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# Intelligent Agents for Flexible Workflow Systems

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## Introduction

Many practitioners and researchers in workflow systems have stressed the importance of flexibility in such systems. On the one hand, organizational control requires detailed modeling of workflow processes and stringent procedural guidelines. On the other hand, dramatic organizational changes and frequent exceptions demand system flexibility.

Few satisfactory solutions have been provided thus far to deal with this issue of flexibility because workflow systems developed using conventional software techniques are costly to modify and offer limited flexibility in general. However, recent progress in intelligent agents, especially autonomous and adaptive agents, seems to hold promise in providing increased flexibility in software systems.

In this paper, we discuss the problem of flexibility in workflow systems, overview the features of intelligent agents, survey their applications in workflow system prototypes, and propose several research issues on the development of agent-based workflow systems to achieve increased flexibility.

## The Need for Adaptive and Flexible Workflow Systems

Management of change in business processes has been stressed by many researchers as an important issue from strategic, operational, and system perspectives (Bowers, Button, and Sharrock, 1995; Earl, 1994; Ellis and Rozenberg, 1995). For a more general discussion of technology flexibility, please see (Nelson, et al., 1997).

There are many possible measures of system flexibility according to the dimensions one emphasizes. In this paper, we focus on two levels of flexibility: system adaptability and system versatility. *System adaptability* refers to the capability of the system to be modified quickly to cope with major changes in business processes with little or no interruption in on-going processes. That is, existing processes during and before the major process changes must be supported without interruption. This requires flexible workflow management systems that can manage transitions naturally in business organizations and processes. Adaptability is high when unforeseen changes in the structure of the process or the requirements for its execution can be accommodated quickly and cheaply.

*System versatility* refers to the capability of the system to allow flexible procedures to deal with exceptions in processes and procedures. It measures the amount of freedom that users of the system have to take actions and exercise unplanned options that follow common sense rather than the command of a pre-planned step-by-step procedure. That is, system versatility is concerned with the ability of the system to cope with process variations rather than dramatic organizational and procedural changes.
System adaptability and system versatility both have to do with change management and require the system to be capable of dealing with changes to the workflow patterns. However, they are different in terms of the scale of change and the frequency of occurrences. System adaptability requires refitting the system to cope with new processes that are dramatically different from the existing ones, while system flexibility deals with minor changes to and variations in business processes as an on-going requirement.

Recently, software techniques have been proposed to deal with dynamic change and exception handling in workflow systems (Ellis and Rozenberg, 1995; Kumar and Zhao, 1996; Chiu, Karlapalem, and Li, 1997). However, systematic treatment of change management in workflow systems is still an open problem. In this paper, we look at the possibility of using intelligent agents toward achieving this goal.

## What are Intelligent Agents?

According to Hedberg (1996), intelligent agents are autonomous software entities that can navigate heterogeneous computing environments and can, either alone or working with other agents, achieve some goal. Thus, they require on-board intelligence to achieve their task, such as planning, reasoning, and learning algorithms. For a detailed survey on various other definitions of intelligent agents, refer to (Wooldridge and Jennings, 1994; Franklin and Graesser, 1997).

Intelligent agents have been built in research labs (Maes, 1994) and for commercial applications (Etzioni and Weld, 1995), such as electronic mail handling agents, meeting scheduling agents, and Internet searching agents. However, most of the agents implemented are relatively simple and do not have all the features suggested in the literature. Currently, there are many open research topics dealing with intelligent agents including: planning with incomplete information (Etzioni and Weld, 1995), multiagent communication techniques (Sycara and Zeng, 1996), adaptive intelligence agents (Hayes-Roth, 1995; Decker and Sycara, 1997), and automatic generation of intelligent agents (Spector, 1997).

## Intelligent Agents in Workflow Systems

One possible venue for new solutions to adaptability and flexibility in workflow systems is the use of intelligent agents for the modeling and enactment of workflow (Edmonds et al., 1994; Mahling, Craven, and Croft, 1995). Several examples of agent-based collaborative systems are being investigated; this section highlights on a few representative prototypes.

### *Intelligent Agents for Collaborative Design*

Edmonds et al. (1994) studied a collaborative design problem involving participants with heterogeneous skills and suggested that multiagent systems can be deployed to support design with a range of functions when considered from a number of perspectives.

For instance, in their geographic decision system, five types of group agents were used to support a collaborative design conference. These five types of agents are: *User agent* to handle the interactions between a user and the system, *Group agent* to control the behavior of users such as under what situations one is permitted to exit the system, *Floor agent* to sequence the user inputs, *Conference agent* to control the initialization of the conference, and *Application agent* to provide services for interacting with external components.

### *Intelligent Agents for Office Work*

Mahling, Craven, and Croft (1995) presented an overview of the evolution of their office work systems. The most recent generation is Polyflow, which was designed as a goal-based workflow system that uses the power of goal-based knowledge representation to assist in planning, monitoring, and repairing workflows with emphasis on the users and their workgroups (Mahling, Craven, and Croft, 1995). The internal features of the intelligent agents are not clearly specified in the paper, leaving the impression that these agents are quite primitive according to the criteria of intelligent agents in (Decker and Sycara, 1997).

