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Integration of Workflow and Agent Technology for Business Process Management

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Abstract

Both workflow and agent technology have recently been applied to business process management. The integration of these two technologies will definitely provide solutions to the problems not to be solved by any of them. This paper summaries the capabilities of these two technologies and discusses the forms and their benefits of integrating them for business process management. Generally, agent enhanced workflow management and agent-based workflow management are the main forms for applications of intelligent agents to workflow systems. Some research issues in each form are discussed. A conclusion with discussions of future research directions is also given.
Keywords: Workflow, Software Agents, Multi-Agent Systems, Agent-Based Workflow, Agent-Enhanced Workflow, Business Process Management.

1. Introduction

Many organizations have realized that although they have adapted the Information Technology (IT) to improve their working efficiency, the business processes within their organizations and between themselves and their partners have not been clearly described and streamlined. During the execution of business processes, there are not enough techniques and methods to follow-up and control the processes. This leads to the misunderstanding of responsibilities, blocks in coordination, and slow reaction to the changing market.

Workflow management technology is among the ones under development to overcome these shortcomings. It promises to provide an efficient way to model and control the complex business processes within and between organizations. Although workflow management technology has emerged for years, it is only in the last few years that it has become very popular in the commercial as well as the research world. The benefits of workflow management technology include explicit process definition, quick reaction to changing environments, and easy track of operations. While workflow management focuses on managing the process logic, it needs to integrate other technologies so to fully control a business process, such as activity assignment, and resource allocation. Comparing to the formal workflow management methodology, software agent technology provides flexible, distributed, and intelligent solutions for business process management. And a combination of these two technologies will definitely provide solutions to the problems not to be solved by any of them.

Integration of workflow and agent technology has recently attracted a lot of attention of researchers in the related areas. This paper provides an overview of this exciting research area. The paper is organized as follows: Section 2 discusses the advantages and shortcomings of the

workflow technology for managing business processes; Section 3 introduces the recent research work on applications of agent technology to business process management; Section 4 overviews the integration of these two technologies; Section 5 gives a brief conclusion with some discussions of future research directions in this area.

2. Workflow Management for Business Process Management

Workflow management comes from office automation area, where all kinds of documents need to be digitalized and transferred among co-workers. Nowadays, the workflow management attracts a lot of attention due to its ability in modeling, executing, and monitoring processes. The processes can be not only the business processes, but also any procedures that need to be presented and managed. But the motivation for its booming is its promising usage in managing business processes.

One widely accepted definition of workflow comes from the Workflow Management Coalition (WfMC, 1994):

> "Workflow is the computerized facilitation or automation of a business process, in whole or part."

The benefits of applying workflow technology to business process management are as follows:

- The business processes are explicitly defined, so that the responsibilities and the coordination relations are clearly determined.
- It is easy to optimize the business process because of their explicit definitions.
- Business processes are modularized and these modules can be reorganized by the WFMS to form new business processes, so as to react quickly to unexpected changing business needs and conditions.
- WFMS can track daily operations.
- WFMS integrates applications on different platforms into a business process.
- WFMS provides personal workplaces.
- WFMS stem separates business logic of a process from the tasks themselves in the process. Therefore, the user in the workflow system does not have to deal with the route of the business process, but only concentrates on the task itself.

From a technical perspective, WFMSs bring together principles, methodologies and technologies from various areas of computer science and management science. For example, workflow techniques involve database management, client-server computing, heterogeneous distributed computing, graphical user interfaces, application and subsystem integration, messaging, document management, simulation, and business practices and re-engineering. However, the current generation of WFMS has some shortcomings:

- Relying on one central control: WFMSs have a central workflow server that defines and controls all business processes. While in distributed enterprises or large companies, the business processes have no way to be managed by a central point. The independent companies make their decision on how to do their pieces of business.

