each medicinal product includes one or more drugs and has one or more substitutable medicinal products.
- Each medicinal instruction is associated to zero or more tasks which are parts of a workflow. That is, each medicinal instruction is associated to a task and a workflow which represents functionalities in a day-to-day work patterns.

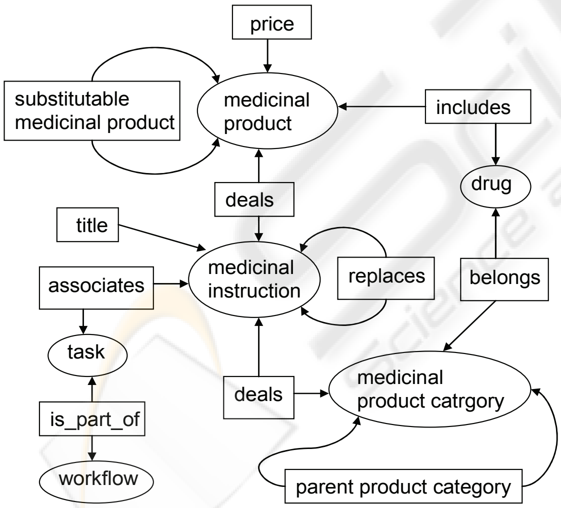

Figure 2: A medicinal ontology.

The ontology of Figure 2 allows making queries such as:

- Give me medicinal instructions having keywords *Prescription based pain drug* and *Pain drug for topical use* (i.e., a query that corresponds to a Boolean expression).
- Give me the medicinal instruction that is replaced by the medicinal instruction "*New warnings of using pain drugs in topical use with children".*
- Give me the names of the medicinal products that relate to the medicinal instruction *"New warnings of using pain drugs in topical use with children".*
- Assuming that the result includes the medicinal products *A* and *B*, then it allows querying (browsing by clicking the edges) the substitutable medicinal products and prices for *A* and *B,* as well as the drugs that are included to these medicinal products.

In the next section we illustrate how our used medicinal ontology can be specified by an ontology language.

4 USING OWL FOR PRESENTING MEDICINAL INFORMATION

Web Ontology Language (OWL) (Daconta, Obrst and Smith, 2003; OWL, 2006) has more facilities for expressing meaning and semantics than XML, RDF and RDF Schema, and thus OWL goes beyond these languages in its ability to represent machine interpretable content of the ontology (Mattocks, 2005). In particular, it adds more semantics for describing properties and classes, for example relations between classes, cardinality of relationships, and equality of classes and instances.

The instances in OWL-ontologies are presented by RDF-descriptions. RDF (Resource Description Framework) (Davies, Fensel and Harmelen, 2002) is essentially a data model. There are various ways in capturing knowledge with RDF, e.g., as natural language sentence, in a simple triple notation called N3, in RDF/XML serialization format, and by as a graph of the triples (Daconta, Obrst and Smith, 2003).

RDF's modeling primitive is an object-attribute-value triple, which is called a statement. For example, the medicinal instruction titled "*New warnings of using pain drugs in topical use with children"* deals the medicinal products *"Pain drugs for topical use"* and *"Pain drugs for topical use*" is a natural language sentence that can be presented by RDF/XML serialization format (Figure 3) by using the vocabulary (ontology) presented in Figure 2. However note that in capturing knowledge the designers are not burdened by using RDF/XML serialization format (Antoniou and Harmelen, 2004) as there are graphical editors that are used in design and which automatically produce the descriptions in RDF/XML and OWL-format (e.g., the Protégé editor (Protégé, 2007)).

```
<rdf:RDF
    xmlns : rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
    xmlns : xsd="http://www.w3.org/2001/XMLSchema#"
    xmlns : mo="http://www.lut.fi/ontologies/medicinal_ontology#">
    <rdf:Description rdf:about=" # Instruction123">
    <rdf:type rdf:resource="&mo;medicinal_instruction"/>
        <mo : title> New warnings of using pain drugs
            in topical use with children </mo : title>
       <mo : deals>Pain drugs for topical use</mo : deals>
       <mo : deals> Prescription based pain drugs</mo : deals>
       <mo : replaces> rdf: resource
             Instruction122</mo : replaces>
        <mo : assocoates> rdf: resource
             Check_the_dose</mo : replaces>
  </rdf : Description>
 </rdf:RDF
```

Figure 3: An RDF-statement in a medical ontology.

Note that the above illustrative RDF-description uses the vocabulary (named medicinal_ontology) having url

http://www.lut.fi/ontologies/medicinal_ontology#.

The rdf-description also states that the new instruction identified by *Instruction123* replace the instruction identified by *Instruction122.* In addition the description associates the instruction to a task named "*Check_the_dose*". How this association is presented in our used business process specification language is the topic of the next section.

5 ATTACHING INSTRUCTIONS TO DAY-TO-DAY WORK PATTERNS

Though the ultimate goal of using Business Process Modeling Notation (BPMN) (White, 2006; BPMN, 2005) is the automation of the coordination of business processes we use BPMN to model medicinal processes and for attaching medicinal instructions to day-to-day work patterns which are presented in BPMN.

