Why Rigid Process Management Technology Hampers Computerized Support of Healthcare Processes?

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Abstract. *Healthcare processes are characterized by frequent changes, numerous exceptions and complex deviations from the norm. Despite the increasing adoption of process-aware healthcare information systems (PAHIS), there still exist numerous issues related to the handling of exceptions in clinical processes that are not effectively supported in contemporary PAHIS. This paper presents preliminary results of a research whose goal is to get a deeper understanding of clinical work practices and to better understand how IT process support should look like for them. Altogether, adequate handling of failure and exceptions in PAHIS, while still enabling a certain level of control and assistance to clinical staff.*

1. Introduction

A Process-aware Information Systems (PAIS) can be defined as a software that manages and executes operational processes involving people, applications, and information sources on the basis of process models [Russell 2000]. Considering computers as labor and time saving, exceptions occur frequently in PAIS affecting the possible savings. These exceptional situations, in turn, might influence the process execution, requiring deviations from its normal behavior [Reichert et al. 2009]. Generally, PAIS need to cope with different kinds of exceptions, which are usually classified into expected and unexpected exceptions [Reichert et al. 2009], [Mourão and Antunes 2007], [Luo et al. 2000]. In this context, exception handling in business process automation can be considered as a very complex and expensive task [Sadiq and Orlowska 2000]. Managing adverse events or deviations from the normal flow and at the same time to assure a certain level of flexibility has been always a challenge in business process automation. Healthcare processes, in particular, are very complex, with more than 50 different types of medical specialties and subspecialties interacting with each other [Lenz and Reichert 2006].

As example, consider the process for ordering drugs at the pharmacy of a clinic (cf. Fig.1). This process includes the following sequential activities: a) first, information about the patient is obtained; b) then, the dosage of the drugs to be applied is calculated; c) the doctor must fill the prescription; d) the prescription is sent to the pharmacy; e) a physician verifies the dosage; and f) the drugs are produced. This simple process must be able to cope with several exceptions. For example, if the order does not arrive in the pharmacy before 11am, the latter will be not able to produce the drugs. In this case the clinic itself must produce the drugs (see 1]). In case some difficulty happens when transporting the drugs the process to produce the drugs must be aborted (see 2] and 3] respectively). The same kind of exception procedure applies when the health state of the patient changes (e.g., the patient feels better) (see 4]).

