PROCESS AND E-SERVICE CUSTOMIZATION
For Coordination in Healthcare Networks

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Abstract: Coordination in healthcare networks becomes increasingly important. A process-oriented coordination approach is introduced which enhances integrated care scenarios by an IT-driven coordination of interorganizational treatment processes – the concept of process-based e-service logistics. The allocation of e-services is based on a model describing services and coordination tasks between roles in a healthcare network. The underlying system's architecture is presented which implements process-based e-service logistics by designing and executing individual treatment processes, identifying coordination tasks between network actors and dynamically allocating e-services. A solution for automated individualization of processes and e-services based on Case Based Reasoning (CBR) technology is discussed.

1 HEALTHCARE NETWORKING

The healthcare industry is an important economic sector in Germany causing annual expenses of about 230 billion euros and employing more than 4.2 million people. Starting point of the research project was an empirical study addressing German and Swiss ambulant healthcare networks (healthcare network managers as well as physicians) to evaluate the maturity of healthcare network organizations regarding strategy, processes and information technology (Schicker et al., 2006a). The empirical study reveals that 81 percent of the respondents expect that networking in the healthcare industry will increase in the next three to five years. Moreover, 88 percent of the survey participants agree that the demand for coordination and IT-support in healthcare networks is going to rise in the future (Schicker et al., 2006a: 21). An important driving force of networking is the concept of integrated care which is often associated with the following instruments:

- Intersectorial cooperation (Ramming, 2004: 147; Mühlbacher, 2002: 65)
- Financial responsibility (e.g. capitation)
- Coordination and control of medical treatment processes (Mühlbacher, 2002: 66)
- Information integration (Ramming, 2004: 147).

Whereas many research projects deal with the integration of health data this project concentrates on the coordination and control of interorganizational processes within healthcare networks by providing patients and suppliers with a customized set of electronic services. To analyze the requirements the research team cooperates with the healthcare network "Qualitäts- und Effizienzgemeinschaft Nürnberg-Nord" which is organized as a gatekeeper system. The integrated care contract spans ambulant, clinical and home care service providers and is financed by a full capitation model (Wambach et al., 2005: 13).

2 PROCESS-ORIENTED COORDINATION

Process-oriented coordination is seen as one important way to enable integrated care scenarios, to enhance patient satisfaction and to reduce costs of treatment processes (Güntert, 2004: 100ff). Schmalenbach argues for process-oriented control especially to cope with the problem of managing multiple interfaces (Schmalenbach, 1908/09; 211f.). Based on that belief the research project focuses on the treatment process from a cooperative view regarding the patient's way throughout the whole healthcare network.

2.1 Process Characteristics and Requirements

Process-oriented coordination faces important challenges to cope with. Therefore the characteris-

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tics of healthcare network processes and their requirements will be discussed next. To transfer the general tasks and principles of coordination to the healthcare domain, it has been analyzed which processes (e.g. management, medical treatment and support processes) and coordination tasks exist within healthcare networks (Schicker, 2006b: 39).

2.1.1 Process Characteristics

Table 1 depicts characteristics of interorganizational treatment processes that need to be considered when requirements for the IT-support in healthcare networks are defined (Schicker et al., 2006b: 39).
Especially the uniqueness of one patient´s treatment process (Müller-Mundt, 2001: 95) and the high degree of volatility are key characteristics which have to be considered when supporting healthcare network processes by information technology. During their execution processes have to be modified, detailed and customized to the patient´s needs depending on his individual treatment context (cybernetic model of medical treatment) (Prokosch, 2007).

Table 1: Characteristics of treatment processes.

• unique • requiring intensive coordination and information • cross-sectorial • important and risky	• stepwise changing and volatile, requiring in-depth knowledge • involving numerous participants • long-lasting and complex

2.1.2 Requirements

The individual characteristics of each patient, the high degree of volatility during the real-time execution of the process instance are crucial challenges when supporting modelling, adaptation and execution of individual processes by information technology (Purucker et al., 2007).

For that reason process models should be adapted to the individual needs of the patients (Haas, 2005: 553ff). To avoid modelling efforts a new automated process design is needed.