The BPMN is a standard for modeling business process flows and web services. Basically BPMN and the UML 2.0 Activity Diagram from the OMG (White, 2006) are rather similar in their presentation. However, the *Activity diagram* has not adequate graphical presentation of parallel and interleaved processes, which are typical in workflow specifications.

The BPMN defines a *Business Process Diagram* (BPD), which is based on a flowcharting technique tailored for creating graphical models of business process operations. These elements enable the easy development of simple diagrams that will look familiar to most analysts. In addition BPMN allows an easy way to connect documents and other artifacts to flow objects, and so narrows the gap between process models and conceptual models. Also, a notable gain of BPMN specification is that it can be used for generating executable BPEL (Business Process Execution Language) (BPEL, 2004) code.

We now give an overview of the BPMN. We first shortly describe the types of graphical objects that comprise the notation, and then we show how they work together as part of a Business Process Diagram (BPD) (White, 2006). After it, we give a simplified pharmaceutical process description using BPD.

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 task that is performed in companies. The types of tasks are Task and Sub-Process. So, activities can be presented as hierarchical structures.
- A *Gateway* is represented by a diamond shape, and it is used for controlling the divergence and convergence of sequence flow.

In BPD there are also three kind of connecting objects: *Sequence Flow*, *Message Flow* and *Association.*

- A *Sequence Flow* is represented by a solid line with a solid arrowhead.
- A *Message Flow* is represented by a dashed line with an open arrowhead and it is used to show the flow of messages between two separate process participants.
- An *Association* is represented by a dotted line with a line arrowhead, and it used to associate data and text with flow objects.

In Figure 4, we have presented how the process of producing electronic prescription can be represented by a BPD. As illustrated in the figure we use *Association* to attach instructions to *Activities* and Gateways. For example, *Instruction A* is associated to activity "*Produce prescription*", and *Instruction B* is associated to gateway "*Check negative effects".*

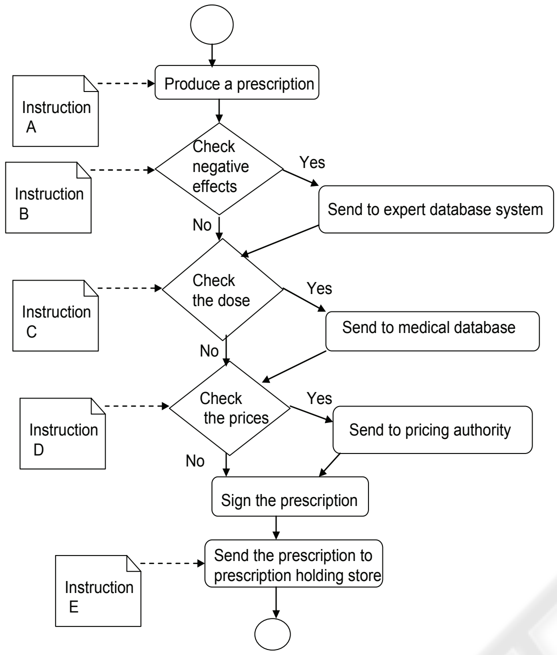

Figure 4: Attaching medicinal instructions to a BPD.

We can support automatic integration of medicinal instructions to business processes in two ways. If the relationship of the medicinal instruction and the task of a workflow (Figure 2) are presented in the medicinal ontology, then this information can be used.

Otherwise the integration can be made by comparing the similarities of the metadata descriptions of the instructions and the tasks. This requires that the metadata items of the workflow tasks are picked up from the same taxonomy that is used for annotating medicinal instructions. Hence we can conclude that an instruction is relevant for the task, if they have similar metadata description. That is, it is appropriate to integrate *Instruction I* to *Task T*, if they have somehow similar keywords. To illustrate this, assume that *Instruction I* has *m* keywords and *Task T* has *m* keywords, then they have at most *min{m,n}* common keywords. So we can assume that the higher the number of the common keywords is, the better the *Instruction I* match for the *Task T*. Hence, we order the instructions of the *Task T* according to the number of their common keywords.

6 CONCLUSIONS

Healthcare is a field where the fast development of drug treatment and technologies requires specialized skills and knowledge. At the same time the amount of new instructions concerning new medication increases rapidly. How to ensure that healthcare staff is aware of the new instructions is not an easy task. However, applying computing technology for retrieving and disseminating medicinal information this complexity can be alleviated in many ways.

Particularly, we have considered taxonomy-based and ontology-based retrieving of medicinal instructions. It is turned out that by deploying ontology-based retrieving method the expression power of searching expressions can be considerably increased. On the other hand, the drawback of ontology-based searching is that the ontology must be updated whenever a new medicinal instruction is published. However, such an update can be done by medicinal authorities, and thus it does not burden the medicinal organizations that use the ontology.

We have also presented how the dissemination of medicinal instructions can be carried out by integrating the instructions to daily tasks. The gain of this approach is that dissemination processes are integrated in a natural way into day-to-day work patterns, and thereby minimize the extra time required for retrieving the instructions.

The introduction of a new technology in retrieving and disseminating medicinal instructions is also an investment. The investment on new ICT-technology 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 more expensive in the long run.

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