The Role of Care Pathways in Personal Health Records

Juha Puustjärvi
University of Helsinki
Helsinki, Finland
juha.puustjarvi@cs.helsinki.fi

Leena Puustjärvi
The Pharmacy of Kaivopuisto
Helsinki, Finland
leena.puustjarvi@kolumbus.fi

***Abstract*— Care pathways, also known as clinical pathways, are one of the main tools used to manage the quality in healthcare concerning the standardization of care processes. They promote organized and efficient patient care based on evidence based medicine. It has been shown that their use reduces the variability in clinical practice and improves outcomes. However, so far the use of care pathways is restricted on healthcare personnel. We have analyzed the gains of care pathways in the context of new emerging healthcare models such as patient-centered healthcare. Especially we have extended Personal Health Records by the functionalities related to care pathways. We have used Business Process Diagrams for graphical representation of care pathways. Further, these diagrams can be easily translated into executable WS-BPEL code. Their executions coordinate care pathways and automate many of their functionalities, such as the reservation of clinical resources and information therapy.**

Keywords - Care Pathways; Clinical Guidelines; Evidence-Based Medicine; Personal Health Records; Patient-Centered Healthcare; Healthcare Processes

I. INTRODUCTION

A *Personal Health Record* (PHR) is a confidential and easy-to-use tool for managing information about patient's health [1]. It can include a variety of information depending on where that information comes from, e.g., from patient himself, health care providers, pharmacies, insures, and the consumer [2]. It includes information about medications, prescriptions, allergies, vaccinations, illnesses, laboratory and other test reports [3]. It is accessible to the patient and to those authorized by the patient.

Care pathways, (also known as *clinical pathways*, integrated care pathways, or care maps) are one of the main tools used to manage the quality in healthcare concerning the standardization of care processes [4]. They promote organized and efficient patient care based on evidence based medicine, and they aim to facilitate the communication, coordination roles and sequencing the activities of the multidisciplinary care team, patients and their relatives and by providing the necessary resources [5]. It has also been shown that their implementation reduces the variability in clinical practice and improves outcomes.

Generally care pathways refer to *clinical guidelines* [6]. However, a single care pathway may refer to guidelines on several topics in a well specified context [7]. A clinical guideline is a document with the aim of guiding decisions and criteria regarding diagnosis, management, and treatment in specific areas of healthcare [8]. Such documents have been in use for thousands of years during the entire history of medicine [9].

In contrast to historical approaches in clinical guidelines, which were often based on tradition or authority, modern clinical guidelines are based on an examination of current evidence within the paradigm of evidence-based medicine, i.e., the use of current best evidence in making decisions about the care of individual patients. Hence, these modern guidelines usually include summarized consensus statements on best practice in healthcare. Further, a healthcare provider is obliged to know the medical guidelines of his or her profession, and has to decide whether or not to follow the recommendations of a guideline for an individual treatment.

It has been shown that the use of clinical guidelines and care pathways reduces the variability in clinical practice and improves outcomes [4]. However, so far the use of care pathways is restricted on healthcare personnel and their used Electronic Health Records (EHRs) [10]11].

In this paper, we describe our work on extending traditional PHRs by care pathways. So the use of care pathways is not only restricted on healthcare personnel but rather on patient's healthcare team, which may include patient's family members as well. In our solution care pathways are presented by Business Process Diagram (BPD), which are increasingly being used to support healthcare processes. BPD [12] is based on a flowcharting technique tailored for creating graphical models of business process operations [13]. These elements enable easy development of simple diagrams that are easy to understand. Further, BPD processes can be automatically translated into executable WS-BPEL (Web Service Business Process Execution Language) processes [14][15], which activation can be based on the data stored in patient's PHR.

We use WS-BPEL as a computer interpretable clinical guideline language. Such languages explicitly model a care process by specifying the steps and the order in which these steps are to be executed [6]. However, our way of exploiting such a language deviates from its traditional use in that it does not retrieve patient's medical data from EHRs but rather from PHRs. Further, we have restricted on automating the reservations on clinical resources as well as automating information therapy.