Moreover, members of the healthcare network (especially gatekeepers) should be able to modify the individual process model easily as soon as new information about the state of treatment or illness exists (Schwarz et al., 2001: 10; Remus, 2002: 115). Finally, e-services (e.g. information and application services) must be linked to individual process activities in a flexible way.

3 PROCESS-BASED E-SERVICE LOGISTICS

3.1 Basic Principles

The concept of process-based e-service logistics (PEL) aims to support the coordination of healthcare network processes by providing patients and healthcare suppliers with a customized set of electronic services. E-services are software components which encapsulate functions (e.g. logic or data centric services) in a coarse-grained manner, e.g. using web services as technical representation (Krafzig et al., 2004: 70ff). The e-service requirements regarding information and coordination in networks are derived from customized process models. They result in a process-based e-service logistics model executed by a process management platform supporting the coordination of individual treatment processes by providing network participants with e-services.

3.2 Architecture Overview

The proof of the concept described above is being implemented and called Individual Value Web System (IVWS). IVWS is a process platform supporting configuration, execution and control of processes across healthcare networks. The system architecture follows a four-tiered approach (see figure 1).

3.2.1 Presentation Layer

Application front ends initiate and control all activities of the IVWS. Typical application front ends are graphical user interfaces enabling direct interaction of users with the system (WebParts implemented with C# using the Sharepoint Portal Server). Within the research project role-specific process portals for patients, service providers and network managers are implemented (Schicker et al., 2005: 7ff).

3.2.2 Customization and Flow Control Layer

This layer consists of three components including features for orchestration and execution of web services.

- Service bus: This component ensures the execution of web service orchestrations and provides functionalities of a service bus: connectivity, integration and communication services, process orchestration and execution (Krafzig et al., 2004: 65).
- Process and e-service customization: An important issue of PEL is how to adapt and

model one patient's treatment process and the underlying e-services needed for supporting the process (for details see section 4).

- Meta orchestration server (MOS): MOS enables the configuration, execution and monitoring of treatment processes. MOS represents a process engine which acts as a broker between the front ends and the e-services invoked during process execution. It also initiates the execution of web service orchestrations by the BizTalk Server and integrates process proposals created by the customization component for process individualization (for details see Purucker, 2007).

3.2.3 Application Layer

This layer contains all e-services needed for execution and support of treatment processes. E-services of a SOA are software components encapsulating business functions in a coarse-grained manner. An e-service consists of a service contract, a service interface and an implementation. The implementation is the physical representation of the required business logic and the relevant data (programs, configuration data and database) (Krafzig et al., 2004). E-services include IVWS-specific services (e.g. the customization component described below) as well as third party web services and adapters for the integration of existing information systems.

3.2.4 Data Layer

A MS SQL-based process and e-service repository provides features for searching and applying process models and e-services, e.g., physical location, service provider, charge fee, technical constraints, security data and service level agreements.

4 PROCESS AND E-SERVICE CUSTOMIZATION

4.1 Traditional Methods

There are many approaches which enable the customization of processes in general and which can be applied for the customization of treatment processes and e-services. Following the classic approach, each treatment process model and each e-service is manually developed from scratch for each context with respect to guidelines (Lang, 1997: 29). The steady process of creating customized treatment processes and e-services is very time-consuming and inhibits the reuse of experiences. To overcome this disadvantage new concepts have been developed. The process modelling approaches based on reference models (vom Brocke, 2003: 31ff), process skeletons (Remme, 1997:114ff) and process modules (Lang 1997: 4ff) enable the reuse of treatment process knowledge. The approaches for creating e-services by using design patterns, frameworks and libraries allow the reuse of e-service knowledge. However, these concepts require a time-consuming search and adaptation to the current context.

The disadvantage of existing approaches (e.g Wargitsch et al., 1997: 3ff; Rupprecht, 2002: 67ff) is that only one of the two steps (search and adaptation) is automated whereas the other step must be executed manually. An approach is needed which enables an automatic search and adaptation (Schicker et al., 2007). Here, such a system based on Case Based Reasoning (CBR) is introduced.

