Agent-Based Business Process Management

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Abstract

Traditional approaches to manage business processes are often defective for dynamic, open, inter-organizational business environment. However, with the development of Internet, many business processes exhibit these characteristics. And the business process has become more dynamic and unpredictable. So aiming at these new characteristics we provide a new approach which well adapts the new environment. We present a framework of business process management based on intelligent agents. In our framework we use roles to construct the relations between task-environment and agents. And various roles can be delegated to a number of autonomous agents. In order to enact their roles, these agents typically interact and negotiate. This approach leads to a system that is significantly more agile and robust than their traditional counterparts.

Keywords: business process management, role, intelligent agent, negotiation

1. Introduction

With the rapid development of Internet, it has greatly changed the way that modern enterprises conduct businesses. Many new business paradigms have emerged such as virtual enterprises, dynamic enterprise coalition, and agile manufacturing. These business organizations consist of a series of cooperating ‘nodes’ of core competence, which form into a supply chain in order to address a specific opportunity in the marketplace (Walton and Whicker, 1996). There is no centralized control, neither is there a hierarchy of enterprise management levels. Instead, the cooperation of independent, self-interested units results in convergence towards an overall welfare (Iyan Rahwan, 2000). Traditional approaches to manage business processes are often defective for large-scale, inter-organizational, dynamic settings. However, since Internet and Intranet technologies have become widespread, an increasing number of business processes exhibit these properties (N.R. Jennings, 2000).

The concept of “enterprise” has been extended and it can be applied to an organization in which a dominant enterprise extends its business boundaries to all or some of its suppliers, partners or other organizations. The typical modern commercial enterprise consists of a number of, possibly physically distributed, semi-autonomous units, each with a degree of control over local resources or with different information requirements. However, these semi-autonomous units of a single or a number of collaborating organizations must be coordinated via a “business process”. This business process specifies the tasks that must be performed and the decisions to be made in the generation of a product or services.

Agents are autonomous, proactive, and adaptive software that contain some level of intelligence to perform tasks autonomously. Agents can also cooperate with other agents to carry out more complex tasks than they themselves alone can handle. These characteristics show that agent technologies have great potential to apply in the business process management. The main advantages of agent-based business process management over traditional approaches such as management information system are that it offers greater flexibility, agility, and adaptability.
There are many researches on developing multi-agent systems for business process management in recent years (Fu-ren Lin, 2004). But most of these systems are based on static workflow technologies. The business processes are predetermined and cannot be modified flexibly in the execution processes. Otherwise, most of them only deal with intra-organizational business processes and neglect the inter-organizational processes. In this paper our purpose is to design a framework based intelligent agents which offers greater flexibility, agility, and adaptability.

The remainder of this paper is structured as follows. The next section describes the domain of business process management. Section 3 analyzes the agent-based business process management and provides a conceptual framework. Because the negotiation and coordination technologies are very important for such systems, section 4 explains these two aspects. The final section provides some conclusions and highlights open issues that need to be more fully addressed.

2. The Basic of Business Process Management

Over the past decade, there are many systems which are developed in order to integrate and automate enterprise business process, both within and across organizations. However, with the development of e-commerce and the blurring of enterprise boundaries, there is renewed interest in business process coordination, especially for inter-organizational processes (Umeshwar Dayal 2001). Some new characteristics of business processes have emerged which forcing by the competitive pressure in the global market. And many new methodologies of business process modeling have been brought out.

Traditionally, a business process can be viewed as a persistent unit of work started by a business event such as an invoice, request for proposal or a request for customization. In more detail, a business process can be split into a number of constituent components (Figure 1).

![Figure 1. Constituent Components of a Business Process](adopted from Hollingsworth (1994))

First, the business process should be defined. The definition describes the activities that need to be performed, the roles who could or should perform them, and the interdependencies that exist between them. The activities in the process description may be automated or involve manual tasks.
Second, the business process should be executed and managed by the business process management system. Such system must be capable of ensuring that the process description is realized. When some events trigger the process management system to create a process instance, the system then coordinates and monitors the process execution.

Traditionally, there are two approaches of representing business processes. First, the sequence of steps to be traversed in executing a business process is defined before the process instance is initiated and a flow diagram is used to represent such process. Secondly, some systems only simply use a collection of rules to represent the process without explicitly delineating the paths. Traditional business process management systems are designed following above notions. But with the evolution of organizational structure and the emergence of new business paradigms, the design of business process management system should take into account the following key characteristics.

1) More than one independent enterprise may be involved in the same business process. The sharing of processes and resources may last for a limited period of time according to the execution of dynamic business process, and the business process is more dynamic.

