A PROCESS META-MODEL BASED APPROACH FOR DEVELOPMENT OF COLLABORATIVE APPLICATIONS BUILT ON WORKFLOW AND SOA

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Abstract

With the emergence of new technologies such as workflow and web services supported by Service Oriented Architecture (SOA), services needed and provided by organizations become more and more important. The combination of these technologies gives a greater degree of flexibility, scalability and efficiency in the development of collaborative business applications, improving then better collaboration and cooperation among business partners. In this context, several research works have focused on specification, technological and conceptual aspects. This paper deals with conceptual aspects for development of collaborative applications combining workflow and SOA (particularly web services). For that, we propose an approach based on process meta-model for design and development of collaborative applications that include human, semi-automatic and automatic activities. The method of development that we describe covers all views of the collaborative process taking into account workflow aspects and SOA aspects together. In fact, human and semi-automatic activities are supported by the workflow and automatic activities are implemented as web services and supported by SOA. We show that our approach has MDA (Model Driven Architecture) orientation but more work must be done to define mapping rules between PIM (Platform Independent Models) and PSM (Platform Specific Models) levels.

Keywords: collaborative process, workflow, SOA, web service, process meta-model, modeling views, PIM, PSM.

1 INTRODUCTION

For many years, organizations are confronted to the exceptional growing of services that they must provide to their customers in order to give them more satisfaction and better supports of their needs. Since the 90’s, workflow technology has been largely used in the organizations, allowing them an automatic support of their business processes, so called workflow processes (Levan, 2000), (Aalst, 2002a).

Furthermore, for cooperation and collaboration, the need of openness to the environment (other organizations) becomes inevitable. From that, we talk about the concept of collaborative process implying many business partners in the context of B2B (Business to Business) collaboration. This concept has appeared in the e-commerce area and has been supported by inter-organizational workflow (Aalst, 2000).

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Later on the years 2000, a new architectural model for collaborative applications has emerged: we talk about Service Oriented architecture (SOA), a research area in perpetual expansion (Papazoglou & Heuvel, 2007). This model is supported by a concept of service that can take a form of web service (Alonso & al, 2004). The technology of web services favors interoperability among heterogeneous business applications because of their principal characteristics: loosely coupled, distributed, publishable, and business oriented.

Many research works like (Leymann & al, 2002), (Crusson, 2003) and (Gorton & al, 2009) have focused on combining workflow and web services for implementing collaborative processes in order to take benefits from both technologies together. In fact, the workflow allows definition, coordination and tracking of activities flow between participants (actors, applications, etc.) in the process. Where the web services allow interoperability among heterogeneous systems and favor inter-enterprise cooperation, they allow also the re-use and the scalability of business processes for newly defined requirements.

For design and modeling aspects, the most part of research works like (Lopez-Sanz & al, 2008), (Stojanovic & al, 2004) and (Rahmani & al, 2006) deal with SOA applications without talking about workflow aspects, especially human workflow, because they consider collaborative processes built by combination of automatic services.

In this paper, we propose a conceptual approach for modeling and developing collaborative applications combining workflow and SOA (web services). In fact, we consider a workflow process including human, semi-automatic and automatic activities that implements a business of an enterprise and allows invocation of web services provided by another enterprise, the global process is so called collaborative process. Our approach is defined around three levels: the meta-model level, the model level and the instance level. First, we describe a process meta-model that combines workflow concepts and SOA concepts in order to show relation between them in developing collaborative applications. Generally, a meta-model based approach guarantees correctness of process models generated and allows easier and coherent modification in case of novel business requirements.

At the second level of the approach, we describe phases of a method of development covering the lifecycle of a collaborative process since its modeling to its implementing. The method of development is supported by the process meta-model and contains two main phases: phase of analysis and design and phase of generating models and code. The first phase is based on appropriate UML diagrams and generates models which are platform independent (PIM). These lasts are used at the second phase to generate process models which are related to a specific platform (PSM). From that, we can see that our approach has an MDA orientation but we must work on defining mapping rules and tools to do this mapping.

