

# Distributed Workflow Management Based on UML and Web Services

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## INTRODUCTION

The definition and the management of business processes are considered a relevant issue to support organizations in their activities. Indeed, in the last few years many organizations have been changing their business processes to keep competitive in the global market. Workflow management is an emerging technology enabling process performance improvement in a cooperative working environment. In particular, a workflow management system (WfMS) enables processes automation through the integration, the coordination, and communication of both human and automatic task of business processes. WfMSs provide a process definition language (PDL) for modeling business processes. A PDL sentence is named process model and is enacted by a component of the WfMS, namely the process engine. The main task of this component is executing the enactment rules and the activities specified in the Process Model.

A huge number of PDLs based on several formalisms have been proposed in literature. Recently, some authors suggest exploiting the unified modeling language (UML) proposed by the Object Management Group (OMG, 2002) to model business processes (Aversano, Canfora, De Lucia, & Gallucci, 2002; Di Nitto, Lavazza, Schiavoni, Tracanella, & Trombetta, 2002; Eriksson & Penker, 2000; Jager, Schleicher, & Westfechtel, 1999; Marshall, 2000). UML is a natural choice for representing business processes, as it is a well known notation that can be easily understood and used by any kind of users.

In this article, we propose a Web services-based WfMS that lets users manage and enact business processes. The proposed system offers a visual environment based on an extension of UML activity diagrams that allows to graphically design a process model and to visually monitor its enactment. Since UML does not have a well defined operational semantics and is not executable, we had to make the process model executable by

appropriately enriching the syntax and semantics of UML activity diagrams. The architecture of the proposed WfMS is based on Web services to manage and enact distributed business processes.

## BACKGROUND

In the last decades workflow management systems (WfMSs) (Workflow Management Coalition, 1999) have been developed by researchers to provide support to the modeling, improvement, and automation of business and industrial engineering processes (Cugola, Di Nitto, & Fuggetta, 2001; Eder & Panagos, 1999; Winograd & Flores, 1986), including software processes (Bandinelli, Di Nitto, & Fuggetta, 1996; Heimann, Joeris, Krapp, & Westfechtel, 1996; Kaiser, Dossick, Jiang, Yang, & Xi Ye, 1998).

Most of the WfMSs of the last decade are client-server systems, with centralized enactment facilities, although they do not exploit the web as basic infrastructure to ease the accessibility by remote users. Recent research on workflow management is focusing on the use of web technologies and/or specialized middleware to support distributed processes across organizations (Aversano et al., 2004; Cugola et al., 2001; Eder & Panagos, 1999; Kaiser et al., 1998; Kammer, Bolcer, Taylor, & Hitomi, 1998; Maurer et al., 2000). The new frontier for the management of distributed e-business processes is provided by Web services (ebXML, 2001; Leymann, 2001). In particular, Pautasso and Alonso (2003) propose a visual approach to compose the various services as task of a process. A process is modeled by using two different diagrams, one for data flow and another for control flow. This requires two different process views.

In general, a number of process definition languages have been proposed in the literature, based on several formalisms such as event-condition-action mechanisms (Aversano et al., 2004, Loops & Allweyer, 1998), graph

rewriting mechanism (Heimann et al., 1996), Petri Nets (Bandinelli et al., 1996), etc.

Several authors have recently proposed to adopt UML (OMG, 2002) for representing business processes (Di Nitto et al., 2002; Eriksson & Penker, 2000; Jager et al., 1999; Marshall, 2000). UML is a well known notation that can be easily understood and used by a project manager. It is important to point out that UML has been conceived for the communication among people. As a consequence, it does not have a well defined operational semantics and is not executable. Indeed, most approaches proposed in the literature use UML to model business processes at a very high level (Loops & Allweyer, 1998; Eriksson & Penker, 2000; Marshall, 2000) and in some cases manually translate the UML model into the PDL of a specific workflow management system (Loops & Allweyer, 1998; Aversano et al., 2002).

In the last years some research efforts are being made to add a well defined operational semantics to UML notations to automatically derive executable process models (Di Nitto et al., 2002; Jager et al., 1999). In (Jager et al., 1999) UML class diagrams and state diagrams are used to model the structure and the behavior of a process. Semantics is attached to UML process models by mapping them to programmed graph rewriting systems (Heimann et al., 1996). In (Di Nitto et al., 2002) a process is modeled by using a subset of UML diagrams, including UML activity diagrams with object flow to model the control and data flow, class diagrams to model structural properties of the process, and state diagrams to model the behavior of activities. The XMI standard representation of these models produced using a UML CASE tool can then be translated into an executable process description for the OPSS Workflow Management System (Cugola et al., 2001). De Lucia, Francese, and Tortora (2003) have presented a case study of mapping UML activity diagrams with object flow on the process definition language of the GENESIS environment (Aversano et al., 2004). The authors showed that UML activity diagrams do not support all the control flow and data flow rules of the GENESIS process definition language. As a consequence, the syntax and semantics of this type of UML diagrams often need to be extended to make them suitable for modeling business processes in workflow management systems.

## AN UML BASED DISTRIBUTED WORKFLOW MANAGEMENT SYSTEM

In this section we present a distributed WfMS that uses UML activity diagrams as process definition language (PD) and Web services for the execution of distributed automatic activities.

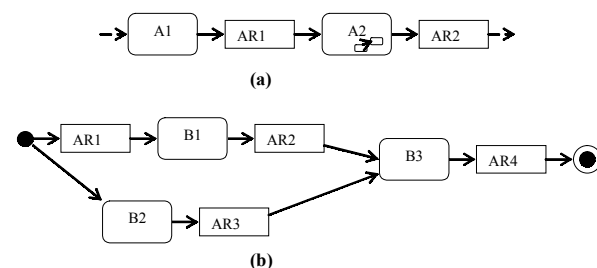
## The Process Definition Language

UML activity diagrams provide an intuitive and easy to learn PDL. In particular, we use an extension of the activity diagrams with object-flow (OMG, 2002). UML activity diagrams are a particular variation of UML state diagrams where states represents actions (or activities) and are modeled by rounded rectangles and transitions between states depicted as solid arrows model the control flow between two activities. Activity diagrams have been enriched with object flow to depict the data flow between activities.

Although structural properties and relations between process elements, such as artifacts, activities, and roles, could be specified using other UML diagrams (Di Nitto et al., 2002), we did not include them in the proposed PDL, to avoid the use of too many diagrams. Indeed, a process modeling tool can provide other features to model these aspects, such as forms or simpler graphical notations (e.g., organizational charts for the roles). Some approaches (Di Nitto et al., 2002; Jager et al., 1999) use state diagrams for modeling the internal behavior of activities. In our approach activities may be interactive or automatic depending on if they are performed by humans or by a tool, respectively. For interactive activities, unlike other WfMSs, we do not provide a visual notation to model them. Rather, their user interface is automatically generated from the definition of the input and output objects of the interactive activity. Automatic activities are associated to Web services using Web service description language (WSDL) specification and executed on remote machines.

We needed to suitably enrich the syntax and semantics of UML activity diagrams to enable the specification and execution of particular aspects of a distributed business process. In particular, distributed processes are organized in a hierarchical way and modeled as subprocesses in UML activity diagrams (see Figure 1 for an example). A compound activity is depicted as an activity with the addition of an icon in the right lower corner denoting a nested activity diagram, see activity A2 in Figure 1(a). In particular, Figure 1(a) shows a partial

Figure 1. Process and sub-process modeling



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