ABSTRACT
Process-oriented workflow management in healthcare is a prerequisite to deliver high quality of care and to decrease treatment costs. Clinical workflow management systems (WfMS) cover the definition, execution and reconstruction of healthcare processes, which aims to identify main causes of high medical costs. Nevertheless, almost all existing clinical WfMS share one common drawback: they build upon proprietary hospital information systems (HIS). This paper presents a HIS independent workflow reconstruction approach based on the IHE integration profile “Cross-Enterprise Document Workflow” (XDW). XDW addresses the management of clinical, cross-enterprise workflows and makes use of a specific document, the Workflow Document. This document tracks every step of a workflow (e.g. ePrescription) including control information as well as input and output documents. Therefore it is ideally suited to reconstruct a fine-grained clinical workflow including associated documents and metadata. Furthermore this approach enables a nominal-actual comparison between a clinical workflow and a process definition.

Keywords: Integrating the Healthcare Enterprise, Cross-Enterprise Document Workflow, Clinical Workflow Management System, Reconstruction of Clinical Workflows

1. INTRODUCTION AND MOTIVATION
In our previous work (Strasser et al. 2011; Altmann and Mayr 2011) we focused on the definition and execution of administrative and clinical processes and the reconstruction of patient pathways based on Integrating the Healthcare Enterprise (IHE) (IHE International Inc. 2011) and Business Process Model and Notation 2.0 (BPMN) (Object Management Group Inc. 2011). First results showed that this approach has some limitations due to insufficient prospects on the part of IHE. First of all, the definition and execution of processes was based on selected IHE integration profiles, such as Cross-Enterprise Document Sharing (XDS), Patient Demographics Query (PDQ), Patient Administration Management (PAM) and Patient Identifier Cross-referencing (PIX). These integration profiles are well suited to define administrative processes but are not usable in the context of clinical processes. Moreover, the reconstruction of patient pathways was based on PAM audit messages stored in the Audit Record Repository (ARR). Although the entries stored in the ARR are suited to reconstruct a patient’s way through a healthcare facility, a complete reconstruction of a clinical workflow failed.

In this work we focus on the reconstruction of clinical workflows based on the Cross-Enterprise Document Workflow (XDW), an IHE integration profile which handles the workflow of documents in a clinical context. The presented approach is part of the research project IHExplorer (IHExplorer 2011), whose main objective is to support hospital operators and clinical process managers with a set of tools to monitor, analyze and visualize clinical transactions and workflows.

2. METHODS
This section describes the essential methods and standards used by the XDW-based process reconstruction approach.

2.1. Integrating the Healthcare Enterprise
Integrating the Healthcare Enterprise (IHE) is an international initiative by healthcare professionals and industry to improve the integration and interoperability of medical information systems with standardized descriptions of medical use cases and the systematic use of well established communication standards like Health Level 7 (HL7) and Digital Imaging and Communications in Medicine (DICOM).

IHE issues technical guidelines called integration profiles that describe clinical use cases with actors, which represent software systems or software components, and standard-based transactions,
representing the communication between IHE actors. Integration profiles provide instructions for software manufacturers to develop interoperable software systems (IHE International Inc. 2011).

### 2.2. Cross-Enterprise Document Workflow

The IHE integration profile Cross-Enterprise Document Workflow (XDW) focuses on the management of cross-enterprise clinical workflows and makes use of a specific document, the Workflow Document. This document administrates all documents related to one clinical workflow and handles the changing of document states (Zalunardo and Cocchiglia 2011).

The Workflow Document is a structured document, characterized by tasks, representing a single step in the workflow. Every task results in the creation of a new document or represents a document state change. Each task has the same structure, based on three elements (see Figure 1): control information, input and output data. The control information element contains metadata needed to describe the specific step (e.g., author, date and time, organization). The input could be data or references to documents needed to perform the current step. The output of a task is a reference to one or more documents created during this step.

The structure of the Workflow Document is kept general and extensible to take account of further use cases. The current revision of the XDW integration profile describes a large number of different use cases to cover as much scenarios as possible. The use cases are simplifications of real life scenarios, e.g. ePrescription and eReferral.

The XDW integration profile is currently submitted for public comment and is a supplement to the IHE IT Infrastructure Technical Framework 7.0 (IHE International Inc. 2010).

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### 3. RECONSTRUCTION OF CLINICAL WORKFLOWS BASED ON XDW

This chapter presents a novel clinical workflow reconstruction approach based on the IHE integration profile XDW. The functionality can be used in addition to the PAM-based reconstruction approach (Strasser et al. 2011) or standalone. Finally, the reconstructed clinical workflow can be compared to an existing BPMN 2.0 process definition.

#### 3.1. Process definition and execution

The initial point of the presented reconstruction approach is a process definition based on BPMN 2.0, describing a clinical pathway which in turn is executed on a WfMS. Each action performed during process execution creates a new entry in the XDW Workflow Document according to the structure presented in section 2.2. The execution of a process leads to a comprehensive record of actions performed.

As the main field of application of the XDW integration profile are document-based workflows such as eReferral or ePrescription, the structure of the XDW Workflow Document contains references to other documents created during process execution as well as information about the authors and their organizations.

A typical example of an action which creates a new entry in the Workflow Document is the creation of an electronic prescription (see Figure 2). A prescription depends on clinical information which is often provided by means of one or more documents. Therefore, the input section of the appropriate task in the Workflow Document is used to store references to the according input documents. Moreover, the result of the prescription placement task is a new document. This information is stored in the output section of the according task.