- Lack of automation: WFMSs only determine the process logic, but most of the activities are still fulfilled by human. WFMSs can't even start a workflow without human's intervention.
- Lack of reactivity (Trammel, 1996; O'Brien and Wiegand, 1998): WFMSs require a pre-defined representation of a business process and all potential deviations from that process.
- Lack of resources management (Trammel, 1996; O'Brien and Wiegand, 1998): WFMSs do not control the resources of a business process, and so rely on a business process being dimensioned beforehand.
- Lack of semantics (Trammel, 1996; O'Brien and Wiegand, 1998): WFMSs lack an appreciation of the content of a business process and do not make decisions based on the nature of the information generated by a business process.
- Lack of generic interfaces: WFMSs need to exchange data between activities or interface to other applications. Currently, these operations depend on API calls. There should be some generic interfaces to eliminate the effort to develop interfaces between WFMSs and other applications.
- Lack of interoperation (O'Brien and Wiegand, 1998): independent vendors now develop WFMSs. Though WfMC has presented its work to enable the interoperation, this does not help much.

One solution to these shortcomings is to "embody" WFMSs with mechanisms from other technologies. For example, integrating project management for resource management and scheduling, integrating groupware for message passing and personal working environment. Software agent technology is among the ones that can benefit more the workflow technology. We will discuss more on this in the following sections.

3. Software Agent Technology for Business Process Management

For the notion of agent and autonomy used in this paper, we comply with Jennings and Wooldridge's definition (Jennings and Wooldridge 1998): "an agent is a computer system situated in some environment, and that is capable of autonomous action in this environment in order to meet its design objectives." An autonomous agent should be able to act without the direct intervention of humans (or other agents), and should have control over its own actions and internal state. And an "agent based system" means one in which the key abstraction used is that of an agent (Jennings and Wooldridge, 1998).

Agent technology provides an extension and alternative to business process management problems. Among many of the properties software have, the properties of autonomous, collaborative, and intelligent are those most interested for distributed business process management systems. The benefits of applying agent technology to business process management include:

- Distributed system architecture: For the scenario concerning multiple workflow systems, agent technology provides loose coupled distributed system structure for integrating distributed business process management systems.

- Automation: The inherent autonomy of software agents can fulfill activities as human substitution. Moreover, agents can start a workflow based on event trigger or more complex reaction to environment changes.
- Interaction: Software agents enable organizations to interact with each other, normally through semantic message exchanging.
- Resource management: Agents can represent resources. Task assignments and resource allocations are done through negotiation among these agents.
- Reactivity: Agents react to changing circumstances and have the ability to generate alternative execution paths. This ability normally involves agent's intelligent features, such as learning.
- Interoperation among heterogeneous systems: Agents can be heterogeneous. The interactions rely on semantic messages for exchanging plans and service definitions. That makes interoperation more feasible than API calls.
- Intelligent decision-making: Some high-level features of agents, such as learning, are also very helpful in workflow management, thought they are not matured techniques nowadays.

However, implementation of business process management systems using only agent technology has the following problems:

- A coordination mechanism is usually missing, which could make the systems unstable and unreliable.
- Business process optimization is difficult due to the lack of explicit definitions and representations of the business processes.
- It is not easy to track the daily operations as it is easily done in workflow management systems.

4. Integration of Workflow and Agent Technologies

Some workflow management systems vendors have declaimed that they have implemented software agents in their commercial workflow products. However, these agents are usually very basic, and used to implement autonomous activities. More and more researchers believe that agent technology can provide system architectures for integrating multiple workflow systems. From the system point view, most workflow management systems implemented with agents are multi-agent systems. Applications of agents to workflow management systems can be classified into two forms: agent-enhanced workflow management and agent-based workflow management.

4.1. Agent-Enhanced Workflow Management

Agent-enhanced workflow management is the basic form for application of agents to workflow management (cf. figure 1). There is one central workflow engine, which controls all the activities. Agents are invocated during the execution of one work item to implement certain tasks. Workflow system controls the generation and elimination of the agents. This form is how current commercial WFMSs use the concept of agents. There are several things agents can achieve in this scenario:

- Human interface: it is part of the workplace environment the workflow system provides to its user. The agent acts as a personal assist. Some typical usages are

sorting emails, replying email, reminding events, acquiring work items. Example is A1 in figure 1.