For illustration of the approach, we present a case study related to a fictive organization which subcontracts regular training of its employees with schools providing courses and interacting with their partners via published web services.

The rest of the paper is structured as follows: section 2 situates the context of the work and introduces some basic concepts. Section 3 exposes quickly some related works and explains the motivation of this paper. Section 4 presents our conceptual approach that means the meta-model for process modeling and the method of design and development. Section 5 illustrates our conceptual approach by a case study. Section 6 concludes the work and talks about some future works.

2 CONTEXT OF THE WORK

The work of this paper focuses on modeling and development of collaborative processes based on workflow and (web) services. In our context, a collaborative process is defined as a private workflow process representing a business procedure of an organization that subcontracts some activities of its local workflow with an external partner providing its services via the web (see Figure 1).
Collaborative process = private workflow process + external services

A workflow process is the automation of all or part of a business process in which information flows from one activity to another (respectively, one participant to another) according to a set of predefined rules.

External services are provided according to a SOA scheme, since SOA can be defined as a set of guiding principles which are supported by a range of standards that make it possible to define, implement and deliver a service in a uniformed way so that it can be reused in different contexts. Three components are required in SOA, service provider, service requester and services agency where a service can take a form of web service (Papazoglou & Heuvel, 2007).

For the W3C consortium, a web service is defined as follows “A Web service is a software system identified by an URL, whose public interfaces and bindings are defined and described using XML. Its defined can be discovered by other software systems. These systems may then interact with the Web service in a manner prescribed by its definition, using XML based messages conveyed by Internet protocols”.

3 RELATED WORKS AND MOTIVATION

Many research works have focused on composition of services, particularly on dynamic composition (Casati & al, 2000), (Fensel & Bussler, 2003), (Parera & Gannon, 2006). For example in (Casati & al, 2000), the authors proposed a system called eFlow that supports specification and enactment of composed services. (Fensel & Bussler, 2003) proposed a framework for dynamic composition of complex web services. In the area of business processes, several works deal with orchestration and choreography of web services (Peltz, 2003), (Decker & al, 2007) especially based on BPEL4WS (Business Process Execution Language for Web Services) (Jordan & Evdemon, 2006).

Other research works such as (Leymann & al, 2002), (Crusson, 2003) and (Gorton & al, 2009) show the interest of combining BPM (Business Process Management) and SOA for the re-use of services to construct dynamic business processes. For example in (Gorton & al, 2009), the authors propose an approach combining workflow and SOA for business process modeling. (Crusson, 2003) describes a complete environment for collaborative processes allowing interaction between business partners via web services. The author of (Virdell, 2003) discusses informally different aspects relating workflow and web services in the world of business processes. In (Hofreiter & Huemer, 2006) and (Hofreiter, Boukhedouma Saida and Alimazighi Zaia

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2007), the authors propose transformation rules from choreography models to BPEL specification for business processes based on web services.

Several papers such as (Lopez-Sanz & al, 2002), (Stojanovic & al, 2004), (Rahmani & al, 2006), (Kim, 2008) and (Vidales & al, 2008) deal with approaches and methods for design and development of SOA applications. The most part of them like (Lopez-Sanz & al, 2002), (Rahmani & al, 2006), (Kim, 2008) and (Vidales & al, 2008) talk about MDA (Model Driven Architecture) for development of SOA applications. For example (Lopez-Sanz & al, 2002) presents an UML profile for the design of PIM-level SOA based architecture models. Authors of (Rahmani & al, 2006) describe a model driven approach to SOA modelling and designing complex distributed systems. All the proposed approaches are limited to SOA concepts for design, since they consider business applications built only by composition of services. Also Public methods such as SOMA (Arsanjani & al, 2008), SOAD and PRAXEME have been proposed for the design of SOA applications which are completely automatic and built by composition of services.

