iCare: Intelligent Medical Information Logistics*

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ABSTRACT

The diversity and quantity of medical information emerging from patient treatment makes it a challenging task for medical staff to identify and handle the information they need to perform their tasks in the best possible way. The doctor's ward round, for example, is a knowledge-intensive process comprising complex information-centric tasks such as patient examination and diagnosis. Goal is to provide medical staff with relevant information dependent on their work context. This paper picks up this challenge and presents iCare, a semantic application enabling an intelligent integration, analysis, and delivery of personalized medical information.

Categories and Subject Descriptors

H.4.1 [**Information Systems Applications**]: Office Automation—*Workflow Management*

General Terms

Documentation, Management

Keywords

information logistics, semantic technology, healthcare

1. INTRODUCTION

The diversity and quantity of medical information emerging in patient treatment and administration makes it a challenging task for medical staff such as doctors and nurses to identify and handle the medical information they need to perform their tasks in the best possible way [8]. During a ward round, for example, doctors have not only to rely on patient records, but also on laboratory reports, and medical knowledge. Generally, the effective and efficient delivery of medical information is a prerequisite to make well-grounded decisions, diagnoses, and treatments.

Today, medical staff is confronted with very limited time. Existing studies show that doctors, for example, can spend only 7.5 minutes for searching and handling medical information per patient and ward round [13].

A solution for this problem is iCare. iCare is a web-based Java application relying on semantic technology. The application's overall goal is the personalized delivery of medical information to medical staff. Using iCare, medical staff does not need to search for medical information anymore, but is automatically supplied with relevant medical information dependent on their current work context.

Section 2 introduces the iCare scenario. Section 3 presents the application's main features and shortly discusses technical concepts. Section 4 describes how the application scenario can be supported by iCare. Section 5 discusses related work. Section 6 concludes with a summary and an outlook.

2. SCENARIO

The iCare application scenario has been developed based on results of an exploratory case study we performed at a large German university hospital [8]. The focus of our study was the analysis of an unplanned, stationary hospitalization, including patient admission, medical indication in the anesthesia, surgical intervention, post-surgery treatment, patient discharge, and financial accounting in a hospital.

iCare specifically aims at supporting the doctor's ward round (cf. Fig. 1). First, the ward round is prepared, i.e., the doctor looks at patient information (e.g., name, pre-existing diseases) and medical orders (e.g., prescribed drugs, current therapy) (task T1). The doctor then communicates with the patient and asks for additional information about his health status (task T2). This information is documented. Afterwards, the patient is examined (task T3) and patient information (e.g., pulse rate) is updated accordingly.

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Finally, the doctor reflects the patient's status and, depending on his assumptions, gives medical orders (e.g., on the procurement of drugs) (task T4). Again, patient information and medical orders are updated (task T5). Though this process may vary across different hospitals and even within one hospital, it can be found in every hospital.

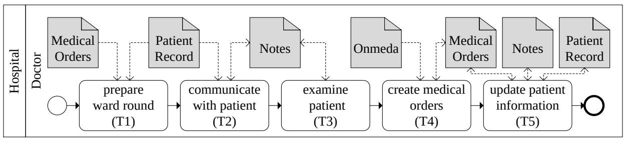

Figure 1: The doctor's ward round (BPMN model).

For each of the tasks shown in Fig. 1, a variety of heterogeneous medical information is needed, e.g., patient records, notes, medical orders, laboratory reports, medical guidelines, and patient protocols. This medical information is typically stored in widespread sources, for example, in hospital information systems, medical databases, applications, and libraries. iCare collects and integrates such distributed information, at least as long as it is electronically available.

3. APPLICATION

iCare[1] is a web-based semantic Java application based on the semantic middleware iQser GIN server 1.6 [15], the build automation tool Maven, the web framework Wicket 1.5.6, the JavaScript library jQuery 1.72, the database MySQL 5, the text search engine library Lucene 2.4, HTML5, and CSS3. The home screen of iCare (cf. Fig. 2) shows the tasks as introduced in Section 2.