- Autonomous activity: it implements the tasks autonomously without human's interruption. Example is A2 in figure 1.
- Interface to other applications: agent can provide interface to other applications. Instead of defining API for application interoperation, semantic messages can be defined to exchange high-level information. This is also a direction for designing generic interface to applications.

In this scenario, agents are like services provided by the workflow management system. The aim to using agents here is to increase automation for workflow system. As substitution for human, agents can carry out many tasks without human involvement. The main beneficial features of agents include autonomous, communication, and reactivity. From the system view, agent does not necessarily interact with each other. In fact, the workflow engine controls their actions. The information exchanging if there is any is through workflow engine. The workflow engine is

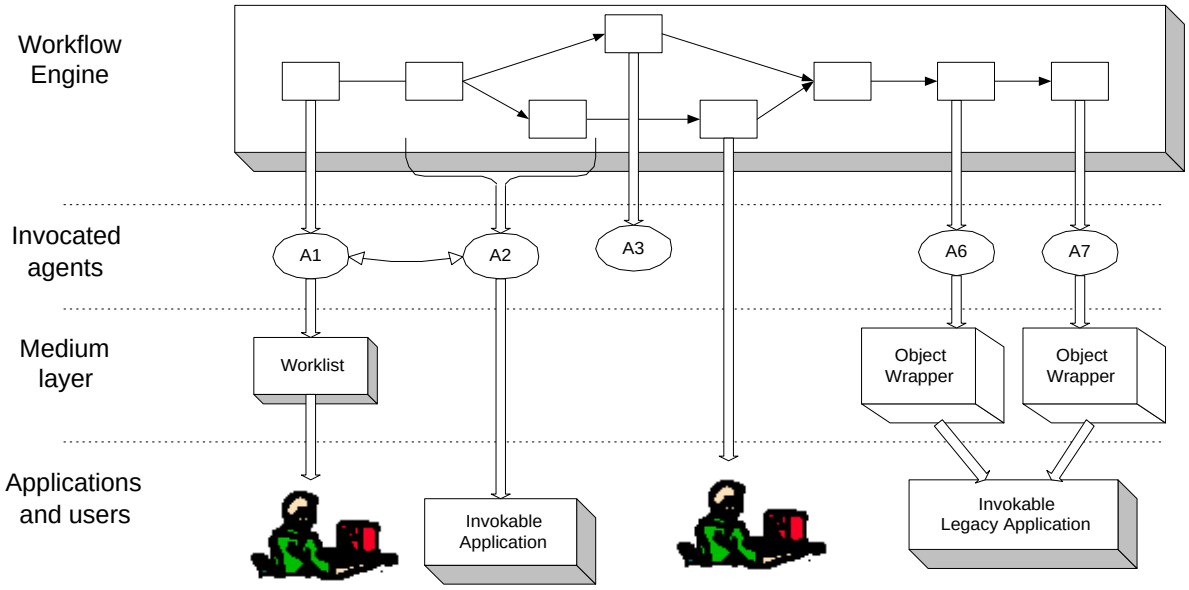

Figure 1 Agent Enhanced Workflow Management System

responsible to create and eliminate the agents. Second, the agents in this scenario do not necessarily be "intelligent", which means, it might not have the strong notion of agents. In most commercial WFMS products, the agent is more like a piece of ordinary software, e.g. IBM MQSeries Workflow (IBM, 2000) and InConcert (InConcert, 2000).

Some research projects on this schema try to fully use the agent abilities in every dimension. One example is the project in BT Lab by Shepherdson and colleagues (Judy et al, 1998; Shepherdson et al, 1999). The agents correspond to activities one by one. (Judy et al, 1998) illustrates the ability to route work items at the or-split point in a workflow definition. The following activities are some identical activity, which means the work item can go through either path. In current WFMSs, path is chosen probably or wait until the user represents on activity acquires this work item. Now, by using agents to represent activities, the work item is routed by the result of negotiation. The contract net (Davis and Smith, 1983) is the supporting negotiation technique. The work item is reward to the agent that posts the lowest cost. (Shepherdson et al, 1999)

mentioned other benefits, such as provisioning, interoperability, supporting for visualization and verification services, and protecting investment in workflow technology. Zeus agent toolkit developed in BT is chosen as the agent development environment.
Another example is TRP support environment (TSE) by Chang and Scott (1996) in Andersen Consulting. Their work has a central workflow agent (as workflow engine) and a set of agents acting personal assistant, communication facilitator, database connection manager, etc. TRP Agent Communication Language is defined for communication. This system also has a WWW interface.

