Clinical Workflows based on OpenEHR using BPM

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Abstract: The integration of clinical workflows in electronic health records systems has been problematic due to the complex nature of clinical processes. For that reason, many health institutions have opted to maintain a few clinical workflows on paper, which has been compromising the quality and efficiency of several provided services. The purpose of this study is to investigate if the OpenEHR model can be applied in the configuration and management of clinical workflows using Business Process Modelling (BPM), with the focus on clinical forms based on OpenEHR archetypes and having has background the institution Centro Hospitalar do Porto (CHP). The need to review the workflows is pertinent due to the lack of integration of clinical workflows on their Electronic Health Records system. To analyse this possibility, a prototype was created containing: i) a BPM tool to configure and manage the clinical workflows; and ii) a web application to execute them and call the external clinical forms. The obtained results proved that the use of a BPM tool to configure clinical workflows allows the interoperability and flexibility of the prototype, which helps to improve the quality and efficiency of the clinical practice.

1 INTRODUCTION

Nowadays, Electronic Health Records (EHR) are essential in the health sector. The integration of this technologies on health institutions instigated a change on how clinical workflows should be executed, which was viewed with some distrust by the health professionals, who saw the clinical activities performed daily suffering changes (Kilsdonk et al., 2011).

Sometimes, the workflows of clinical work are not contemplated on EHR systems, having consequences like the loss of control by the health professionals over their patients and the treatments to be given. These problems can seriously compromise the efficiency and quality of the services provided by the health institutions. A lot of these institutions find it difficult to keep technologically up to date because of the lack of financial means to invest on those technological solutions that could improve their processes (Pearce and Bainbridge, 2014).

This study aims to address the integration problems of clinical workflows on EHR, so the control and quality of the daily tasks performed by health professionals can be improved. The investigation's idea is to understand if it is possible to apply the OpenEHR model in the configuration and management of clinical workflows using a Business Process Modelling tool, with the focus being on the clinical forms based on OpenEHR archetypes. To perform the investigation has described, an Artefact was developed to formalize the workflows and solve the integration problems found and the problems brought by the absence of the workflows.

This paper is organized in 6 sections. Section 1 introduces the work context; Section 2 presents the background and related work. Section 3 presents the Research Methodology used in this study. Section 4 describes how the Prototype was developed. Section 5 presents the obtained results. Finally, Section 6 discusses the findings and concludes with some guidelines for future work.

2 BACKGROUND AND RELATED WORK

2.1 Clinical Workflow

Clinical workflows are defined as being a set of steps of clinical processes, that involves multiple people, for example, health professionals and

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patients, and it's expected they consume, produce, transform or exchange information (Militello et al., 2014). The clinical workflow is also defined as the allocation of multiple tasks performed by one or many clinicians in the healthcare processes and the way those clinics collaborate. We can separate them into four categories: first the clinical tasks structuring; second the tasks performance coordination; third allow the information flow to support the task performance and finally the fourth category, monitoring tasks performance (Niazkhani et al., 2009).

2.2 Business Process Modelling

BPM has been defined as a set of principles, methods and tools to manage business processes with the main goal of improve them (Dumas et al., 2013).

The BPM life cycle is presented in Figure1. It starts identifying the process, where the boundaries, processes relationship and prioritizing are studied. The process discovery phase focus on understanding the business process model As-is. Next, the process analysis includes a set of techniques which allows the process performance analysis. This analysis will enable the identification and evaluation of improvements to the process, which will lead to the To-be model. After implementing the To-be model, it's necessary to develop mechanisms and techniques for monitoring and control to assess if the process is fulfilling the defined performance goals (Dumas et al., 2013).

2.3 Electronic Health Records

An EHR system is defined as a repository of patient information, stored in electronic format. This information can be exchanged, if the proper security mechanisms are secured so only authorised users can access and view it. The main purpose of EHR is to support the continuous, efficient and qualitative integration of healthcare (Häyrinen et al., 2008).

The storage of information, relevant to business processes, by healthcare institutions in electronic format, allows the application of a set of data mining techniques. This application can enable the finding of related patterns to adverse events, mistakes and unnecessary costs hidden in the clinical processes structure. Thus, this analysis can allow the identification of bad performance causes and allow managers to take action to optimize the identified processes (Ruffolo et al., 2007).

