Modeling Healthcare Processes in BPEL: A Colon Cancer Screening Case Study

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Abstract. In healthcare, process modeling has been recognized as a preliminary and fundamental step to provide suitable solutions to the process of designing and building innovative healthcare systems. To achieve such goals the application to clinical practice of the concepts of Service Oriented Architecture has been proposed. Business Process Execution Language (BPEL) is a standard for process description and service orchestration. In this paper we present the application of BPEL to a real case by designing a system for the management of colon cancer screening program in the local Health Care Service Trust.

Keywords: Process modeling, BPEL, Colon cancer screening.

1 Introduction

For years now information technology (IT) has been playing a role in clinical environments, with a great improvement potential coming with it: better service quality and security, increased efficiency, and cost decrease [1].

In healthcare, process modeling has been recognized as a preliminary and fundamental step to provide suitable solutions to the process of designing and building innovative healthcare systems [2]. The introduction of business process modeling and the development of service oriented architecture (SOA) challenged research studies about the application of such methods, already applied in business fields such as e-commerce [3], to clinical practice. SOA consists of a composite set of business-aligned services that support a flexible and dynamically re-configurable end-to-end business process realization using interface-based service descriptions. In need of a language for description and execution of business processes, the Business Process Execution Language (BPEL) is a possible choice, being a standard language for process orchestration and, amongst other things, allowing and facilitating the linkage between systems and agents carrying out coordinated activities and supporting services. To specify a process using BPEL it is crucial the understanding and knowing of the exact details of that [4]; hence, we employed UML as intermediate modeling language between the natural language process description and the BPEL executable model.

In this paper we describe the application of such technologies to a real case by designing a BPEL system for the management of the colon cancer (CC) screening process in the local Health Care Service Trust, showing how some operations,

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at present manually performed by nurses, can be automated. Through the implementation and simulation of the executable model we claim the suitability of BPEL for the medical domain.

2 Related Work

Several works have proposed the SOA approach for the clinical practice modeling problem, some of them exploring the application of BPEL. In [5] Anzböck and Dustdar presented a first approach to the definition of Web Services, analyzing medical services and introducing a model for designing those services, which seemed to fit well the BPEL modeling approach. In a later paper they further elaborated on this and applied those concepts to a simple clinical workflow as exemplification [6]. Morrison et al. [3] investigated the modeling of a clinical process, looking for representations of such processes and models both descriptive and executable, facilitating the linkage to other systems carrying out activities and services. They found that BPEL was an effective tool in medical workflow supporting services provided by both humans and computers. More advanced applications can be found in [7], [8]. and [9], where BPEL was applied to develop Clinical Decision Support applications, confirming BPEL a valuable technology for healthcare applications. Some authors, however, (e.g., [5]) point out the necessity of implementation and simulation of workflow models to actually support the suitability of BPEL for the specific domain.

3 Background

3.1 The Colon Cancer Screening

Screening in medicine is a strategy used to detect a disease in a population of individuals without clinical signs or symptoms of that disease. The intention of screening is to identify the disease in a community early, thus enabling earlier intervention and management in the hope to reduce the risk of disease-specific morbidity and mortality. The screening for the early diagnosis of CC prescribes the subject undergoing a faecal occult blood test (FOBT) every two years. This means, among other things, that when subjects enter the screening program, the management system must keep track of their history until they leave the program for whatever cause. In the following, we briefly describe the CC screening.

Weekly a nurse in charge of the screening activity queries the personal data registry into the Hospital Information System (HIS) to obtain a list of subjects eligible to be admitted to the CC screening program. To those people an invitation letter to perform a cost-free FOBT test is sent. If they apply to the test within 90 days delivering a sample to the laboratory they will have the sample searched for blood. Once a week the nurse receives the results of the executed FOBT tests from the HIS and manages each case accordingly:

– If the result is negative she sends to the person a report letter with the result, and the subject is invited again to perform a FOBT two years later.

- If the sample is not suitable for the test, she sends to the subject a letter explaining the case and inviting to deliver a new sample.
- If the result is positive she phones to the person, explaining the situation and inviting him/her to undergone further examinations.
- If no result is received within 90 days of the sending of the invitation letter, a second invitation letter is sent to the subject.