4.2. Agent-Based Workflow Management

An Agent-based workflow system is a distributed system consisting of multiple agents (cf. figure 2). These agents are independent to each other and each is responsible for process execution. In this scenario, the whole business process is formed by the pieces of sub-networks within those agents. The process logic is embedded in the agents, rather than being explicitly represented elsewhere.

This scenario is quite interesting in real world; the business process is across several units in a company or even spreads across several companies. Thus a central workflow engine is unable to get all the information of the whole business process in order to control it. A more likely solution is to have one workflow engine residing in each organization or unit. Through interactions among the multiple workflow engines the whole business process is fulfilled.

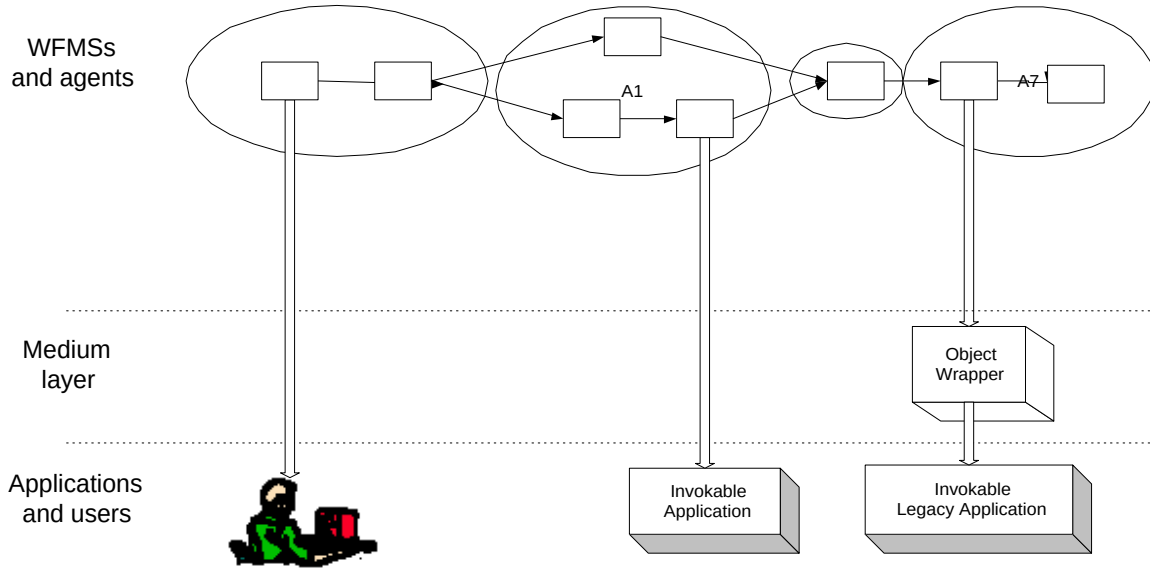

Figure 2. Agent-based Workflow Management System

Agents in this scenario take full responsibilities of a workflow management system, which means agent has all the means to analyze, automate, integrate, and inspect workflows. More important, agent should have means to communicate and interact with each other. Third, agents' high-level ability, such as learning, negotiation, can add values to workflow system.

Agents in this scenario should be much more complex than the first one. The main features include: autonomous, communication, self-consistent, goal-oriented, and react to environment. Other high-level features such as learning, negotiation are also benefit. But since these techniques are not matured, these features are just promising ones.