2) The business processes are dynamic and unpredictable. It is impossible to give a prior detail specification of all the activities that need to be performed. The process of execution may often be disrupted by unavoidable delays or unanticipated events (e.g., tasks take longer than expected). So there needs a flexible coordination method which can effectively handle the unexpected events.

3) The business process involves a mixture of human activities and automated tasks. Many entities may be involved in such processes. These entities may be self-interested and attempts to maximize their own profits. And within organizations there is a decentralized ownership of the tasks, information and resources involved in the business process.

Just as the business environment is highly unpredictable and a rigid one-time design does not accommodate such changes. Instead, a general definition of business processes could be implemented, in which autonomous, adaptive components deal with specific business processes and their internal problem. So in our system we view a business process as a collection of autonomous, problem solving agents which interact with other agents when they have interdependencies.

3. An Agent-Based Business Process Management

A new way to design and implement the business management system is to make each business entity an autonomous agent. Such agents have specific goals to achieve and interact with one another to manage their interdependencies.

3.1 Business Process Model

We can classify the business processes as static business processes and dynamic business processes. In static business processes a set of entities is linked together in a static way and the business processes are fixed. In dynamic business processes a set of entities is linked dynamically, on-demand, and according to the requirements of the customers. The business processes might change continuously based on the market driven criteria.

The process of forming a business process begins as soon as a customer’s requirements arrive. And it may include four major steps: (1) identify the customer’s requirements; (2) lay out schemes to meet the customer’s requirements; (3) streamline the process of execution and identify the entities which may participant in the business process; (4) coordinate with participants corresponding to activities to execute the business process.

When the business process includes a particular sub-process which need the core enterprises collaborate with other enterprises, following processes will be implemented, including that search the electronic marketplace, and locate all the potential partners which
can fulfill the particular sub-process. As soon as the list of candidate partners for a particular sub-process has been found, the selection process starts. And the selection process is usually performed through negotiation. Because the organizations (such as humans, enterprises, intelligent agents) that participant in the business process are dynamically changed, there are no explicit static business relationships and thus, no integration among the processes of partners is required.

We provide a business process model which consists of the following key phases:

- **Business Process Specification and Registration Phase**: During this phase system can specify the general business process and make certain the various roles participating in the business process. Then the system comes out with the different roles, and in order to fill certain roles agents that have the capabilities to enact these roles can negotiate with system. The specification of business process is performed by deploying a business process definition language. When achieving some roles needs collaborations across enterprises, these requests can be declared to the electronic marketplace which include the terms and conditions under which these roles will be filled by other enterprises.

- **Business Process Management Phase**: During this phase business processes are executed and managed, and the customers’ requirements are satisfied. Whenever a customer requests services, the system initially starts the provision of the service. System can control and monitor the execution of the business process. When some unexpected events happen, system can dynamically interact with agents and adjust the process. However, system cannot interfere the autonomous actions of agents. When the requested roles should be carried out by other enterprise, the system then conducts the marketplace, locates all the potential candidate partners, and negotiates with them dynamically in order to select the best one that satisfies certain selection and negotiation criteria. When a partner has been found, then the partner fills the roles. System serves the customer, and requests the remote process when necessary.

In such business process model we provide a collaborative process to extend the traditional centralized process management technology. The collaborative process may involve multiple partners, each play a certain role in the process.

### 3.2 The Conceptual Framework

Our business process management system adopts interacting, autonomous agents to enact certain roles and perform particular activities. So we must use an appropriate method to assign activities or tasks to agents. The conceptual process see figure 2.

![Figure 2. Different View of a Business Process](image)
In figure 2 the upper layer is a business process that includes many sub-processes. And we can analyze the business process from the view of organizational design. Different sub-processes are carried out by different roles. A role can be viewed as an abstract description of an entity’s expected function and involves a set of activities. Responsibilities and permissions are the important attributes of role. Responsibilities determine functionality and permissions thus identify the resources that are available to that role in order to realize its responsibility. According to the different business processes, roles can be instantiation. Roles are played by agents. And agents are selected to play roles based on their capabilities and qualifications.

The specification of business processes is done by using a business process definition language. For every business process, the sub-processes, the tasks and the conditions among the sub-processes and tasks are specified. Additionally, every sub-process can be carried out by certain roles. Some roles can be executed by local agents including human and intelligent agents, while other roles can be filled only by remote enterprises, which need collaboration.

The business process registration performed by deploying the existing service types provided by the agents. If there is no associated service type for a particular process, a new one is being created by possibly inheriting existing service types. During the registration process, certain values for certain attributes related to the service type, like location, quantity, etc., are specified. These attributes are usually related to the provision of the process to remote enterprises. In addition to the service provision related attributes, a set of attributes that will influence the negotiation process is also specified e.g. price.