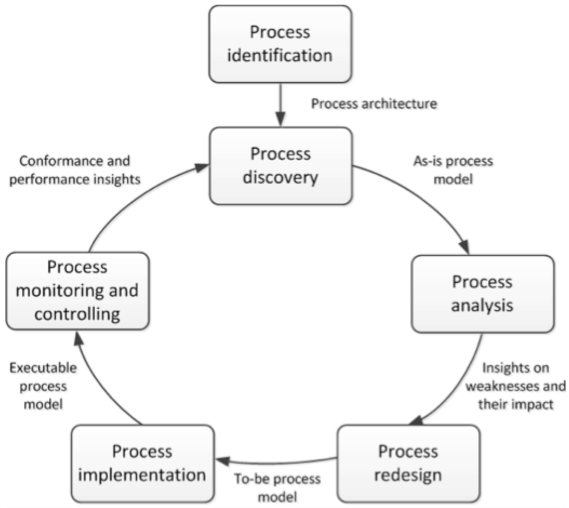

Figure 1: BPM Life Cycle (Dumas et al., 2013).

EHR systems are often perceived as having a lot of potential to significantly improve clinical and administrative services quality in healthcare institutions. This improvement happens because an EHR system eases patient monitoring and allows patients to have more control and responsibility in their treatments and care (Pagliari et al., 2007).

2.4 OpenEHR

The use of the OpenEHR approach allows for the structuring, management, storage and commutation of patient data in a secure and reliable way between different health organizations. The main idea behind this approach is to standardize health related concepts used in databases or EHR systems in a set of libraries, denominated archetypes (Buck et al., 2009).

2.5 Related Work

The work developed by (Yao and Kumar, 2013) had the main goal of demonstrate how the design of flexible clinical processes, with the formalization of clinical knowledge in rules and the contextualization of information details, in a way that clinical workflows with multiple participants can improve healthcare quality.

To verify the objective of the investigation, a Prototype was created. This Prototype allowed the design and execution of clinical workflows, to prove its flexibility on clinical practice. The BPM tool chosen was Drools-Flow 5.2 and the notation to design the workflows used was BPMN 2.0 (Yao and Kumar, 2013).

The results obtained by (Yao and Kumar, 2013), allowed demonstrating that the new approaches of designing flexible and adaptable clinical workflows can bring some benefits to the medical community, like reducing the incidence of treatment mistakes, which improves patient safety. Other benefits described are the faster and better recommendations in many decision points, which allow the improvement of services provided in health institutions.

3 RESEARCH METHODOLOGY

The research methodology used in this investigation was the Design Science Research (DSR) Methodology for Information Systems. To (Hevner et al., 2004), this methodology requires the creation of an innovative and relevant artefact to approach a certain problem and the evaluation of the artefact is essential to check its relevance for the problem being studied. A Process Model for DSR was made by (Vaishnavi and Kuechler, 2008) which is based in five steps: Awareness of Problem, Suggestion, Development, Evaluation and Conclusion.

The Awareness of Problem must produce an output with the proposal for the identified problem. In this investigation, the identified problem is the lack of integration of certain clinical workflows in the EHR system, which can compromise the efficiency and quality of the provided services in CHP.

In the Suggestion phase, the objectives and functionalities of the investigation must be defined, accordingly with the existing literature. In this investigation, the suggestion defined to approach the problem was the development of a Prototype than can integrate a BPM tool in a web application. The BPM tool will allow configuring and managing the workflows, while the web application will run them.

On the Development phase, the defined Suggestion is developed and implemented. In this investigation, the Prototype was developed, after defining its requirements.

The Evaluation phase is performed after the Development phase, so the Prototype can be evaluated accordingly with the defined criteria. In this phase, the utility, quality and efficiency of the Prototype is also evaluated. In the context of this investigation, the Prototype is evaluated based on the defined requirements and if it fulfilled them.

In the last phase, Conclusion, the investigation results are analysed and interpreted. In this investigation, the developed Prototype was validated with members that are developing the EHR system on CHP, so they could draw conclusions about its utility to suppress the integration problems found.

4 PROTOTYPE DEVELOPMENT

This section contains the relevant information related with the development of the Prototype. Initially, a list of requirements defined is presented, followed by the BPM tool chosen for the Prototype. Next, we present the Architecture developed for the Prototype, its functionalities and, finally Sequence Diagrams that represent messages exchanged between systems.

4.1 Requirements

The Prototype was built with the goal of developing a solution that solves the lack of the workflow's integration and the problems generated by that absence.