The usage of agents in this scenario benefits workflow technology in the following ways:

- Providing distributed system architecture. There are several system architectures in multi-agent systems (Shen et al., 2000), which can be used in a distributed system for implementing workflow management systems.
- Providing communication methods. Agent communication languages are studied quite much. There are several communication languages based on semantic messages, such as KQML. Theses languages can enable interoperation of workflow systems, especially for the heterogeneous ones.
- Providing automation behavior. Agent has the ability to execute tasks on its own without human involvement. Agent also has some decision power according to its goal.
- Reacting to environment. Agent can adjust itself, for example, forming new activity and new routing.
- Benefits of high level features. These high level features include learning, negotiation, and planning. Though these features are not fully implemented for industrial applications, they are what promising.

Nowadays, none commercial product falls in this category. But several prototype systems exist in research areas, namely ADEPT (Jennings et al, 1996) and FireFlow System (Yan, 1999). This is an area attracting most research attentions. Some important research issues are:

(a) System architecture: various system architectures are presented. Normally an agent represents a functional team/department, sample systems are ADEPT (Jennings et al, 1996). (Debenham, 1998) presents an ad-hoc workflow system for processing applications received by a university department from potential research students. In his proposal, agents act as application agent, supervisor agent, control agent, and admin agent. These agents delegate the functions of correspondent users. Another routing agent is to mediate the communication between agents. Another kind of system architecture uses mobile agents (Budimac et al, 19999). Mobile agent represents work item and the mobile agent takes care which of the path the agent should go. On each node a server agent resides, which accepts mobile agents, interface to user, invokes the function condition for each work item agent, and prevent the work item idle in one node. (Inomoto, 1999) presents another ad-hoc system to deal with internal document delivery. He uses e-form agent as mobile agent to delivery document. A manager agent dispatches the e-form agent and has the ability of learning.

(b) Negotiation: negotiation is an important topic in multi-agent systems. Same negotiation methods and protocols can be used in agent-based business process management systems. The methods are categorized into theoretical one, such as Game Theories (Shoham, 1993), contract nets (Davis and Smith, 1983), and non-theoretical ones, such as knowledge-based, model-based methods (Jennings et al, 1996). Communication language is a relevant topic of negotiation. Though many proposals in communication language, some protocols especially useful in

exchanging business process information are presented. (Jennings et al, 1996) presents SDL (Service Description Language). Provided by an agent, a service is described by a name, its inputs, its outputs and its body.

(c) Resource management: via negotiation. Normally, agents represent resources, through negotiation to commit to certain tasks (Jennings et al, 1996).
(d) Scheduling: via negotiation, decide start time (Jennings et al, 1996).
(e) Modeling: all kinds of ways to analyze and model the workflow (Maamar and Shen, 2000; Aknine and Pinson, 1999; Inamoto, 1999).
(f) Learning: decide new processes, communication is necessary.
(g) Agent architectures: Many architectures proposed and developed for multi-agent systems (Shen et al, 2000) can be used to implement agent-based workflow management systems.

4.3. Remarks

In the above two sub-sections, we discussed the two forms of integration of workflow management technology with agent technology. Here we will summarize the features of their combination.

If we consider the life cycle of a business process management, according to (O'Brain, and Wiegrand, 1998), it can be divided into three phases: creation, provisioning, and enactment (cf. Figure 3).

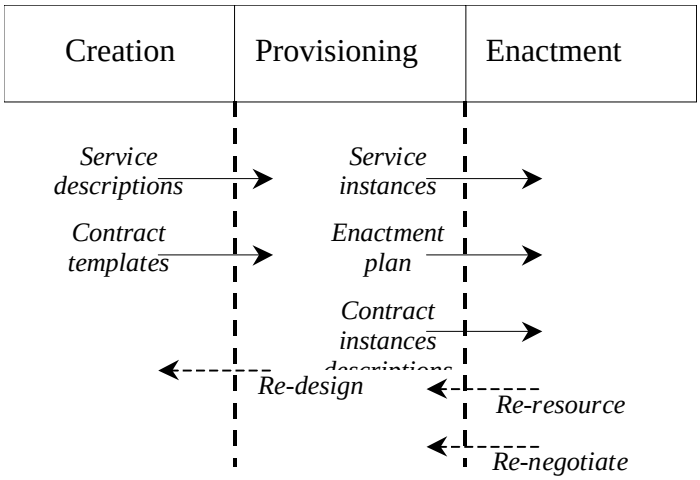

Figure 3. Life Cycle of Business Process Management
(adapted from O'Brain, and Wiegrand, 1998)