The business process is fulfilled by a set of autonomous agents that cooperate to provide the requested business process. And our agent-based business process management has following features:

- More than one independent enterprise can be involved in the business process.
- The number of enterprises which join in the business processes might be static or dynamic according to the needs and requirement of the system.
- The time limit of business relationships among the partners can be short, medium, or long term.
- It is robust that can cope naturally with failure.
- It offers greater agility since new services can be added and configured with minimal effect on other agents.

In our framework, we use roles to construct the relations between task-environment and agents. Agents can enact some roles according to their capabilities. Role modeling of business process is an important problem and includes following aspects:

First, there need an explicit specification of roles which specifies the capabilities of role enacting agents and interrelations between roles.

Secondly, according to the specification of roles, different roles can be dynamically assigned to agents (humans or software agents) in a deliberate or reactive way. Such assignment may be temporary since an agent may play it in a well-defined period of time or in a well-defined context.

Thirdly, certain methods are adopted to specify which roles should be employed in a business process instance for achieving specific goals. According to process instance the interrelations between roles are designed which specify how role enacting agents could interact with each other. Roles can be generic and are not tightly bound to specific application.

Fourthly, it is important to revise the assignment of roles to agents or deactivating existing agents because of the openness and dynamics of environment. There needs a complex mechanism to control such processes.
3.3 Generic Architecture of Intelligent Agent

Intelligent agents should be autonomous, cooperative and adaptive. The term ‘agent’ is used here, following in the sense that “an agent is a computer system, situated in some environment, that is capable of flexible autonomous action in order to meet its design objectives (Jennings, NR, etc. 1998). In this paper we use the BDI (Belief, Desire, and Intention) model to model the business process agents. BDI agents are driven by their internal mental states. A mental state is comprised of three concepts:

Beliefs: the information that agents currently believes true. This information could be about the agent internal state or about the environment.

Desires (goals): Desired future states.

Intentions: Commitment to action. In certain situation an agent might have a number of possible plans. The selected plan and the commitment to taking actions become an intention. In other words, an intention is an instance of plan.

![Diagram of Architecture of Intelligent Agent]

Figure 3. Architecture of Intelligent Agent

In figure 3, we provide a generic architecture of intelligent agents. Its main components include communication module, control module, reasoning model and knowledge base. Conceptually, each time that an agent is notified of an event, it updates the goals which stored in the knowledge base accordingly, and it activates the reasoning module. The reasoning module can read these changes in the knowledge base, attempts to deduce new plans(intentions) and refute the existing ones, and updates the mental state stored in the knowledge base accordingly. Depending on the state of the knowledge base after the revision process, the control module determines whether it should terminate the execution of services, suspend the current services or create a new service. It is also through these modules to control the interactions between different agents.

4. Negotiation and Coordination Technologies

According to management process of our system we know that when the roles cannot be executed by the local agents, collaborations between different enterprises are needed. In the environment of an open electronic market, there are many potential enterprises that have the ability to play such roles. How to select the most appropriate enterprise is another important problem which need to be solved.

The whole process can be classified as three stages: First, when needed the system declares the specification of the roles to the electronic market. Secondly, all enterprises which are interested to fill such roles can submit bids to the system. Then the system filters all enterprises based on the evaluations of their bids. And the remainder enterprises are the potential partners. Thirdly, just the system and potential partners carry out one-to-many negotiation to determine the best partner.
Otherwise, our system contains many different agents. And in order to enact their roles, these agents typically interact and negotiate with each other or the system to coordinate their actions and obtain the services they require.

All agents must adhere to a negotiation protocol. The protocol defines the interaction processes. Negotiation is initiated when an agent utters *cando*. The system can then either indicate that it is capable or that it is not. If the system has acknowledge the agent’s capability or if the agent knows it is capable because of information contained in its knowledge base, the agent may send out a proposal which is based on the roles that agent want to enact. The system can then either reject the proposal, accept the proposal, or give a counterproposal. If the system accepts, the agent may either deny the contract to the system or else confirm the contract. Otherwise, if the system has given a counterproposal, then agent may either accept the new contract, reject it, or else propose a new contract. There may be several rounds. If it is the agent who eventually accepts the contract, then the system may decide to either award the contract to the agent (negotiation is success) or else deny it to that agent (negotiation is failure). The negotiation process specifies the roles of agents.

5. Conclusions

Because of the emergence of new business models, there is renewed interest in redesigning the business process by adopting a new approach. This paper describes the conceptualization and design of an agent-based business process management. In our framework, the business process is model as different roles which performed by various agents. And the use of roles increases the flexibility and adaptability of agent-based system.

Then several research efforts have been spend on managing dynamic business process. For example, we have separately designed the conceptual framework and the architecture of intelligent agents. Our approach can well adapt the dynamic business environment and present a new direction of designing business management system. But most of them are conceptual and need further researches.

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