Except those people whose test result is found positive, subjects remain in the screening program, undergoing the FOBT every two years. People with positive results enter a second stage of the screening program, which comprises further medical examinations. At this level a colon cancer could be diagnosed; in this case the subject leaves the screening program and enters a cancer care pathway. Otherwise he/she remains in the second level of the screening program, entering in the follow up stage.

3.2 Unified Modeling Language (UML)

UML is a semi-formal object-oriented analysis and design standard language proposed by the Object Management Group (OMG) [10]. The language provides a visual modeling notation for visualizing, understanding and developing complex systems. Valuable aspects of UML are: i) a widely known and readily understood graphical notation, allowing to describe systems at different levels of abstraction, and ii) a rich semantics for capturing key features of object-oriented systems. UML 2.0 has 13 types of diagrams. Six structural diagrams describe the static entities and their relations; three behavioral diagrams specify what must happen in the system; four interaction diagrams emphasize the flow of control and data among the things in the system being modeled. We employed activity diagrams, which are used to represent the business and operational step-by-step workflows of components in a system. Essentially, an activity diagram is a flowchart, showing flow of control from activity to activity, containing *Activity* and *Action* states, *Transitions*, *Branching*, *Forking*, and *Joining*.

3.3 Business Process Execution Language (BPEL)

A business process is a collection of coordinated service invocations and related activities that produces a business result. The composition of business processes has specific requirements, such as support for many process instances, long-running processes, and compensation. The BPEL [11] is a specialized language providing a rich vocabulary for composing services into business processes that is quickly becoming the dominant standard.

Activities are the building blocks of BPEL; their composition in the model definition implements the process logic. Activities are divided into two classes: basic activities describe elemental steps of the process behavior; structured activities encode control-flow logic, and therefore can recursively contain other basic and/or structured activities. For example, simple activities are: the `<receive>` activity, which allows the business process to wait for a matching message to

arrive; the <invoke> activity, used to call a Web Service provided by a partner; the <assign> activity, which can be used to copy data from one variable to another, as well as to construct and insert new data using expressions; and the <wait> activity, which specifies a delay for a certain period of time or until a certain deadline is reached. If annotated with a createInstance=yes attribute, the <receive> activity starts the process. Important structured activities we employed in our project are: the <flow> activity, which provides concurrency and synchronization, since it completes when all of the activities it encloses have completed; the <sequence> activity, used to define a collection of activities to be performed sequentially in lexical order; and the <pick> activity, which waits for the occurrence of exactly one event from a set of events, executes the activity associated with that event while the other events are no longer accepted, and completes when the selected branch completes.

BPEL also provides flow control activity, such as the <repeatUntil> activity, which provides for repeated execution of its child activities until the specified Boolean <condition> becomes true. The <condition> is tested after each execution of the loop body.

These building blocks allow BPEL to describe the logic of business processes, e.g. expressing conditional behavior and the construction of loops, handling synchronous and asynchronous (often long-running) operation invocations on services, and managing callbacks that occur at later times

4 Process Modeling

4.1 Process Analysis

The first step toward the design of the screening management system was the modeling and analysis of the screening workflow currently followed in the local Health Care Service Trust, together with requirements and comments. To this end, we organized regular meetings with domain experts (clinicians and nurses) during which the computer scientist conducted non standardized interviews to gather information about the process and to define the requirements and the functionalities the system had to implement. From this activity we produced a narrative description of the entire screening workflow, based on information reported by domain experts (clinicians, nurses, computer technicians). Working together with domain experts on the written document we deeply investigated and defined in detail the relevant aspects of the process regarding the system to model: actors, actions, data, goals and interactions. Finally this description gathered the up-to-date characteristics of the screening process (what operators currently do, the information flow, the rules governing the workflow).