The following requirements where defined for the referred Prototype:

- Use of a free BPM tool;
- BPM tool should allow the configuration of clinical workflows;
- The tool chosen must allow workflows to be executed in external application, to secure the Prototype interoperability;
- The BPM tool should allow the integration with external databases;
- The Prototype must allow the integration of OpenEHR based clinical forms;
- The Prototype needs to be flexible, so the configurations made in the workflows using the BPM tool are reflected on the web application developed to execute them;
- The Prototype must secure the user access to the web application;
- The Prototype should allow the users to visualize the information about the workflows they worked on.

4.2 BPM Tool

The BPM tool chosen to configure and manage the clinical workflows was the ProcessMaker.

This tool offers a free version which fitted the defined requirements perfectly fine, not imposing boundaries in any of the main functionalities. But, the main reason for this choice is related with the documentation provided by the platform for their API. The amount of information made available,

really facilitated the tool's use and the understanding of the API use and handling.
The API provided by ProcessMaker is built in PHP. It enables the remote access to ProcessMaker through external scripts and the access to many endpoints provided by the platform. These endpoints allow the actions that can be performed inside ProcessMaker can also be done remotely. The BPM tool also has the functionality of allowing the connection with external databases, one of the requirements of the Prototype.

4.3 Architecture

The Architecture designed for the Prototype can be viewed Figure 2. The user, in the context of this Prototype can be a Health Professional or a Patient, can start a clinical workflow. To begin the process, the user chooses the workflow that he intends to execute, and the decision is routed to the BackEnd, responsible to consume the ProcessMaker's API to create an instance of the selected workflow and receive the initial form. The BackEnd handles the information received, in JSON format, and interacts with the FrontEnd to present the form to the user. This interaction is recurring, until the decisions made by the user dictate the end of the workflow or the next form is assigned to another user. On some scenarios, the relevance of data leads to the need to insert it in a database (DB) that simulates an existing in an EHR system. In this case, the BackEnd will interact with ProcessMaker API and the DB. Sometimes, it's necessary for the BPM tool to communicate directly with the DB, to receive essential information for the continuity of the workflow execution. This communication is made by triggers, an object than can be created in ProcessMaker.
One of the main requirements of the Prototype, was to guarantee its flexibility. This means the configurations and changes made to the workflows present on ProcessMaker need to be reflected during their execution on the web application. This requirement allows for the modifications to be quicker and accessible, otherwise when a change needed to be made, the base code would need to be altered. The current Architecture allows the fulfilment of this requirement, because the execution of the workflows is made with calls to the API, task by task, which means the workflow version being executed it is always the most recent one.

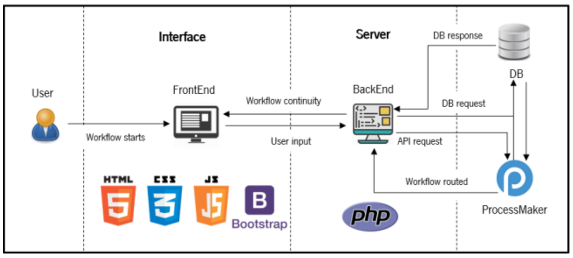

Figure 2: Prototype Architecture.

4.4 Functionalities

The following functionalities were developed for the web application.

- Structure to enable the communication with ProcessMaker;
- Login structure. The users are validated accordingly with the users configured on ProcessMaker;
- Allow the users to see the following Case lists: "Inbox", "Draft" and "Participated";
- Users can create new Cases of workflows, when the first task is assigned to that user. They can also answer Cases when they are routed to a task they are assigned;
- Execute workflows on the web application;
- Structure to route users to forms based on OpenEHR archetypes;
- The only variables send to ProcessMaker are the ones needed to execute the workflow;
- Allows the creation and storage of document with information related to the workflows concluded.

These functionalities were developed having in mind the requirements defined for the Prototype.

4.5 Sequence Diagrams

To ease the understanding of the developed functionalities, Sequence Diagrams were created to demonstrate the exchange of messages between the different systems of the Prototype. The language used to model the Sequence Diagrams was UML.

Access Application
The Sequence Diagram related to how the users can access the application can be viewed in the Figure 3.
The process starts when a user inputs the authentication information in the Login interface. This information is validated by ProcessMaker, to check if the user exists in the platform. If it returns the user does not exist, then an "Invalid data" message is shown, otherwise ProcessMaker returns a token needed to consume its API. The token and

username are stored in the web application in Cookies.

If the authenticated user is a Health Professional, then an API request is made to receive the Case list associated to him and the user is forwarded to the interface Case List. When the user is a Patient, then he can select the workflow he wants to start and is forwarded to the Initial Form of the selected workflow.