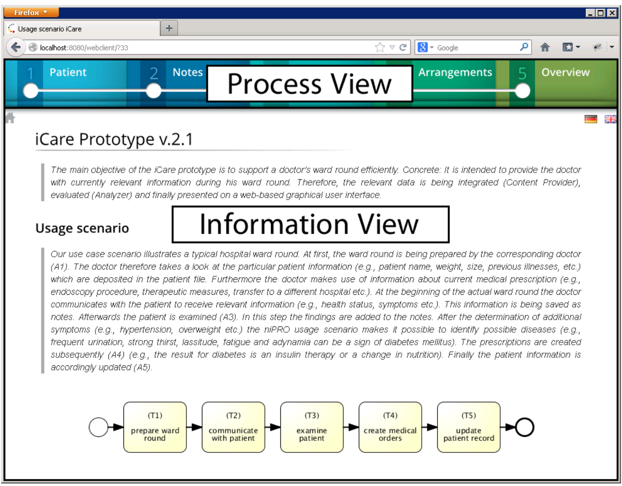

Figure 2: Home screen of iCare.

The user interface of iCare is divided into two parts: the *process view* and the *information view*. The former illustrates the currently executed process (i.e., the doctor's ward round), whereas the latter shows the corresponding medical information (e.g., patient records, laboratory reports, medical orders, notes). iCare works both in desktop browsers and on mobile devices.

[1]A screencast presenting the iCare application is available at http://nipro.hs-weingarten.de/screencast.

3.1 Features

The main features of iCare are the *integration* and *analysis* of medical information as well as the *delivery* of needed medical information to medical staff:

- iCare enables the integration of structured, semi-structured, and unstructured electronically available medical information from different data sources.
- iCare enables the automatic syntactic and semantic analysis of medical information to determine semantic relationships from which medical staff can derive and generate new medical knowledge.
- iCare enables the delivery of needed medical information to medical staff and represents a central access point and unified view on medical information.

3.2 Technical Architecture

The iCare application is based on a four-tier architecture comprising a data layer, a semantic integration layer, a context layer, and an application layer (cf. Fig. 3).

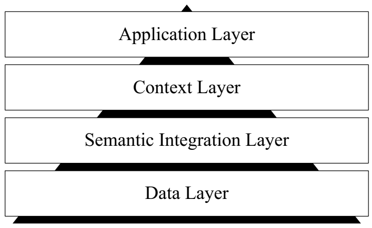

Figure 3: Architecture of iCare.

The *data layer* concerns the set of data sources to be integrated (e.g., hospital information systems, databases, digital libraries, medical guidelines, health records, shared drives etc.). For each data source, a so called *ContentProvider*[2] is implemented. Its main task is to transform proprietary medical information into a generic and uniform information format. This is a necessary prerequisite for the subsequent syntactic and semantic analysis.

The *semantic integration layer*, in turn, is responsible for the syntactic and semantic analysis of medical information. For this purpose, we use the semantic middleware iQser GIN server [15]. Syntactic and semantic analysis is performed in several steps. In a first step, basic attributes of integrated information such as authorships are compared ($\sim$ *syntactic analysis*). This allows, for example, to link information with the same author (e.g., a specific doctor). Second, the raw full text of all available information is analyzed ($\sim$ *semantic analysis*). For this purpose, algorithms from the fields of data mining, text mining (e.g., text preprocessing, linguistic preprocessing, clustering, classification, information extraction), pattern-matching, and machine learning (e.g., supervised learning, unsupervised learning, reinforcement learning, transduction) are applied [14]. Goal is to further classify and group correlated information. Finally, user behavior is investigated, for example, the frequency of using certain information in the context of specific process tasks.

The result of the analysis is a semantic information network (SIN), a labeled and weighted digraph representing

[2]These ContentProviders are available as open-source plugins at http://sourceforge.net/directory/?q=iqser.

information and their semantic relationships [10]. In particular, the SIN allows identifying information linked to each other in the one or other way, e.g., information addressing the same topic (e.g., "flu") or needed when performing a particular process task (e.g., "prepare ward round") [7].