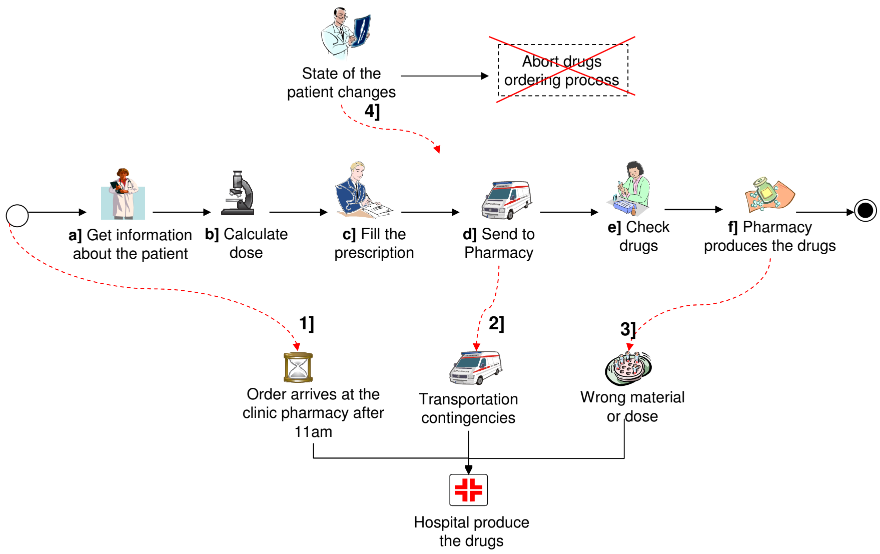

Figure 1. Process to order drugs at the clinic pharmacy

In dynamic environments like healthcare, processes need to be continuously adapted, but without affecting the production of expected outcomes. Recently, huge efforts have been undertaken to make process management systems more flexible and different approaches for providing flexible process support have emerged (e.g., adaptative process management, late modeling, case handling, declarative processes, and data-driven workflows) [Weber et al. 2009]. All these approaches enable some kind of process flexibility, but they have not been applied in the clinic context yet [Lenz and Reichert 2006], [Becker and Janiesch 2007]. In order to effectively provide IT process support for dealing with exceptions during process execution it is important to understand their nature and the way they are handled in practice. Otherwise, physicians, nurses and staff would not accept the PAHIS.

This paper reports on the results of an analysis of a set of real-world healthcare process models from a Woman's hospital in Germany. With our analysis we try to give insights into the reasons that lead to process deviations from the norm, into how these deviations look like, and into the way process participants (e.g., nurses, physicians) cope with these exceptional situations in real hospital practice. We believe that this kind of analysis is fundamental for better understanding how next generation PAHIS should be designed in order to meet flexibility requirements in clinical practices.

The remainder of this paper is organized as follows: Section 2 characterizes work practices of real healthcare environments. Section 3 describes exceptions and exception handling in real-world clinical processes. In particular we characterize kinds of events which can cause exceptions based on a literature study and on several case studies we performed in cooperation with a Woman Hospital in Germany. This characterization helps us to better understand the nature of the exceptions, i.e. their causes and how process participants deal with them. In this Section we further discuss results from the performed case studies were we investigated how clinical staff deal with exceptions in real-world. Section 4gives background information on how clinical processes are supported by the current generation of workflow systems. Section 5 discusses limitations of existing PAHIS and first insides on how we expect to provide more effective IT process support to cope with real-world clinical exceptions. We conclude with a summary and outlook in Section 6.

2. Clinical Work Practice

In hospitals, the work of physicians and nurses is hampered by numerous organizational as well as medical tasks. Medical procedures must be planned and prepared, appointments be made, and results be obtained and evaluated [Dadam et al. 1997]. Usually, in the treatment process of a patient various, organizationally more or less separate units are involved. For a patient treated in a department of internal medicine, for example, tests and procedures at the laboratory and the radiology department become necessary. In addition, biological sample or the patient herself have to be transported, physicians from other units may need to come and evaluate the patient, and reports have to be written, sent, and interpreted. Thus, the cooperation between organizational units as well as the medical personnel is a vital task, with repetitive but nevertheless non-trivial character. Healthcare processes of different complexity and duration (up to several months) can be identified. One can find organizational processes, like order entry and result reporting for radiology, but also complex and long-running patient treatment processes like chemotherapy for in as well as out-patients.

Physicians have to decide which interventions are convenient, necessary or which are not (under the perspective of information necessity, costs and invasiveness) or which are even dangerous because of possible side-effects or interactions. Many procedures need preparatory procedures of various complexity levels. Before a surgery can take place, for example, a patient has to undergo numerous preliminary examinations, each of them requiring additional preparations. While some of them are known in advance, others may have to be scheduled dynamically, depending on the individual patient characteristics and her state of health. All tasks may have to be performed in certain orders, sometimes with a given minimal or maximal time interval between them [Dadam et al. 1997].

Usually, physicians have to coordinate the tasks related to their patients manually, taking into account all the dependencies existing between them. Changing a schedule is not trivial and requires time-consuming communication. For some procedures, physicians from various departments have to work together. So, coherent series of appointments have to be arranged, and for each step actual and adequate information has to be provided. The interrelated roles of physicians and nurses complicate the problem. They are responsible for many patients and they should provide an optimal treatment process for each of them. Medical tasks are critical to patient care and even minor errors may have disastrous consequences. The working situation is further burdened by frequent context switches. Physicians often work at various sites of a hospital in different roles [Dadam et al. 1997].