The goal of this paper is to propose a conceptual approach combining workflow and web services for development of collaborative processes including human, semi-automatic and automatic activities. We more focus on modeling aspects and highlight concepts for workflow and SOA together. Our approach starts with a process meta-model combining workflow and SOA concepts. The approach supports invocation of web services from a workflow process which implements a business process containing some activities not implemented locally (in the workflow process) and must be subcontracted to outside. The meta-model serves as a frame for the method of development that we summarize in three phases, we can see that a proposed approach has MDA orientation since it distinguishes PIM and PSM models and it is based on process meta-model.

4 OUR APPROACH

Our conceptual approach is process oriented and is based on a scheme with three levels (see Figure 2), the meta-model level, the model level and the instance level. The first two levels of this scheme recall the two levels used in MDA (Model Driven Architecture) approach for generation of PIM (Platform Independent model) and PSM (Platform Specific models) models.

Figure 2. Levels of our approach

The meta-model level exhibits the principal concepts and links between them for process modeling. The meta-model guarantees a correct definition (eventually redefinition) of process models. More generally, a meta-model based approach insures conformity of models generated according to the set of concepts identified in the meta-model, and allows easier adaptation of models in case of new requirements.

The model level represents the different views of a particular process related to a real case study. Process models are built conformably of concepts identified at the meta-model level according to a set of phases that we will define for a method of development.

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The instance level shows the enacting of the process according to the generated models on specific cases. This level is not considered in MDA approach.

4.1 The first level of the approach: A process meta-model

In this section, we present a meta-model for collaborative processes which are built by combination of workflow and web services. The meta-model (see figure 3) regroups the main concepts attached to the workflow process definition according to the WFMC standards, and the main concepts attached to SOA, such as the concepts of service, provider, consumer and contract which insure visibility and invocation of a service. The goal is to exhibit relation between concepts related to the two technologies in order to guarantee a correct integration of external services into workflow solutions, for gradual converge to SOA architecture allowing more flexibility, re-use and scalability. In addition of concepts identified by the WFMC, we extend the meta-model by concepts for support of collaboration and interaction between the private workflow process and the services invoked. At a conceptual level, an invoked web service can be seen as a participant (software resource) to a workflow process and as an implementation of an automatic activity not available in the local information system. Consequently, the collaborative process is a workflow process which implies internal and external resources for performing manual, automatic and semi-automatic activities. In the following, we show the process meta-model and we detail the five views of process modeling.

Figure 3. Meta-model of collaborative process
4.1.1 The functional view of the process

This aspect describes the cutting of a workflow process in terms of sub-processes and activities. In fact, we see that a workflow process can be broken up into sub-processes. Each sub-process can be broken into activities (see Figure 4). Activity is considered as the smallest entity of work that cannot be broken down and also as the central concept of the meta-model linking the five views of process modeling.

![Figure 4. Functional Meta-model of collaborative process](image)

4.1.2 The behavioral view of the process

The behavioral aspect is defined by the concepts of activity, transition condition, IS application and web service like shown in figure 5.

![Figure 5. Behavioral meta-model of collaborative process](image)

This aspect focuses on the intrinsic flow of control in the workflow, it shows the states of activities. An activity is submitted to simple or complex condition allowing the definition of sequence, alternative, parallel and synchronizing flows which are expressed by appropriate operators supported by the formalism of modeling. The class Activity is specialized in three sub-classes which are Manual activity, Semi-automatic activity and Automatic activity. The first one corresponds to a part of work that must be done by a human actor. The second one is a part of work which implies human actors,
material and/or software. The third one is a part of work which is performed without the intervention of a human actor because it’s completely automatic. In our sense, automatic activities should be performed by invoking applications of the information system or by invoking web services.

4.1.3 The organizational view of the process

Like shown in figure 6 bellow, the organizational aspect identifies all participants implied in performing activities of the collaborative process. It shows, in one hand, the set of organizational units composing the full organization responsible of the workflow process and in the other hand, the concepts related to SOA like service, provider and consumer.