The rest of the paper is organized as follows. First, in Section II, we give a short introduction to new emerging healthcare models. Then, in Section III, we shortly consider clinical guideline languages. In Section IV, we present our way of using BPDs in presenting care pathways. In Section V, we first present our developed cloud-based PHR-architecture and then we present how we exploit SQL-triggers in automating the activation of WS-BPEL-processes. Section VI concludes the paper by considering our future research.

II. EMERGING HEALTHCARE MODELS

Evidence-based medicine, or *evidence-based health care*, addresses the challenge of finding a way to ensure that clinicians base their day-to-day decision-making on current best evidence [16]. It is explicit and judicious use of current best evidence in making decisions about the care of individual patients. Practicing evidence-based medicine requires the integration of individual clinical expertise with the best available external clinical evidence from systematic research and our patient's unique values and circumstances [10].

Patient-centered care [17] emphasizes the coordination and integration of care, and the use of appropriate information, communication, and education technologies in connecting patients, caregivers, physicians, nurses, and others into a healthcare team where health system supports and encourages cooperation among team members. It is based on the assumption that physicians, patients and their families have the ability to obtain and understand health information and services, and make appropriate health decisions [18]. This in turn requires that health information should be presented according to individuals understanding and abilities [19].

Care pathways model an extended process of patient-centered care by specifying key events, clinical exams and assessment that have been shown to produce the best outcomes for an appropriate episode of care [4]. They are increasingly seen as a means to put clinical guidelines in practice by interdisciplinary teams, as they help reduce patient uncertainty, improve resource utilization and encourage family-centered care. In particular, care pathways can be effective in supporting proactive care management and ensuring that patients receive relevant clinical interventions and assessments in a timely manner.

Information therapy promotes patient-centered healthcare. It is a type of healthcare information service that has emerged in the past decade. The goal behind information therapy is to prescribe the right information to right people at right time [20]. Information therapy is also described as "the prescription of specific evidence based medical information to specific patients at just the right time to help them make specific health decisions or behavior changes" [21].

Information therapy applies to a wide range of situations and context. For example, information therapy may be a physician-written prescription telling a patient what to read, or it may use to help a patient to make treatment decision such as whether to continue medication.

Information therapy can be compared to similar concepts in medicine, such as drug therapy, physiotherapy or bibliotherapy. However, information therapy differs from these in the sense that by exploiting information technology information therapy aims at providing personalization, targeting and documentation.

Many studies have demonstrated that the provision of information therapy can increase compliance with treatment regimens, satisfaction with the health care provider and medical facility, and improve the ultimate health outcome for the individual [21]. It is also turned out that patients who do not understand their treatment instructions, disease management, or prescription requirements are more likely to mishandle their health, be hospitalized more frequently, and have much higher medical costs than their more involved counterparts.

III. COMPUTER INTERPRETABLE CLINICAL GUIDELINE LANGUAGES

The *computer-interpretable clinical guideline languages* explicitly model a care process by specifying the steps and the order in which these steps are to be executed [22]. Examples of these languages include Ashru, EON, GLIF, GUIDE, PRODIGY, and PROforma. A prerequisite for developing these languages is creating computer interpretable representations of the clinical knowledge that is contained in clinical guidelines.

The computer-interpretable clinical guideline languages can be classified into process languages and declarative languages [23]. In the former approach a sequence of tasks is defined for the computer to perform while in the latter approach the logic of computation is defined without describing its control flow, and so leaving a lot of freedom to the user in selecting tasks and defining the order in which they can be executed.

Although process languages allow flexibility by means of modeling alternative paths, they are incapable of handling exceptional or unpredicted situations. Exceptional situations have to be modeled explicitly. However, modeling all possible scenarios results in complex models and is not feasible since exceptional situations and emergencies may arise at any point in time [24]. This makes it difficult or even impossible to oversee what activity should be performed next.

A gain of declarative languages is that they enable late binding, i.e., it is possible to choose an appropriate task at the point of care [25]. On the other hand, late binding resource allocation's point of view means late "reservation", which in the context of scarce resources often means long delays in obtaining the resources.