Medical personnel must be free to react and is trained to do so. In an emergency case, for example, physicians may collect information about a patient by phone and proceed with the process, without waiting for the (electronic) report to be written; i.e., activities of a workflow may have to be dynamically skipped or moved in order to avoid a mismatch between workflow and real-world process. A medical procedure may have to be aborted if the patient's health state gets worse or one of its prerequisites is not met. Such dynamic deviations from the pre-planned process are frequent and form a key part of process flexibility in healthcare. Any PAHIS which is employed to assist physicians and nurses in their daily work, therefore, must allow them to gain complete initiative whenever needed. The PAHIS must be easy to handle, self-explaining and most important its use in exceptional situations should be not more cumbersome and time-consuming than simply handling the exception by a telephone call to the right doctor or nurse; otherwise the system will not be accepted by the medical personnel.

3. Exceptions and Exception-Handling in Healthcare Processes

Based on a literature study and an analysis of clinical processes from a Woman Hospital in Germany (cf. Section 3.1) we verified that exceptions can be caused by different kinds of events such as medical errors, changes in patient status, organizational guidelines and technical contingencies. In the following we discuss these causes in details.

- ***Exceptions Related to Medical Errors:*** Errors in medicine can cause severe harm [Blaser et al. 2004]. Quality problems in medical discharge letters, for example often constitute a source of subsequent medical errors. Missing information and inconsistent or even wrong data in such letters can lead to wrong diagnosis and thus to wrong patient treatments.

- ***Exceptions Related to the Patient:*** This category comprises specific circumstances involving the patient which can lead to deviations from the norm. For example, changes in the health status or non-compliant patients (e.g., in case a patient refuses to start or continue a treatment) might result in the abortion of a treatment or eventually the starting of an alternative one.

- ***Exceptions Related to Organizational Guidelines:*** Organizational processes (e.g., patient admission and patient discharge) generally follow some protocol. In emergency cases, however a certain level of flexibility is needed. Usually, during the admission of a patient at a hospital, he must provide personal information and sign certain consent forms before the medical treatment starts. If the respective patient is critically ill, however this information will be obtained from a family member and the medical examination will start in parallel to the admission. Other situation is when time constraints of the hospital or pharmacy are not followed. Typical example include a lab analysis which is normally performed during the morning but in an exceptional situation is performed in the afternoon.

- ***Exceptions Related to Technical Contingencies:*** Another source of exceptions are technical problems that happen during healthcare processes. For example, a lab machine might stop while performing a lab test, then the machine must be restarted and the test performed from the beginning.

3.1. How Clinical Staff Deal with Exceptions in Real-World?

To get insights into how process participants (e.g., physicians, nurses, administrative staffs) deal with exceptions in practice we analyzed 10 healthcare process models. These models were collected at a Woman Hospital in Germany and are related to chemotherapy treatment. The process models comprise between 4 and 9 activities including subprocesses (cf. Table 1). Respective process models include several deviations from the norm. For example an allergy detection which can lead to the interruption of a medical treatment or the requesting of wrong doses to be produced in the hospital pharmacy.

Initially, we looked at the 10 processes and designed a new model of each of them including respective exceptions in their context. Finally, we related each exception with the events introduced in this Section. Here we present an example of a real clinical process that was subject of our analysis. This process model comprises the normal flow and respective deviations from the norm (see dashed line and corresponding activities in Fig. 2).