### *Intelligent Agents for Lightweight Workflows*

Combining the idea of components-based architecture and intelligent agents, Sull (1998) proposed a distributed environment for lightweight workflows suitable for distributed organizations.

In the proposed architecture, three types of agents were suggested, including: the *courier agent* that handles the transition between two states in the workflow process and to notify a human or an application about the subsequent tasks, the *task agent* that is to accomplish a task in collaboration with other human or intelligent agents, and the *process agent* that supervises a process instance on behalf of the system or the process initiator.

### *Multiagents for Process Management*

A multiagent architecture was developed in the ADEPT (Advanced Decision Environment for Process Tasks) project (Jennings et al., 1996). ADEPT aims to design agent-oriented business process management by means of cooperating and autonomous agents. In this system, each agency may consist of a set of subsidiary agencies represented by a single responsible agent.

The provision of services by one agency for another is initiated through negotiation of a service agreement. Each agent acting autonomously will constantly assess the situation and decide how to commit the resources of its agency, whether to call for services from other agents based on some prior agreement, or negotiate for new service agreements.

## The Role of Intelligent Agents in Flexible Workflow Systems

The intelligent agents technique can be applied to improve the flexibility of workflow systems because of its several inherent features, as is summarized below based on the discussions in the previous sections:

- Intelligent agents can be automatically generated based on scenarios, believes, and behaviors set forth by the system developers. This is *the procreation feature*.
- Intelligent agents can be programmed by individuals to follow their special instructions. This is *the individualism feature*.
- New types of intelligent agents can be deployed to add new features to the system without having to revamp the system architecture. This is *the extensibility feature*.
- Different generations of intelligent agents can coexist in the system, each of which may represent different versions of business procedures and organizational norms. This is *the coexistence feature*.
- Intelligent agents can negotiate with one another to exhibit versatile behaviors in the system that would not be possible through rigid procedures and logic rules. This is *the negotiation feature*.

These fundamental features of intelligent agents can be utilized to develop more flexible workflow systems. We hypothesize on how flexible workflow systems can be achieved by taking advantage of these features:

Proposition 1: Intelligent agents can help improve system adaptability because (1) the procreation feature can reduce the costs of modifying the workflow system for changes in organizational structures and business procedures, (2) the extensibility feature indicates that new workflow types can be added to the system naturally, and (3) the coexistence feature allows the existence of old and new agents during the transitional period.

Proposition 2: Intelligent agents can help increase system versatility because (1) the negotiation feature enables the mechanism for permitting deviations from the normal procedures, (2) the individualism feature provides the means for variations and exception handling, and (3) the procreation feature indicates the possibility of generating more versatile agents.

These two propositions require additional justification either through theoretical analysis or by experiments. Nevertheless, our analysis points to a promising approach that should explored further.

## Research Issues for Agent-Based Flexible Workflow Systems

The previous sections have indicated that system adaptability and flexibility are important to workflow systems, and intelligent agents have been proposed as a potential means for achieving better results on these two system metrics. However, it is not clear how intelligent agents will replace conventional workflow management systems to improve system adaptability and flexibility. This question requires the study of several research issues:

1) There are different types of workflow processes that vary in their requirements on controllability, flexibility, efficiency, and adaptability. Typical types of processes are production, administration, knowledge, ad hoc, etc. (Stohr and Zhao, 1997). What types of workflow processes can be best supported by agent-based workflow systems?
2) Given a conventional workflow system and an agent-based workflow system, what are the criteria for selecting the appropriate one for a given business application? Our understanding with respect to this issue is extremely limited. Any theoretical or pragmatic investigation will be useful for both researchers and practitioners.
3) Between the two extreme cases, i.e., the ADEPT multiagent architecture and the conventional workflow system, there may exist a spectrum of techniques that blend conventional and agent-based process technologies in the same system. How can these techniques be tailored to suit various business situations? This question requires a fine-grained analysis of various process management techniques.

Further research is needed to combine the database and agent techniques to advance our knowledge in this important area. More importantly, experiments and implementations need to be conducted on large-scale problems.

## Conclusions

In this paper, we introduced issues with flexible workflow systems in order to meet the needs of business organizations to deal with constant changes in organizational structures and business procedures. One emerging area of study is the application of intelligent agents in workflow systems to improve the systems' flexibility.

Based on the reports given in the literature, we conceptualized several fundamental features of intelligent agents and developed two propositions that hypothesize the potential rationale on how intelligent agents might help improve the flexibility of workflow systems.

Several issues are raised that require research to advance our understanding on how to develop flexible workflow systems with a mixture of conventional techniques and agent techniques. The key is to find a balance between flexibility and controllability in order to support mission-critical applications.

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