For example, consider late binding with respect to blood test task and radiographer's consultation. Often the delay for the former task is only a few days while for the latter task it is often some weeks or even months. Hence, late binding may significantly delay the whole healthcare process. This case becomes still more complex, if the tasks have mutual temporal dependencies, e.g., blood test must be taken at least one week before radiographer's consultation.

Due to the problems related late binding we argue that process model are more appropriate for our case, i.e., for modeling clinical pathways and their computer interpretable transformations.

IV. REPRESENTING CLINICAL PROCESSES BY BPMN AND WS-BPEL

There are three important requirements for health care process modeling notations. First, the notation should be readily understandable by the analyst that create initial drafts of the clinical processes, and by the health care employees who manage and monitor those processes. Second, the notation should have enough expression power to model the temporal constraints of the executions. Third, the used notation should be easily transformed into an executable process modeling language.

Business Process Model and Notation (BPMN) is a standard for business process modeling [12]. It provides a graphical notation called Business Process Diagram (BPD). It is suitable to presenting business as well as healthcare processes.

In BPD, there are three 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. 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 Figure 1 we present how a resource allocation process for a diabetes patient can be represented by a BPD.

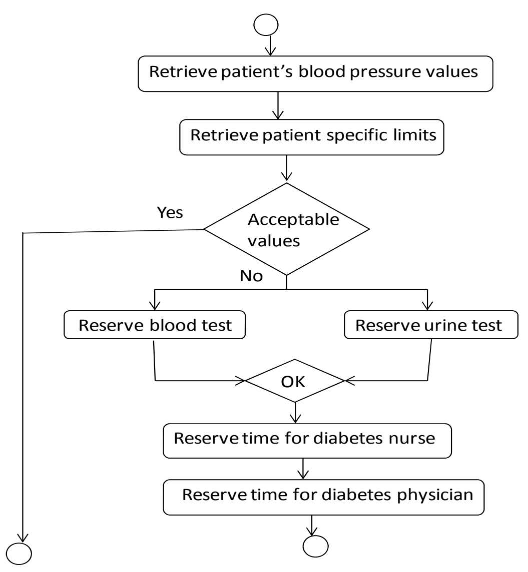

Figure 1. Resource allocation diagram in BPD.

BPD enables the generation of executable WS-BPEL [14]. Thus it creates a standardized bridge for the gap between the business process design and process implementation. In particular, the BPMN specification includes an informal and partial mapping from BPMN to WS-BPEL 1.1 [15]. A mapping of BPMN to WS-BPEL has been implemented in a number of tools, including an open-source tool known as BPMN2BPEL. In such mappings, each activity of the diagram corresponds to an execution of a web service, and the whole process (e.g., Resource allocation process) comprises a Web service. Further, these web services interact with a database management system, and thereby their functionalities can be exploited, e.g. the triggering mechanism as described in the next section.

V. CLOUD-BASED PHR-SYSTEM

A. *Using the SaaS model*

Cloud computing [26] represents new way of delivering organization information technology: anyone with a suitable Internet connection and a standard browser can access an application in a cloud. In addition, cloud computing allows organizations to use applications without installation. It also allows for more efficient computing by centralizing storage, memory, processing and bandwidth [27].

In designing the architecture of the cloud-based PHR-system we have followed the Software as a Service (SaaS) model. In this model, applications are hosted by service provider and made available to customers over the Internet. It provides access to software and its functions remotely as a Web-based service.

Our SaaS-based architecture is presented in Figure 2. In this architecture a user (a member of patient's healthcare team) can invoke the execution of the web services by patient specific parameters. The execution of each service corresponds to an execution of a care pathway or some other functionality that promotes patient-centered healthcare.