![Organizational meta-model of collaborative process](image)

**Figure 6.** Organizational meta-model of collaborative process

In our case, a resource (also called participant or actor) can be external or internal. Internal resource represents any participant pertaining to the organization responsible of the process. It can be specialized into human, material or software resource. Human resources are responsible of accomplishment of manual activities or semi-automatic activities; each human actor takes several roles and each role can be affected to one or more actors. The concept of role gives flexibility at the runtime level of the process when affecting activities instances to humans. Material resources can be machines or robots (in manufacturing processes) or others, where software resources are applications or web services invoked by the workflow process in order to perform some external activities not implemented in the workflow process. Web services are then external resources.

4.1.4 The interactional view of the process

The communication between the workflow process and web services is done via interfaces of web services. The interactional aspect of the process is supported by the concepts of process, web service, provider, consumer, contract and constraint (see figure 7). Interface and description insure visibility of the service. The interface provides necessary and sufficient information for communication with the
service. It contains *syntactical constraints* (format of messages and technological information). The *description* of the service contains complementary information that insures correct interaction, it contains *semantic constraints* and *QoS* (quality of service) constraints.

Figure 7. Interactional meta-model of collaborative process

4.1.5 The informational view of the process

The informational aspect is supported by the generic concept of *artifact* which can be specialized into data, file or form. In fact, an artifact represents any information used or produced by executing activities instances. In a collaborative application, some artifacts are *public* and others are *private* (see figure8). A public artifact can be seen and manipulated by external entities, not only by the organization responsible of the workflow. In our context, it can be all information transmitted by messages when invoking web services. A private artifact is only visible by the local workflow and cannot be manipulated by external activities.

Figure 8. Informational meta-model of collaborative process

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4.2 The second level of the approach: process models

The second level of the approach concerns generation of models covering all aspects of a collaborative process. These models are supported by the five views of process meta-model described before. We can see in figure 9, that the proposed method is defined around three phases and is supported by the process meta-model.

![Figure 9. Phases of the method of development](image)

The first phase of the method uses UML diagrams and so, allows building of process models which are platform independent, it constitutes a PIM (Platform Independent models) level. The second phase concerns generation of process models in a specific platform and constitutes a PSM (Platform Specific Models) level.

4.2.1 Phase I: Analysis and Design

This preliminary phase serves to collect information of the real world in order to design different views of the collaborative process. For this, we use some appropriate diagrams of UML: use case, sequence, activity and class diagrams. This phase is guided by use cases, covers the five views of the
process, generates platform independent models and is structured around four steps like it is explained in table 1.

<table>
<thead>
<tr>
<th>Step</th>
<th>Objective</th>
<th>Inputs</th>
<th>Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specifying needs</td>
<td>Define functionalities, actors, services and application required</td>
<td>Data of real world relative to a case study.</td>
<td>Use case diagrams + scenarios</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+ textual description (inputs, outputs, pre and post-conditions) of services and applications to</td>
<td>+ textual description</td>
</tr>
<tr>
<td></td>
<td></td>
<td>be invoked.</td>
<td>to be invoked.</td>
</tr>
<tr>
<td>Modeling interactions</td>
<td>Show interactions between the workflow system and web services in one hand</td>
<td>Textual description of services and applications to be invoked.</td>
<td>Sequence diagrams</td>
</tr>
<tr>
<td></td>
<td>and eventually, between the workflow system and other applications in the other hand.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modeling procedures of work</td>
<td>Show the activities and the control flow between them</td>
<td>Use case diagrams + sequence diagrams.</td>
<td>Activity diagrams</td>
</tr>
<tr>
<td>Modeling data (artifacts)</td>
<td>Design the informational part of the system</td>
<td>Use case diagrams + textual description of services and applications</td>
<td>Class diagrams</td>
</tr>
</tbody>
</table>

4.2.2 Phase II: Building process models and Generating code

This phase has particular importance in the method of development because it concerns building of process models covering the five views identified in the meta-model. For building these models, we use information collected at the first phase. In fact, there is correspondence between UML concepts and concepts of the process meta-model which insures correctness of models and possible adaptation if new requirements are defined.