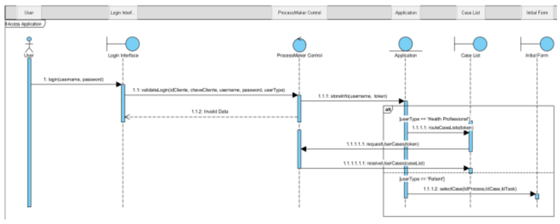

Figure 3: Sequence Diagram “Access Application”.

Start Case

In the Figure 4, it is possible to visualize the Sequence Diagram that demonstrates how a user can start a case.

This sequence begins when a user selects a Case to be started. When this happens a request is made to ProcessMaker’s API to start a Case in the BPM tool, sending Process and Task identifier. If the request succeeds, ProcessMaker creates an instance of the selected workflow and returns the Case identifier, the “url” for the form assigned to the initial Task and the variables the BPM tool needs to give continuity to the workflow execution. This information received, allows the web application to route the user to the initial form of the selected Case and, consequently, start the execution of the workflow associated to the Case.

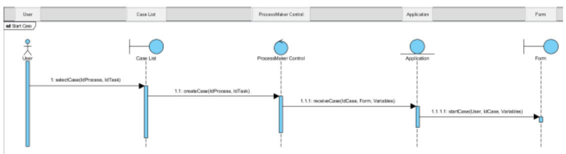

Figure 4: Sequence Diagram “Start Case”.

Execute Workflow

The Sequence Diagram related to how the workflows are executed in the web application can be observed in the Figure 5.

The user fills the form and submits the information he inserted. When the user presses the submit button, a request is made to ProcessMaker’s API, which includes the Case and user identifier and variables filled in the form that ProcessMaker needs to continue to execute the workflow. The BPM tool returns the information of the next Task in the workflow, to understand if the user assigned to the next Task is the same that is authenticated in the web application. If this is the case, then a request is made to the API to receive the information on the next form and forward the user to it, otherwise the user returns to the List Cases interface and workflow is paused until the user which the next Task is assigned continues the workflow.

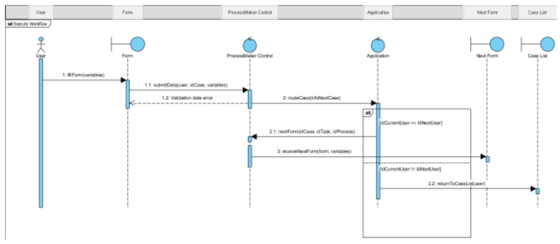

Figure 5: Sequence Diagram “Execute Workflow”.

5 RESULTS

In this section, first there will be an explication of the clinical workflow implemented on this study and executed in the web application created for the Prototype. Next, an evaluation of the defined requirements is made, explaining how they were resolved in the developed Prototype.

5.1 Clinical Workflow Implemented

The implemented workflow, to test the developed Prototype, was the representation of a computed tomography (CT) exam request. The graphic representation was created using BPMN 2.0 notation and can be viewed in the Figure 6.

The workflow can be started by a health professional when he intends to request a CT exam. An initial form is presented, so the health professional can insert the patient identifier. When that form is submitted, a connection is made between ProcessMaker and the DB to check if the patient exists in the system, then another verification is made to check if the patient has records of previous exams performed. When this verification also returns true, then the health professional is routed to a form where he/she can check the list of exams the patient performed, deciding if they are enough or if there is the need for the CT exam. If he decides the exams presented are enough for the evaluation, then the workflow ends, otherwise it is routed for the “Check variables” form. When any of the previous verifications returns negative, if the patient does not exist or the DB does not have exam records of him, then the workflow is redirected directly to the "Check variables" form. On this form, the health professional will be presented with the patient information, like weight, age or if it has a pacemaker, if the patient exists, otherwise he will have to fill this information. If the health professional, after analysing the patient information, thinks he/she cannot perform the exam, then the workflow ends, otherwise it is routed for the technician, which is the element responsible for performing the CT exam.

Once the workflow is routed to the technician, he makes the decision to perform or not the exam. When he refuses to perform it, he must fill the reason of refusal and the workflow will end, sending an email to the health professional with the justification. If he accepts to perform the exam, then the workflow is routed to the "Publish Results" form, which is assigned to the health professional. In this last phase of the workflow, the health professional will fill the medical comment of the CT exam result, publish the results on the BD and end the workflow.