For better comprehension and traceability of the approach this paper exclusively focuses on the IHE pharmacy process ePrescription which is described and illustrated with a sequence diagram in the XDW integration profile (Zalunardo and Cocchiglia 2011). Figure 2 shows the ePrescription use case as BPMN 2.0 process definition.

#### 3.2. Workflow reconstruction

Workflow Documents are updated every time a new task is executed, so all documents created during a patient’s treatment are referenced in the input- and output section of a task. The tasks in the Workflow Document can be sorted chronologically by using date and time of the control information.

Due to the fact that XDW Workflow Documents are well-formed and valid XML documents, it is possible to use a standard mechanism to display and transform the documents. Extensible Stylesheet Language Transformation (XSLT) is a declarative, XML-based language used for the transformation of XML documents (W3C 2007).

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**Figure 1: The structure of a task in the XDW Workflow Document**
In this context XSLT is used to transform the XDW Workflow Document into a BPMN 2.0 process (see Figure 3).

The transformation process relies on the correct implementation of the Workflow Document. Each task in the Workflow Document (e.g. Create Advice) is mapped to multiple BPMN 2.0 activities; there are one or more activities to download clinical documents (e.g. Download Prescription and Workflow Document), one or more activities to create or update clinical documents (e.g. Create Advice) and finally the upload of the modified documents (e.g. Upload Advice and Workflow Document). The activities are consecutively numbered to guarantee unique identifiers. For better readability it is important to define meaningful display names in the tasks code system, because these names are used to title the activities in the reconstructed process. In terms of codes and display names, there is still a huge amount of work to be done by the XDW technical committee, as there is currently no common code system available.

Depending on the author of a task we distinguish between user tasks and service tasks. On the one hand an author can be human like a nurse or a doctor, so the task is obviously an user task, but on the other hand tasks may also be executed by a program e.g. a HIS, which identifies a task as a service task. To access the underlying IHE infrastructure with service tasks, existing actors of the Open Source framework Open Health Tools (Open Health Tools Inc. 2011) are used.

To meet the requirements of the BPMN 2.0 standard definition at least two events must be implemented. The start and end events enclose the entire sequence flow. All activities between them are ordered chronologically in a straight line (see Figure 4).
Since a reconstructed BPMN 2.0 document represents only one patient pathway, it is linear and without any gateways.

The reconstructed patient pathway can be visualized in any BPMN 2.0 editor, because it is available in a standard format.

Furthermore functionality for actual-theoretical comparison of BPMN 2.0 documents is provided.

3.3. Process comparison
In order to compare an document-based, clinical workflow with an existing, predefined BPMN 2.0 process definition one needs to have a tool to match two BPMN 2.0 documents. Currently there is no such tool available, so we decided to implement one on our own.

The tool enables a nominal-actual comparison, by examining all the tasks listed in an existing process definition and comparing them with the display names given in the Workflow Document. Subsequently the resulting information can be used to emphasize the actual workflow in the process definition.

Figure 5 shows the ePrescription process definition with the highlighted reconstructed workflow.

4. RESULTS
The active cooperation with L. Zalunardo, the main author of the XDW integration profile, resulted in the creation of a conceptual design of the HL7 v3 CDA Workflow Document. The Workflow Document draft was introduced to the latest version of the XDW integration profile.

The Workflow Document is ideally suited for document-based workflows, tracking document states, like document creation and document updates. All workflow steps are summarized in one standard-based, structured document. Moreover, the current status of a clinical workflow can be determined with the Workflow Document.

Figure 4: Reconstructed ePrescription process

Figure 5: A reconstructed BPMN 2.0 process definition based on a XDW Workflow Document
A further result is the detailed workflow reconstruction based on the Workflow Document (see section 3.2) which can be used as an extension to the previous process reconstruction work. As every task in the Workflow Document contains control information as well as input and output documents, a fine-grained, document-centered process reconstruction is available.

As reconstructed workflows are available in the standard format BPMN 2.0, new possibilities for further processing open up. This approach, for example enables a nominal-actual comparison based on two BPMN 2.0 documents, e.g. a clinical workflow and a clinical process definition (see section 3.3). The result of the calculation, another BPMN 2.0 document, highlights the executed workflow in the process definition. This functionality enables delta analysis, as there are often discrepancies between the defined and the executed process.

5. CONCLUSION
The presented approach shows the reconstruction of clinical workflows based on the IHE integration profile XDW. In the following, we want to point out the advantages of this new approach in comparison to the previous PAM-based reconstruction approach.

Both approaches are hospital information system independent, because the reconstructions build upon IHE integration profiles. Certainly both approaches can be combined to receive further details about an executed workflow.

The PAM-based reconstruction approach shows some limitations, mainly because IHE doesn’t provide enough integration profiles to reconstruct comprehensive, clinical workflows. The existing integration profiles are restricted to the definition of administrative healthcare processes. Furthermore the PAM-based approach can’t reconstruct holistic workflows without using the event logs of the WIMS. The assignment of clinical documents to a certain workflow is a time-consuming calculation and sometimes infeasible because of multiple parallel patient workflows.

In contrast to the PAM-based reconstruction approach, XDW enables a complete reconstruction of a clinical workflow with an unique assignment of clinical documents to a specific workflow step. Furthermore the presented approach allows a fine-grained reconstruction, because the Workflow Document describes every workflow step in a high level of detail with control information and associated input and output documents. Moreover the reconstructed workflow is available in the standardized format BPMN 2.0.

Next to the reconstruction, functionality was developed to make a comparison between an executed workflow and a process definition. To achieve further information about a certain workflow, the PAM events in the ARR and the tasks in XDW Workflow Document might be combined.

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