The *context layer* is responsible for integrating and analyzing context information (e.g., used device, location, time, user behavior). In [9], we have described a framework realizing the context layer. Context information is gathered from data sources called sensors. We distinguish between physical sensors (e.g., thermometer), virtual sensors (e.g., keyboard input), and logical sensors (e.g., sensors which allow to detect a doctor's position by analyzing logins at devices and a mapping to locations). In addition, further context information can be also derived from existing one (e.g., by aggregation or reduction). A context model (CM), which is constructed based on available context information, allows characterizing a doctor's work context which can then be used to filter the SIN. Note that the CM is completely independent from the SIN, i.e., context information is only stored in the CM but not in the SIN (see [9] for details).

Finally, the *application layer* concerns the personalized delivery of medical information. The application layer is responsible for the joint presentation of executed processes (or tasks) and corresponding medical information.

Further details regarding the layers can be found in [10].

4. SCENARIO SUPPORT

In the following we describe how the scenario from Section 2 can be supported by iCare. To support task T1, a search box is offered to select single patients. After having selected a patient, iCare provides available information such as name, pre-existing diseases, gender, weight, and date of birth, from the respective patient record (cf. Fig. 4).

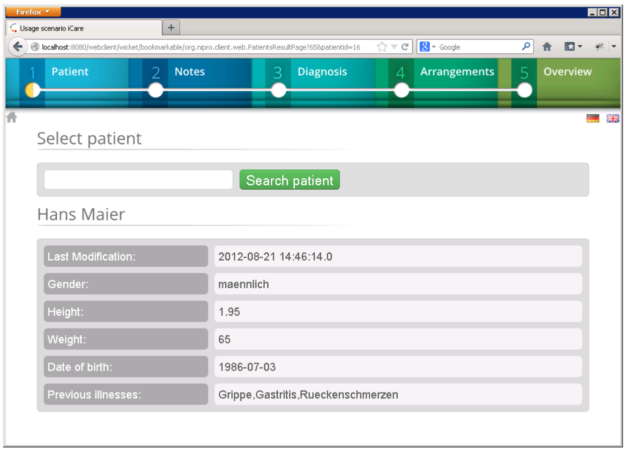

Figure 4: Process step 1.

When performing task T2, existing medical notes for the previously selected patient are shown, i.e., information about the patient's health status (cf. Fig. 5). Upon need, the doctor can add, update, or delete medical notes.

Based on an analysis of available medical information, potential diseases and treatment options are then automatically determined when performing task T3 (cf. Section 3.2 for details). For example, the analysis takes into account the patient record, medical notes, and medical information

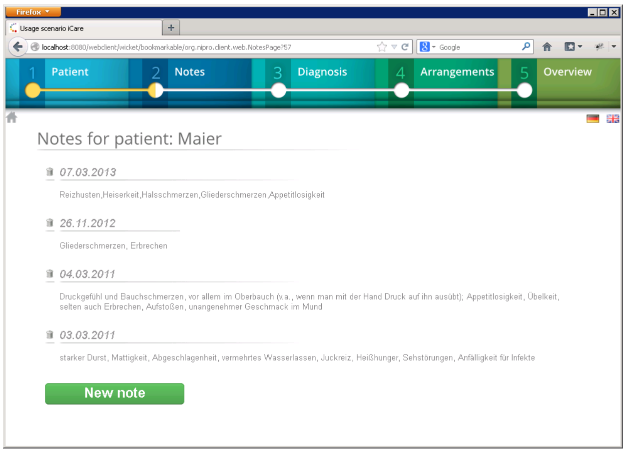

Figure 5: Process step 2.

from Onmeda[3] and can automatically conclude that sore throat, croakiness, rheumatic pains and absence of appetite are potentially caused by the disease "flu" (cf. Fig. 6).