Like shown in figure 9, organizational and informational models are implemented in databases, where behavioral, functional and interactional models (also some elements of the organizational view) are specified using specification language as BPML, WSCL or BPEL which supports control flow patterns, management of human resources and invocation of web services (Aalst, 2002b), (Vasko & Dustat, 2003).

4.2.3 Phase III: Enacting Instances

This phase represents the runtime of the process and corresponds to particular execution of process instances. At this stage, the workflow management system (WFMS) interprets the process model and interacts with the database management system (DBMS) in order to use or to produce data manipulated or generated by activities instances, also organizational data describing participants and roles in the system.

In addition to this, the SGWF supports invocation of web services and captures results of services executions.

According to a workflow view, the first two phases constitute the buildtime of the process and the third phase constitutes the runtime level.

Table 2 bellow summarizes the main aspects of our proposed approach:
Table 2. **Summarize of our approach**

We remark that there is no specific diagram for the organizational view of the process, in fact all concepts of this view appear in the other views and are supported by all diagrams. For example, role and resource (actor) appear in the use case diagrams and are designed in activity diagram using “swimlanes”, in sequence diagram as objects in interaction and in class diagrams in order to store properties of resources and roles.

The process meta-model described in section 4.1 contains all concepts to take into account at both design and implementation levels. This facilitates translation between PIM and PSM levels, according to a scheme shown bellow in figure 10 and gives MDA orientation to our approach. However, we must work on defining all mapping rules between PIM and PSM levels and tools providing this mapping.

In fact, we must define correspondence between the concepts of the process meta-model and the UML concepts in one hand, and between the concepts of process meta-model and concepts of the specification languages and relational model in the other hand. This gives direct correspondence between concepts in PIM and PSM levels.

### 5 CASE STUDY

In this section, we describe some conceptual and implementing aspects of a collaborative process in order to illustrate our approach. The process that we describe is relative to the training of employees in a fictive enterprise (called ‘Lunea’) which subcontracts with training schools.

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5.1 Process Description, Analysis and Design

The collaborative process implies several partners: a fictive organization (Lunea) and three schools publishing their services of training via the web. We assume that the cooperation between the organization and the schools is static (that means services are not dynamically discovered in the UDDI). The main objective of the application is the management of training (specific courses) that the enterprise “Lunea” offers to its employees periodically, in a regular manner by subcontracting with training schools.

For that, the main activities of the workflow process are for example: identifying training needs, establishing lists of employees, doing restrictive calls of tenders, selecting schools, accepting contract, etc. We assume that employees of “Lunea” are dispatched on three departments “department of Studies”, “department of Operating” and “department of Maintenance”.

**Step a: Identifying needs**

Functionalities of the system and actors implied are described in figure 11. We just precise a role of “department header” for the three department heads.

![Use case diagram “Actors and functionalities of the workflow”](image)

Web services required in the process are described in table 3. Thus, we precise pre-conditions, inputs and outputs for each web service.
Step b: Modeling interactions

After textual description of services to be invoked, we can design interactions between the workflow process and the web services (see figure 12).

![Sequence diagram "modeling interactions"](image)

Figure 12: Sequence diagram “modeling interactions”

Step c: Modeling the collaborative process

Activity diagram of figure 13 represents the global process “managing training” which is the collaborative process. Thus, it shows all activities of the process and participant implied in their execution (using “swimlanes”), it also exhibits control flow between activities and invocation/reply of web services. Steps of the process can be summarized as follows:

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1. The committee of decision sends order to start the process of training, to the heads of departments.
2. After receiving the order, each department head establishes needs of training and list of employees to be sent to the responsible of training.
3. After receiving all needs (synchronizing point), the responsible of training consolidates all data, then establishes and validate global specifications.
4. After that, the workflow engine invokes the web service allowing submission of tenders to the training schools.
5. When the offers are received, the responsible of training is notified by the workflow engine. Then, he analyses and selects offers.
6. The workflow engine invokes the web service (s) allowing transmission of selected offer(s).
7. The web service reply with contract proposed to the enterprise.
8. The responsible of training accepts the contract and transmits list of employees to the workflow engine which invokes the appropriate web service.
9. At the end of training, the workflow engine invokes the web service for training results. When the results are received, they are sent to the committee of decision.
10. The committee of decision analyses the results and decides to give eventual promotions to employees.
11. Decisions of promotions are sent to heads of departments and are communicated to the employees.

Figure 13: Activity diagram “Collaborative process of managing training”

5.2 Building process models and Generating code

As already explained in section 4.2, this phase needs to specify the platform of development. Our application has been developed under the framework .Net version 3.0, the SDK framework .Net 3.0, the Visual Studio 2005, the extensions of Windows Workflow Foundation for Visual Studio 2005, the CTP BPEL and IIS 6.0. For implementation of data bases, we have used SQL Server 2005. Figure 14 describes the general architecture of the application and the location of the developing tools.

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The “client” Application is a Winform application, allowing the exploitation of the system. It communicates with the server in “remoting.Net” mode and contains all interfaces and functionalities offered to the internal actors (by roles) of the enterprise. The “server” Application constitutes the kernel of the system, this application is responsible for the managing of users in the system. It supports the workflow engine, the workflow process and the different services of the workflow (persistence, tracking, BPEL messages). It interacts with the client application in remoting.Net mode and with the schools via web services. The server application also supports the management of databases.

6 CONCLUSION

In this paper, we have presented an approach based on process meta-model for the design and development of collaborative applications built by combination of workflow and web services, the purpose is to take advantage from both technologies. In our context, we look to a collaborative process as a workflow process including manual, semi-automatic and automatic activities where participants are human actors, hardware and/or software. For this last class, it can be particularly web services allowing implementation of partner links in context of B2B collaboration.

Several methods and formalisms like OSSAD, WORKEY, UML have been addressed in the literature for the design of workflow applications. Many other methods such as SOMA, SOAD and PRAXEME have been proposed for the design of SOA applications which are completely automatic and built by composition of services. Our approach aims to combine aspects of workflow and SOA since we consider a collaborative process as a set of activities which can be manual, semi-automatic or automatic (implemented as web services).

Our approach is defined around three levels: the meta-model level which constitutes the base of the approach, the model level and the instance level. Thus, we propose a process meta-model which regroups workflow concepts and SOA concepts. For these lasts, we were limited to concepts insuring visibility and invocation of services. The meta-model covers five views of process modeling: the
functional view, the behavioral view, the organizational view, the interactional view and the informational view.

The second level of the approach concerns building of process models; this is done conformably to the process meta-model and according to phases and steps that we define for a method of development. The first phase called “Analysis and Design” uses a set of appropriate UML diagrams and generates process models which are platform independent (PIM). The second phase uses results of the first one and generates process models according to a specific platform (PSM): specification language, DBMS and WFMS. Consequently, we deduce that our approach which is based on process meta-model, is also defined according to the two levels of MDA (Model Driven Architecture) approach.

We have exposed a case study for a collaborative process related to training of employees in an enterprise that must subcontract with training schools via their published web services. The example aims to highlight the main concepts established in the process meta-model and to illustrate the steps identified in the proposed method.

At a broad perspective, integrating web services in workflow solutions allows gradual convergence to SOA architecture (based on web services) for more flexibility, scalability, efficiency and openness.

As future works, we intend to focus on the method of development in order to define mapping rules between PIM and PSM levels and tools for doing this mapping, for MDA adaptation.

In the second time, we try to generalize our approach to support specific architectures of inter-organizational workflows like chained execution, subcontracting, case transfer and loosely coupled architectures identified in the literature of inter-organizational workflow (Aalst, 2000).

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**References**


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