The *creation stage* involves the analysis modeling and definition of the business processes. The business process can be represented as a diagram or a verbal format, for example PIF. Some ad-hoc methods are presented, such as State-transition table (Inamoto, 1999). The main aim of this stage is to present the logic of the activities in business process. Currently, this is mainly done at design time and in a manual way. The *provisioning stage* involves the assignment of resource, including people, equipment, and computing time. This requires negotiating, planning, and scheduling to ensure that there is sufficient resource to handle expected throughput of work for a business process. This takes place at the run time. The *enactment stage* involves the

management activities required to ensure that each instance of a business process is effectively executed. This includes routing of work, passing of information, activation of automated activities, and the handling of work list. This is also done at run time.

Current workflow technology is good at the enactment stage. It uses all means to control and supervise the execution of business processes. Current workflow management systems also provide tools for user to define business process in workflow template. These process-editing tools are vender dependent, and normally are visual graphic tools with/without description languages. But these methods are not mature for they depend on human user's vision and lack of mathematic support. For the provision stage, current workflow technology has not provided support yet.

Agent technology, on the contrary, is good at providing the provisioning functions, for example, negotiation, scheduling, and resource allocation. Some cases can be found in above two sub-sections. But agent can also take part in the other two stages. For enactment stage, one important usage of agent is to provide automation mechanism for activities. Agent can also present work items, and through negotiation to decide the route that these work items will follow. If there is change in business process, agent can react to it. For creation stage, agents can form new business process through negotiation.

Workflow technology combined with agent technology provides potential perspectives in business process management. Some currently successful areas for agent to apply in workflow management are (1) automation activity. Agent helps to fulfill activity. (2) integration with other applications. Agent is a good way to provide a wrapper of other applications. (3) communication. Agent technology helps to set up protocols to exchange semantic information. (4) interaction. Agent technology helps to set up schema for the interactions among different workflow system.

Something agent promising to do but not matured yet includes (1) negotiation. Although this study has plenty results. Real world is still more complex to be handled by current techniques. (2) learning. That would be a very interesting topic, especially when business process not well structured. (3) Personal working environment. By integrating groupware technology and smart agent technology, it is a promising direction.

Combination of workflow with agent technology also has some drawbacks: more complex systems; too many issues joined together; some agent-based methods are not matured yet. Besides the combination with agent technology, workflow management can benefit from integration with other technologies, such as project management, resource management, and intelligent scheduling.

5. Conclusion and Research Opportunities

Agent-enhanced workflow systems are widely adopted by commercial products, while the agent-based workflow systems are still in prototypes in research laboratories. However, the agent-based workflow systems are attracting more and more attention for studying the interaction of multiple workflow systems, which are the requirement of next generation of workflow systems.

Agents can help to automate the management of business processes to a much greater degree than has been possible before. The potential benefits include a reduced need for human

involvement, which impacts the overall cost of managing business processes; a reduced response time to the changing working environment; and improved interoperability among heterogeneous systems.

Following research topics are identified as future research opportunities:

- *Modeling*: Business processes need to be well described. We need modeling methods especially for the processes across organization boundaries. We also need verification methods, based on mathematic analysis.
- *Communication:* Efficient communication languages for exchanging service definitions.
- *Negotiation*: Negotiation methods and protocols compliant to the features of the workflow management process.
- *Personal working environment*: Good user interfaces by using interface agents and personal assistant techniques.
- *Integrated with other technologies*: Integration with other technologies such as project management, intelligent scheduling, and optimization, etc.
- *Learning*: Creation of new business process logic during run time through learning.

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