4.2 UML Activity Diagram

From the narrative description of the process we modeled the logic of the business process and produced the UML activity diagram, which represents the workflow behind the process under examination. Figure 1 shows the screening process

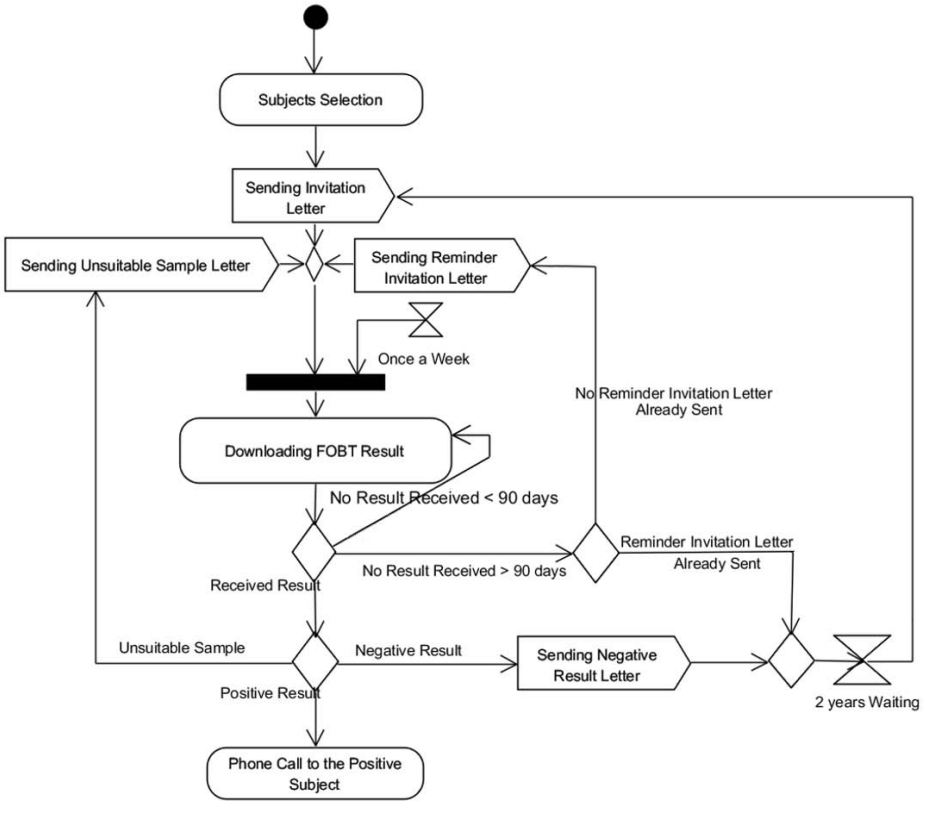

Fig. 1. UML activity diagram of screening nurse swimlane of the CC screening process

swimlane of the CC screening nurse. Actually, the complete diagram comprises the HIS swimlane and the patient swimlane. The rounded-corner rectangles are Activities that specify the coordination of executions of subordinate behaviors (e.g. the selection of the subjects). The boxy arrows represent send signal actions, which are actions that create a signal instance from their inputs, and transmit it to the target object where it may cause the execution of an activity. (e.g., sending the invitation letter to the subject). Diamonds represent either merge or decision nodes with conditions for the choice between different alternatives. Finally, hourglass symbols are wait time actions (e.g., wait 2 years).

4.3 The BPEL Model

The third step was the creation of the executable BPEL model for automating the process, in a service oriented perspective. From the UML activity diagram we defined the activities required, the conditions for their occurrence, the order in which they should occur and their synchronization. In Figure 2 we show a fragment of the BPEL model related to the central part of the screening process.

The starting activity (initial node) is the request made by the nurse (the client of the process) to the system for opening a screening procedure for a selected subject. This means that to each subject corresponds a process instance, which keeps running till the subject stays in the process. The request sent by the nurse is in the form of a message containing the personal data of the subject, that the system will use to manage his/her screening instance.

Upon receiving the nurse's request, the process activates two concurrent activities: one creates the invitation letter to be sent to the subject; at the same time another activity creates a database record populated with subject's data. After going through both those activities, a `<wait>` activity models a waiting time of two weeks in order that the subject can receive the invitation letter and deliver the sample to the laboratory, and the laboratory can perform the test. When this period of time has passed the process performs an asynchronous activity querying the HIS about the FOBT results, and waiting for a response. The arrival of a response message triggers the execution of one of the four branches in Figure 2:

– If the result is negative (first-from-left branch) concurrently a written communication is created to be sent to the subject and the database record is updated with the test result (`<flow>` activity). After both sub-activities are finished, the process waits two years and then it creates another invitation