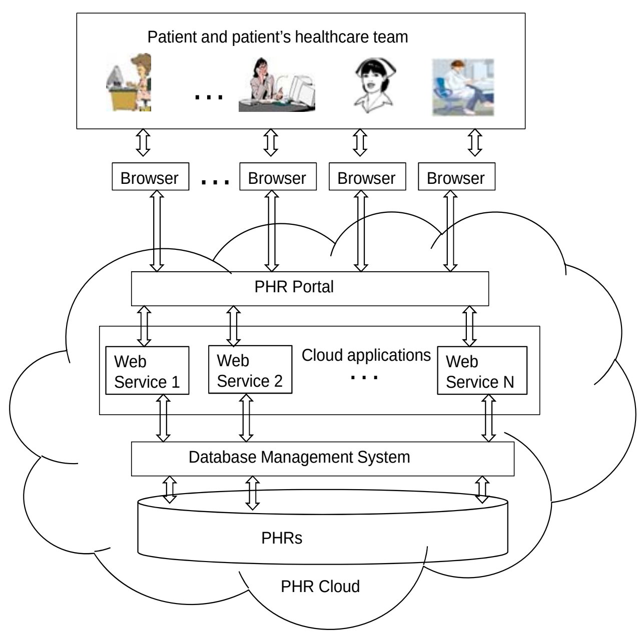

Figure 2. Cloud-based PHR-system.

We have also design a mechanism for automatic activation of executable care pathways based on the values stored on PHRs. In the following subsections, we consider this mechanism.

B. Representing the PHR Ontology in OWL

At the conceptual level the PHRs are based on our developed PHR-ontology, which is graphically presented in Figure 3.

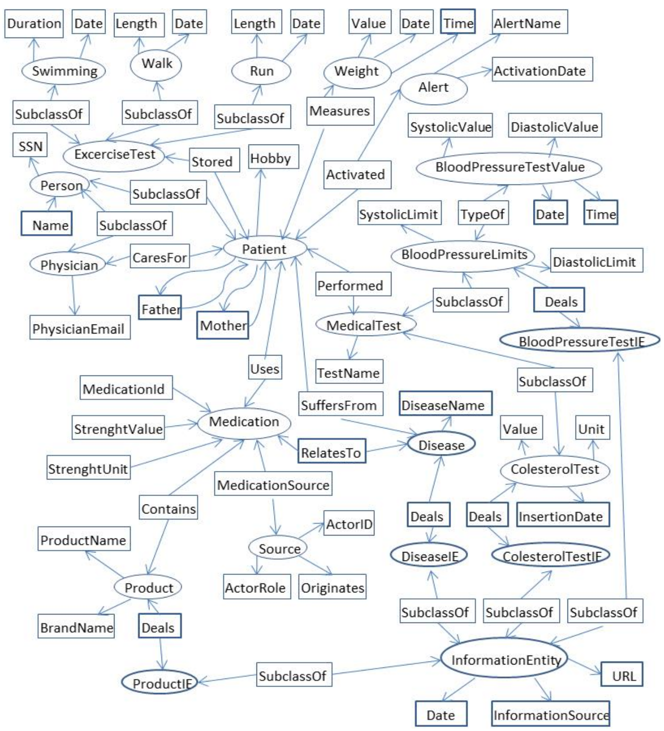

Figure 3. PHR-ontology.

In this graphical representation, ellipses represent classes and subclasses while rectangles represent data type and object properties. Classes, subclasses, data properties and object properties are modeling primitives in OWL (Web Ontology Language) [28]. Object properties (e.g., Uses) relate objects to other objects while data type properties (e.g., MedicationId) relate objects to datatype values. In the graphical ontology in Figure 3 we have presented only a few of objects' datatype properties.

We have used the following rules in transforming the PHR-ontology into relational schema:

- The name of the OWL class is the name of the relation.
- Each property of the OWL class is an attribute of the relation.
- The key of the relation is comprised of the identification of the OWL class and of the identification of those OWL classes that are in a multivalued relationship to the OWL class.

In a *relational database*, all data is stored and accessed via relations [29]. A relation is defined as a set of tuples that have the same attributes. A tuple usually represents an object and information about that object. For example in Figure 4, the first tuple in the first relation indicates that the SSN of Elisa Gray is 1112444-A2, her SystolicLimit is 157 and DiastolicLimit is 71.

The second relation indicates three test values of Elisa Gray's blood pressure tests.