Process name	# of activities	# of ANDSplit	# of ANDJoin	# of XOR	# of Subprocesses	Patient involved € {yes, no}	#Exceptions
Drugs ordering	6	1	1	0	1	No	3
Patientadmission	5	1	0	0	1	No	1
Patient discharge	4	1	0	0	1	No	0
Lab test	7	1	0	0	1	Yes	6
Lab analyses	6	0	1	1	0	No	0
Medical examination	9	0	0	1	0	Yes	6
Physicians brainstorm	8	2	0	0	0	No	0
Discharge letter	6	1	1	1	0	No	0
Final medical report	5	0	1	1	0	Yes	0
History of a chemotherapy treatment	2	1	1	1	3	yes	6

Table 1. Characterizing the analyzed process models

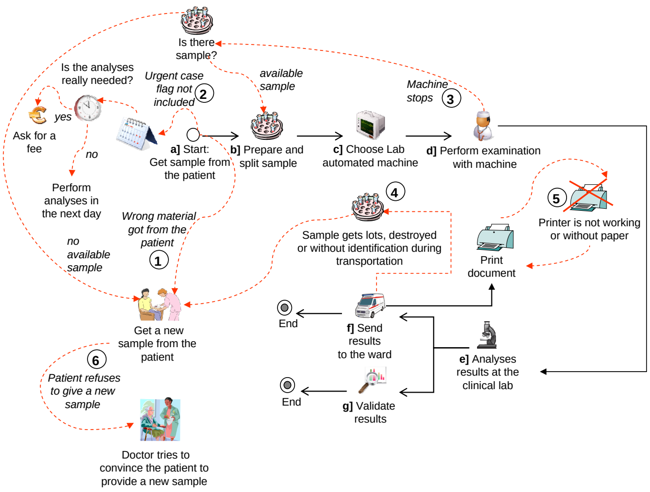

Figure 2. Lab Test

3.2. On the Nature of Exceptions in Real-World Healthcare Processes

In this Section we present examples of semantic exceptions caused by medical errors, patient related exceptions, organizational exceptions and technical exceptions (cf. Table 2). Notice that these examples consider the described events, which might cause exceptions and our observation concerning the analysis of the 10 healthcare process models.

Patient Related Exceptions		
Exception	**Nature**	**Possible Reactions (PR)**
E1: Change in the patient's health state	The health state of the patient improves or become worse during a chemotherapy treatment.	PR1: Interrupt the treatment and cancel appointments PR2: In case there are drugs being produced, abort the production PR3: The patient must spend the night in the clinic
E2: Patient refuses to start or continue a treatment	After being informed about the risks of a treatment or while a treatment is being performed the patient refuses it.	PR4: Apply PR 1 and PR 2
E3: Patient is allergic to a medical drug	During a treatment a patient shows an allergy to specific drugs or he gets another unexpected illness (e.g., a cold).	PR5: Apply PR 1 and PR 2
E4: Patient refuses to provide blood sample	The patient might not agree in providing blood sample.	PR6: The doctor must try to convince the patient in providing a new sample
E5: Patient not available	Occasionally, the patient might be unavailable when an examination is requested. E.g. the patient might stay with another examination unit.	PR7: Recall the patient and postpone the requested examination
Exceptions Resulted from Technical Problems in the Clinic or Lab		
E6: Transportation problem with the drugs	Problems with the transportation of the drugs	PR8: In case of any contingency with the transportation of the drugs the clinic is authorized to produce the drugs internally.
E7: Printer does not work	It can happen that the results of the lab analysis cannot be printed because of technical problems with the printer or because the printer is out of paper	PR9: The document must be sent again.
E8: Lab machine stops	The lab machines, accidently stops while an examination performed	PR10: Restart the machine and perform the examination from the beginning. In case there is no one from the patient, get new sample. If E4 occurs, apply EH 6
E9: The sample or its identification are lost	A sample gets lost or destroyed during its transportation. It can also happen that the identification of the sample gets lost	PR11: A new sample is obtained from the patient. Apply PR 6 in case E4 happens
Exceptions caused by Organizational Guidelines		
E10: No observance of organizational guidelines	The sample is generally extracted from the patient during the morning. In emergency cases, the analysis can also be performed in the afternoon. For that, the analysis request must be indicated as urgent. Otherwise, the analysis will not be performed within the same day of the request.	PR12: A fee will be asked in case the analysis is urgent and must be performed at the same day it was requested
E11: Patient visits the physician without an appointment	Before visiting the doctor the patient must get an appointment before. In emergency cases, however, it might be necessary to arrange an ad-hoc appointment with the physician	PR13: Set an urgent appointment with the doctor
E12: Urgent information required	It can happens that the radiologist needs the images urgently to continue the treatment	PR14: Obtain the results of the examination by phone in order to continue the treatment
E13: Starting of a treatment in parallel with patient admission in the clinic	In ordinary cases first the patient is admitted in the hospital and afterwards the doctor starts treatment. However, in emergency cases the patient cannot wait for the admission and the treatment must be started immediately	PR15: Start the treatment in parallel to patient admission
E14: Wrong tasks are performed or skipped	Certain radiological examination specific lab values must be obtained (e.g., level of keratin)	PR16: not start the radiological examination in case specific lab values are missing
Exceptions Resulted from Medical Errors		
E15: Wrong material or wrong doses	It can happen that the wrong material (e.g., blood instead of urine) is obtained from the patient or wrong doses are requested to be produced	PR17: In case of wrong material a new sample must be taken from the patient. Apply PR 6 in case E4 happens PR18: In case of wrong doses, apply PR 8