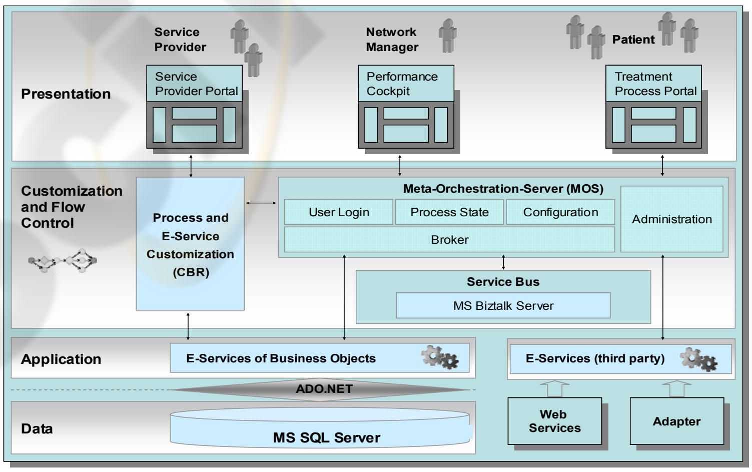

Figure 1: IVWS architecture.

4.2 Case Based Reasoning

4.2.1 Introduction

CBR is a problem solving paradigm of Artificial Intelligence. It solves new problems based on past experiences saved in form of cases in the case base. Each case (patient record) consists of a problem description (patient context) and a solution (treatment process and its e-services). In order to propose a treatment process and e-services for a given patient, CBR searches its case base for the patient record which is most similar to the given patient record and adapts its treatment process with e-services to fit the given case.

Besides fulfilling the requirements of automated search and adaptation, CBR offers several advantages (Nilsson and Sollenborn 2004: 178). First of all, it resembles the physicians' cognitive process of recalling former patients and reusing past experiences. This resemblance does not only prove the force of the approach but also leads to high user acceptance. Furthermore, the collection of patient records can easily be integrated in a CBR system as a case base. Moreover, the reuse of patient records provides an efficient reasoning mechanism which does not require solving each problem from scratch.

The functionality of a CBR system can be divided into four main phases which form the CBR cycle: retrieve, reuse, revise, retain phase (Aamodt and Plaza 1994: 46). The CBR cycle for customizing treatment processes and e-services is illustrated in figure 2 and described in the following sections.

4.2.2 Representation of Patient Records

Each patient record (case) contains the patient context (problem) as well as its treatment process and e-services (solution). While the patient context specifies the patient and his disease pattern, the treatment process and its supporting e-services characterize the therapy of the patient.

Attribute-value-vectors are used to represent the patient context. According to this type of representation, the patient context is specified by a vector of attribute values. In order to reflect the characteristics of different diseases, the set of attributes has to be defined for each disease separately.

Treatment processes and e-services can consist of several elements which are represented in an object-oriented manner. They are specified by a set of instances of classes (e.g. treatment process, service, coordination task, patient task and e-service).

4.2.3 Retrieve Phase

In the retrieve phase a health care provider passes the attribute values of the patient context to the system and requests a treatment process. In order to fulfil this request, the system searches for the patient record on the case base whose patient context is most similar to the context of the given patient. The search for a similar case requires the definition of similarity measures and search algorithms.

The similarity calculation of two patient contexts is based on local and global similarity measures (Stahl, 2003: 50ff). Local similarity measures determine the similarity between one attribute-value of the query patient record and the patient record in the case base, whereas global similarity measures calculate the aggregated similarity of all attribute-values. Different types of local similarity measures are used depending on the type of the attribute.