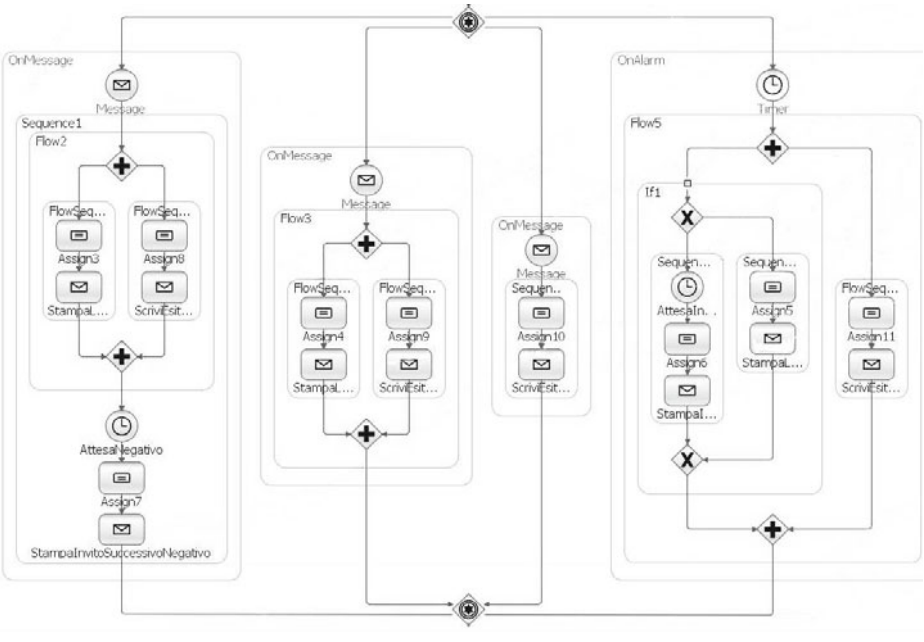

Fig. 2. Fragment of the BPEL diagram showing the central part of the screening process, from which the BPEL file and the WSDL file are generated (see text)

letter for a second round FOBT and queries again the HIS about the result, reentering the cycle from top;
- If the sample is not suitable for the test (second-from-left branch), concurrently a written communication asking for a new sample is created to be sent to the subject, and the database record is updated with the test result. Then the process queries the HIS about the result, restarting from top;
- If result is positive (third-from-left branch), the database record is updated with the result and the process goes on to the activities related to the second screening stage;
- If no result is received within 90 days (last branch), an invitation reminder is created to be sent, and the database record is updated. If an invitation reminder has been already sent, the process waits two years and then creates another invitation letter for a second round FOBT. In both cases the process then queries the HIS about the result, restarting from top.

The previous steps are parts of a `<RepeatUntil>` loop, which the process leaves only when a positive result is retrieved. In this case, the process sends a message back to the nurse, notifying the positivity of test result and inviting the nurse to phone the subject.

5 Simulation

We implemented the BPEL prototype for simulation within the Netbeans IDE, which provides a graphical tool for the definition of BPEL diagrams as well as support for JavaBeans implementation, the Glassfish application server and a BPEL engine to deploy and test the system. From the diagram the IDE generates the BPEL file and the WSDL (Web Service Definition Language) file that describes the interfaces the orchestrated services have to implement. Actually, to design a complete working system, we implemented the needed partner services the BPEL process has to interact with as Java Bean components that simulate the desired services: e.g., database management, reminder generation, letter production, and interaction with the HIS. By substituting the "fake" Java-based services with real components respecting the interface definitions we can straightforwardly deploy the system in the clinical environment.

We ran the system for each kind of possible FOBT result, to test the various branches of the process, finding that the system behaves as required.

6 Discussion and Conclusions

In this paper we present an approach to the problem of applying business process and SOA methods to healthcare, presenting a case study of designing a colon cancer screening management system using BPEL. We described the process by using UML activity diagrams and then defined a executable process model in BPEL. Running the process in the BPEL engine, with simulated partner services,

we found that our system performed well, confirming that this approach can be effectively applied to the medical domain.

As a proof of concept we focused on the first part of the CC screening process. Further work can be done to analyze and model the successive stages that involve different actors and departments. These stages, in particular, need the modeling of some activities executed by people, who play a role in the process (e.g. the phone call to the subject); the specific modeling of these activities, however, is currently not supported by the language. Further work will regard the modeling of people activities with BPEL4People, an extension of BPEL language that is not yet a standard.

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