Table 2. Exceptions Relying to the Analyzed Process Models

4. Exception and Exception Handling in Computerized Healthcare Proceses

For healthcare processes, it is nearly impossible to pre-model all possible task sequences and all exceptions in advance. For example, if a physician comes to the conclusion that an additional medical test, which has not been considered in the process template, becomes necessary in a given situation, the PAHIS must not prevent him to add the respective activity to the process. In addition, it would be very important that PAHIS could automatically obtain clinical data (e.g. on-line information on patient such as temperature, pressure). Otherwise, he would have to bypass the PAHIS causing the problem of missing coordination and documentation.

In order to develop more dynamic healthcare PAHIS it is important to understand the nature of exceptions in real-world healthcare processes. In Section 3 we gave examples of real-world processes comprising several exceptions. We could observe that exceptions are frequent in healthcare processes such as the ones we analysed and PAHIS must be flexible enough to support them. Moreover, PAHIS are complex to be developed because they involve both clinical and administrative tasks, large volume of data, and large number of clinical staff. Changes in healthcare treatments, drugs, and protocols may invalidate running instances, requiring reparative actions [Anyanwu et al. 2003]. For example, when a patient arrives at the clinic, the first procedure is to perform his administrative admission, then the doctor performs initial examinations; after the doctor starts the treatments. In emergency cases, however (e.g., risk of death) the administrative admission can be performed in parallel with the medical one.

Currently PAHIS have focused on the creation, management and delivery of medical documentation (e.g., CareFlowNet [Careflow 2009]), clinical data management, patient information management, and document acquisition and storage (e.g., SoftMed [SoftMed 2002]). The METEOR system has been used to prototype and deploy several healthcare applications. In particular, the system has a layer that permits consistent realization of the dynamic change of instances [Anyanwu et al. 2003].

5. Discussion

Research on exceptions in computerized processes and on workflow management systems has been going on for more than ten years. One of the first insights for contributions was given by [Strong and Miller 1995] who analysed the causes of exceptions in information systems and classified them according to specific perspectives such as: random event, error, and political system. In the *random event perspective*, exceptions are low-probability events that are unexpected, nonrepetitive, and infrequent. The *error perspective* includes exceptions caused by operational errors (mistakes made by people) and process design errors (wrong procedures executed by computers) and errors due to dynamic organizations. The later implies the development of routines for recognizing and handling cases in the organizational environment that computers cannot process correctly. The *political system perspective* explains the persistence of some exceptions, especially in information processes that cross organizational boundaries, e.g., order fulfillment starts in sales and continues into manufacturing.