BloodPressureLimits (

SSN	Name	SystolicLimit	DiastolicLimit)
111244-A2	Elisa Gray	157	71
121248-B9	John Kent	171	77
120351-A2	Jack Cruz	144	61
120941-C5	Bob Jones	164	68

BloodPressureTestValue (

SSN	Date	SystolicValue	DiastolicValue)
111244-A2	06042011	142	75
111244-A2	07042011	155	79
111244-A2	09042011	160	64

Figure 4. Relations BloodPressureLimits and BloodPressureTestValues.

C. Specifying Views and Triggers on Relations

As PHRs are only accessible by the patient and those that are authorized by the patient, we have to control the access of PHRs. In relational database systems such control can be easily carried out by views.

To illustrate this, consider the first tuple of the relation BloodPressureLimits in Figure 4. It should be only accessible for Elisa Gray and her healthcare team. To enforce this we can specify a view 'GrayBloodPressureLimits' in SQL as follows:

Create View GrayBloodPressureLimits AS
*SELECT **
FROM BloodPressureLimits
WHERE Name = 'Elisa Gray';

Now, the virtual relation behind the view 'GrayBloodPressureLimits' corresponds to the relation presented in Figure 5.

GrayBloodPressureLimits (

SSN	Name	SystolicLimit	DiastolicLimit)
111244-A2	Lisa Smith	157	71

Figure 5. The virtual relation of the view GrayBloodPressureLimits.

After the view is specified, we can easily set restrictions on its use, e.g., Elisa Gray has rights to read and update it while her physician Ian Taylor has only rights to read it.

Database triggers play a central role in our designed PHR-system. We can easily specify triggers, which activate executable clinical pathways or the functionalities of information therapy. Technically s database trigger [30] is procedural code that is automatically executed in response to certain events on a particular relation or view in a database.

The SQL trigger statement gives the user a number of different options in the event, condition and action parts. For example, the following SQL trigger activates the execution of the care pathway named ResourceAllocation by a parameter ”Elisa Gray”, if Elisa’s systolic value exceeds her systolic value limit (157mmHg).

CREATE TRIGGER GraySystolicAlert
AFTER INSERTION of SystolicValue
ON BloodPressureTestValue
WHEN SystolicValue > SystolicLimit
EXEC “ResourceAllocation(Elisa Gray)”

By replacing the action part, i.e., the last line of the above trigger, by the action part

“EXEC sendmail´elisa.gray@health-house.com,
“Please familiarize with the advices at http://www.healthinfo.com/high_blood_pressure/”

we can automate information therapy, i.e., advise Elisa to read the guideline stored at the given URL.

In general, providing guidelines does not require the creation of new content as relevant information entities already exist in a digital form [31].

VI. CONCLUSION

The sophistication of information technology and communications is changing our society. In the ongoing healthcare reform, there is an increasing need to control the cost of medical care. In this context the significance of patient-centered healthcare is extensively recognized as it can help by providing information to the patients, their families and physicians, not only for illnesses, but also for prevention and wellness. This, however, requires that patient’s health information as well as other relevant medical information is presented in appropriate format according to individuals understanding and abilities.

Advanced PHR systems have the potential to dramatically contribute to patient centered healthcare as they enable patient to become more involved and engaged in their care, and allow other authorized stakeholders to access information about patient that has not been previously been available or difficult to access electronically. The change that can be caused by the deployment of new PHR systems could also have a significant impact on the efficiency of administrative and clinical process in healthcare sector, and thus they will give rise for considerable cost savings.

There are still many obstacles to the widespread use of patient centered healthcare. For example, many patients are not satisfied with the information concerning their future or ongoing care. Our way to alleviate this problem is the automation of information therapy and the deployment of executable care pathways. This is a promising approach as it has been shown that the use of clinical care pathways reduces the variability in clinical practice and improves outcomes.

Still an arising question is how we can promote the production of care pathways suitable for PHRs. Hence, in our future research we will focus on developing graphical tools that assist physicians in constructing care pathways that can be easily stored and executed in PHR-systems. In particular, we will be focused on designing cloud-based solutions, i.e., we will extend the cloud-based PHR-system by new components.

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