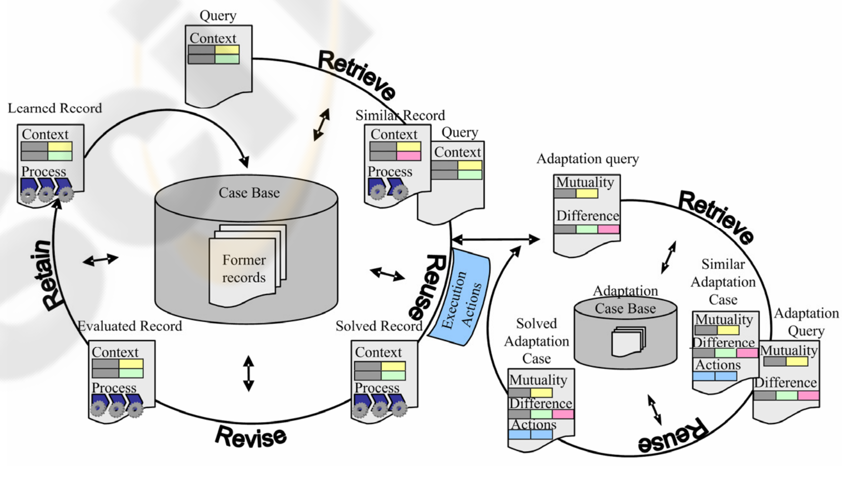

Figure 2: CBR system for customizing treatment processes and e-services.

For determining the similarity of nominal attributes, similarity tables are appropriate. They assign a similarity value to each combination of attribute values of the query patient context and the patient record in the case base. In order to calculate the similarity of metric attributes threshold-based, linear, exponential and sigmoide functions can be applied.

A weighted sum of the local similarities is chosen as global similarity measure. The weights reflect the relevance of the attributes. In order to reduce the high effort for the manual definition of similarity measurements, a learning algorithm for simplifying and optimizing the global similarity measurement has been implemented.

For searching the most similar patient records, sequential search and knowledge-poor indexing based on an extended k-d-tree (Wess, 1995: 163ff, 209ff) are provided (for details see Kaiser, 2008).

4.2.4 Reuse Phase

The reuse phase receives as input the record of the most similar patient which was found during the retrieve phase and aims at adapting it to fit the new patient record. The adaptation for the customizing of treatment processes consists of four successive steps: copy adaptation or compositional adaptation, substitutional adaptation, structural adaptation and consistency assurance.

The first adaptation step takes different turns depending on the phase of the treatment process. If a new treatment process should be created the treatment process of the similar patient record can be copied. However, if an existing treatment process must be extended, elements of the similar patient record are added. The substitutional adaptation replaces the attribute values of treatment elements and e-service elements adopted from the similar patient record according to rules. The structural adaptation modifies the structure of the requested treatment process and its e-services by deleting, adding and rearranging elements. It is realized by an additional adaptation-based CBR system (see figure 2). The adaptation cases of the adaptation-based CBR system describe which modification actions (solution) should be taken when certain differences and mutualities of the patient context (problem) between query and record in the case base occur (for details see Kaiser, 2008). The consistency assurance aims at improving the consistency of the created treatment process and its e-services.

4.2.5 Revise Phase

During the revise phase, the execution of some treatment steps and e-services takes place. In order to support the execution, the treatment process and its e-services are transformed into an XML representation and passed on to the meta-orchestration server for further processing.

4.2.6 Retain Phase

The retain phase is the last phase of the CBR cycle and belongs to the case base maintenance. The aim of the case base maintenance is to detect environmental changes which could decrease the quality and efficiency of the case base and execute counteractive measures. Besides the retain phase, the restore phase and the review phase are also part of the case base maintenance (Roth-Berghofer 2002: 55ff). The retain step uses intra-case quality measures to decide on the insertion of a patient record and is called each time a patient record has passed the revise phase. The review phase and restore phase are executed periodically. Hereby all patient records in the case base are checked with the aid of inter-case quality measures and redundancy measures and added or deleted accordingly.

5 CONCLUSIONS

The importance of coordination and IT-support in healthcare networks is increasing steadily. In order to enhance the quality and efficiency of interorganizational treatment processes, an IT-supported process-oriented coordination approach for healthcare networks has been realized. The approach supports the configuration, execution and control of processes and supporting e-services in healthcare networks.

This paper focuses on the configuration of treatment processes and e-services. Uniqueness and volatility are key characteristics of treatment processes. Treatment processes and e-services have to be configured whenever new information on the status of the patient becomes available. In order to reduce the manual effort for searching and adapting treatment processes and e-services an automated system based on CBR has been developed.

The definition and update of the patient context attributes, treatment process steps and e-services is time-consuming. However, it enables to formalize and expatiate on medical treatment knowledge. The approach offers basic functionality and can be extended by further methods such as the prediction of unknown attribute values of the patient context.

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