[Klein et al. 2000] presents an approach to anticipate the ways a process may fail and then to define how these failures can be detected or avoided. The process model is compared against a taxonomy of elementary process elements and respective failures related to these elements (e.g. activities, resources, goals and assumptions). For diagnosing exception causes an heuristic classification is used. Exception types (e.g. design error, resource unavailability) are arranged into a taxonomy ranging from highly general failure at the top to more specific ones at the bottom.

According to [Sadiq and Orlowska 2000] the majority of exceptions in business processes can be anticipated. Though they are not exceptions in the real sense, they still represent deviations from the normal process. The main characteristic that distinguishes these exceptions from normal process logic is infrequency. In this context, exceptions are driven by events including temporal events, resource violations, and external notification.

In [Russell et al. 2006] exceptions are grouped into classes which are related by similarities that they possess in terms of the conditions under which they might occur. Exception handlers are then programmatic procedures to resolve the effects of specific events as they are detected. The authors investigate the issues that may lead to exceptions during workflow execution and the various ways in which they can be addressed. This provides the basis for a classification framework for workflow exception handling which is subsequently defined in the form of patterns (e.g., work item failure, deadline expiry, external trigger).

Mourão [Mourão and Antunes 2007] classify exceptions as expected and unexpected ones. Even though expected exceptions do not correspond to the normal process behavior they can be foreseen at the process modeling phase. Normally, they are excluded from the process model to reduce complexity. Unexpected exceptions, however, cannot be predicted during process modeling. They correspond to unstructured activities and often require human intervention to be handled. The authors propose a framework targeting at the support of the unstructured activities necessary to handle unexpected exceptions. They distinguish four functions in exception handling: 1) exception detection; 2) situation diagnosis; 3) exception recovery; and 4) monitoring actions.

Finally, an approach enabling automation of exception handling at a high level of abstraction is presented in [Rinderle and Reichert 2006]. The approach includes a formal framework for data-centered exception handling, i.e., process adaptations necessary to deal with exceptional situations are carried out by modifying data structures (e.g., a delivery list of goods). This data change is then propagated to the running process by the concept of data-driven expansion, and not by directly applying changes on the control flow schema of the concerned process instance. In order to automatically derive exception handling strategies at a semantically high level the authors integrate and exploit process information (e.g., data about physical objects).

In our approach we focus on exceptions in the context of healthcare processes. Exceptions are considered as deviations from the normal flow and are mainly related to the semantics of the process (e.g., the starting of a medical treatment in parallel with the patient admission in the clinic). As this kind of exceptions are infrequent they are usually not explicitly included in the process model. Moreover, in order to include them we need more sophisticated and flexible systems. Therefore, our idea is to study these exceptions, their nature and the way how user handle them. To investigate further ways to effectively implement them in PAHIS.

6. Summary and outlook

This paper showed that it appears to be suitable to improve IT process support for healthcare processes by exploiting the features of next generation process management technology. Recently, large efforts have been undertaken to make process management systems more flexible and different approaches and paradigms for providing flexible process support have emerged. Examples include adaptive process management, late modeling, case handling, declarative processes, and data-driven workflows. All these approaches enable some kind of process flexibility, but have not yet been applied in the healthcare context.

The major contributions of this paper are the results from an empirical study performed within a Woman Hospital in Germany. Basically we analyzed several process models related to the chemotherapy treatment. These processes models comprise several exceptions which were reported by physicians of the hospital during their design. We investigated the nature of these exceptions and how users deal with them. Our goal is to relate them to clinic exception handling patterns. In this context we presented examples of exceptions based on different aspects such as organizational guidelines, technical contingencies and changes in the patient health state.

In the future work we plan to analyse additional process models in order to identify more recurrent exceptions and to relate them with existent and new patterns. We also intend to investigate deeper how to provide IT process support for these exceptions.

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