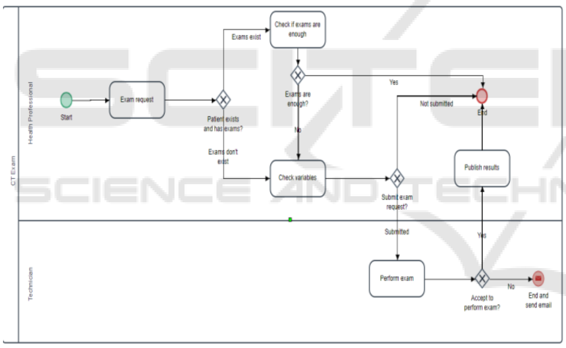

Figure 6: Workflow "CT Exam Request".

5.2 Requirements Evaluation

Use of a free BPM tool: The BPM tool chosen, ProcessMaker, has a community version which is free to use. The functionalities available in this version were more than enough for what the Prototype needed.

BPM tool should allow the configuration of clinical workflows: ProcessMaker allowed the design of workflows, using the BPMN 2.0 notation. The design includes the configuration of the workflows created in the platform.

Secure Prototype interoperability with external applications: The Prototype interoperability allows the communication between ProcessMaker, where the workflows are managed and configured, and the web application, where the workflows are executed. The interoperability between these two systems was possible due to the web application consuming the available ProcessMaker API with REST requests to their endpoints.

The BPM tool should allow the integration with external databases: In certain scenarios, it is necessary for the BPM tool to communicate with databases to check or manipulate the information. In the workflow implemented in this study, it was necessary to check in the DB if the patient existed and if he had any records of exams. To secure this requirement, ProcessMaker contains an object that allows communicating with external databases. To create that object, the user only needs to insert the connection information of the DB and check if the connection is successful.

The Prototype must allow the integration of OpenEHR based clinical forms: This requirement is needed to allow the web application to connect the user with the clinical forms based in OpenEHR archetypes. In each Task of the workflow in the ProcessMaker, we can create forms and link variables to them. For each form, there is a variable called "linkToForm" that contains the url for the external form based on OpenEHR archetypes. The web application receives that variable and routes the user to the url.

The Prototype needs to be flexible: In clinical environments, there is a constant mutation of the clinical processes. Taking this into account, it is only natural that the Prototype developed allows for the modifications in the clinical workflows on ProcessMaker to be reflected in their execution in the web application. The explanation how this requirement is fulfilled is directly related with the interoperability. The web application, while executing the workflow, receives the information task by task, so when a change is made on the workflow design, then it is always reflected when executing in the web application.

The Prototype must secure the users access to the web application: ProcessMaker allows the configuration of users that can have access to the platform and be assigned to tasks in the workflows. To secure this requirement, a login form was created for the web application and if the authentication information inserted by the users matches with a user that is configured in ProcessMaker, then he will be allowed to enter the platform, otherwise a error will be displayed.

The Prototype should allow the users to visualize the information about the workflows they worked on: When a health professional authenticates in the platform, he has access to the list of Cases that can be started by him, the Cases he needs to respond and the ones he participated in. On the last one, when the Case status is concluded, the health professional can download a document that contains all the information about the workflow decisions.

With the evaluation of the Prototype requirements, it is possible to conclude that the defined requirements were fulfilled.

6 CONCLUSIONS AND FUTURE WORK

This investigation and, consequently, the Prototype developed proved useful to understand how BPM can be applied to clinical workflows based on OpenEHR. The developed solution allows the configuration of the clinical workflows using a BPM tool and demonstrates the importance of BPM in securing the interoperability and flexibility of those workflows and their integration with external applications.

The main limitation of this study was the use of a free BPM tool, ProcessMaker. Although all functionalities could be built and ProcessMaker didn't restrict the development of the Prototype, the usage of a tool more centralized on healthcare would facilitate the development phase.

The Prototype developed is the main contribution of this work. We present a solution that is capable of configure and manage the clinical workflows based on OpenEHR and a web application that can execute them, while communicating with the BPM tool and reflecting the changes made to the workflows. This formalization of the workflows can lead to efficiency improvements and, consequently, an increase in the quality of the services provided, due to the decision and clinical practice standardization.

As for future work, it is necessary to extend the Prototype application to other workflows and identify its functional consistency to better guarantee it is a solution to the problems found in CHP related to the lack of integration of certain clinical workflows. It is also important to make sure the Prototype is presented and explained to Health Professionals, so they can understand the benefits a solution like this can bring to clinical practices and its performance.

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