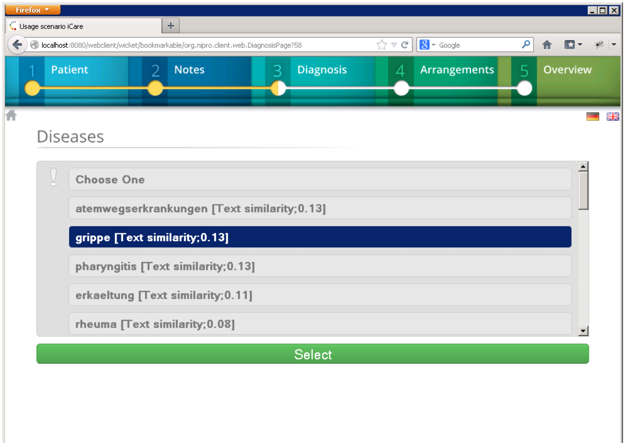

Figure 6: Process step 3a.

As an additional result of the syntactic and semantic analysis, the doctor is also supplied with treatment options which are also automatically determined (cf. Fig. 7). If a treatment option is selected, a more detailed treatment description and respective instructions are displayed.

In task T4, the doctor can then add or update medical orders. Finally, the patient record, medical notes, and medical orders can be updated in task T5.

In summary, iCare supports the doctor's ward round by reducing the time for searching and handling medical information. iCare automatically delivers needed medical information depending on the current work context.

5. RELATED WORK

Medical guidelines have been intensively discussed in recent years as an approach to support medical decision-ma-

[3]Since we have no access to international digital medical libraries we use the German health portal Onmeda (http://www.onmeda.de) instead. Therefore, some screenshots contain German text.

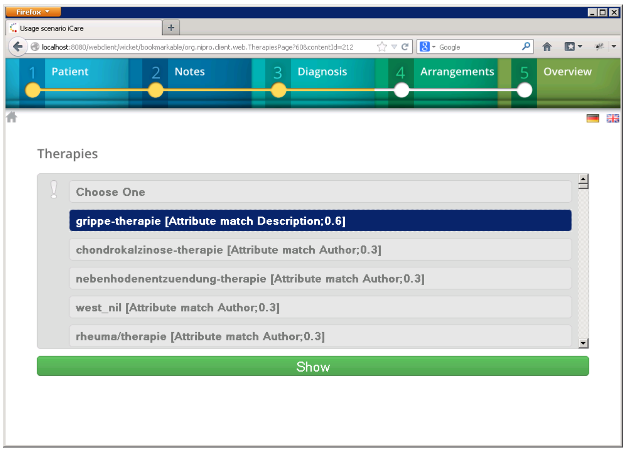

Figure 7: Process step 3b.

king. Burgers et. al [1], for example, discuss and compare structures of medical guidelines. Fervers et. al [2] conduct a survey on the adoption of medical guidelines in healthcare practice. The exchange and representation of medical guidelines in machine-interpretable form is addressed by Ohno-Machado et. al [11] and Fox et. al [3]. Their work has been of great importance when we developed iCare and its underlying SIN (which also integrates medical guidelines in machine-interpretable form). However, though medical guidelines, like iCare, address medical decision-support, they cannot be directly compared with iCare. Instead, medical guidelines can be considered as an additional source of information for iCare (summarizing and documenting well-established medical procedures).

Besides iCare, a large variety of technical tools, platforms and solutions have been introduced to support medical decision-making or other closely related healthcare application scenarios. Due to space limitations, we can only briefly sketch important approaches. Hospital Information Systems (HIS), for example, are large enterprise information systems enabling the management of both administrative and medical information (for an overview see Shortliffe & Cimino [12]). Unlike a HIS, iCare is a much more specific application supporting only one use case, namely the doctor's ward round. Other specific tools concern the management and utilization of electronic medical records. GNUmed [6], GNUHealth [5], or FreeMED [4] are examples of such tools. However, note that all these approaches do not include a semantic analysis of medical information and their context-aware delivery to medical staff.

6. SUMMARY AND OUTLOOK

This paper presents our iCare application, a semantic application enabling the intelligent integration, analysis, and delivery of medical information. The main goal of iCare is to intelligently deliver medical information (e.g., patient records, medical orders, laboratory reports, medical guidelines) to doctors during their daily ward round.

Future work includes the integration of additional data sources (e.g., medical databases, health portals), the support of additional application scenarios (e.g., the procurement of drugs), and the improvement of information delivery (e.g., by additional syntactic and semantic analysis).

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