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Abastract

As the collaboration between companies is facilitated in e-business environment, inter-organizational workflow management becomes an important issue. Because the inter-organizational workflow consists of autonomous organizational workflow, the coordination of these autonomous processes is required. In this paper, a local viewed inter-organizational workflow model is proposed, in which an inter-organizational workflow is defined as a set of block activities. Exception handling rules for internal process are defined with pertinent block activities. Based on the suggested model, a multi-agent system and a coordination algorithm are proposed. For the illustration of the suggested model, an example inter-organizational workflow about book order process is presented.

1. Introduction

The workflow management as a technology that automates business process is widely used for organizational process. As the collaboration between companies is facilitated in e-business environment, the integration of organizational workflows becomes an important issue. But there are many obstacles for the integration. Ideally, details of each participating company's workflow should be opened and linked tightly. But each participating company reluctantly opens details of its process and hands over the authority of control to other companies. Moreover, various heterogeneous systems are used in participating companies. So in reality each participating company executes its own work independently and passes the results. This type of collaboration cannot manage the frequent changes or exceptions in the e-business environment appropriately [1].

There are several approaches for dealing with the inter-organizational process. WfMC suggests the standard inter-workflow interface in their reference model in order to link workflows [19]. It supports the exchange of limited control messages including queries and changes [20]. Recent approaches for web service propose the interface standard in order to link services provided in the web [4]. They support the invocation of other company's process and the returning of the results of that service. But they don't consider the characteristics of inter-organizational process. Existing researches cannot be applied directly to the real situations of the inter-organizational process.

In this paper, the concept of 'block activity' is proposed for modeling autonomous participating workflows. Block activity is the unit of inter-organizational workflow and is the boundary where independent execution is guaranteed. Block activity refers internal activity set of external sub flow. Internal activity set contains applicable exception handling rules. External sub flow contains the information of pertinent company. The criterion of internal and external is depending on who the owner of the workflow is, so proposed inter-organizational workflow model only captures partial view of the whole process in perspective of each company.

To implement the adaptive inter-organizational workflow, multi-agent system is used. This multi-agent system is laying on the existing legacy process management systems and determining the exception handling process. The agent layer communicates with legacy systems using standard XML messages, so the heterogeneity problem can be overcame. To resolve the effects of invoked change or exception on the inter-organizational workflow, software agents coordinate about the requirements for exception handling to attain the common goal. One agent per each company infers the exception handling rules and determines the effecting boundary. Change propagation is invoked when the effect of exception handling is over the boundary of the block activity.

This paper is organized as follows. In section 2, the characteristics of the inter-organizational workflow are described with an example process. Section 3 briefly reviews related works. Section 4 presents the suggested inter-organizational workflow model and its components. Section 5 presents the multi-agent system for adaptive inter-organizational workflow and the coordination mechanism between participating agents. Section 6 presents the detailed description of example inter-organizational process and the usage of the proposed model for some probable exception cases. Finally, section 7 presents a conclusion and further research issues.

2. Inter-organizational Workflow

Inter-organizational workflow can be defined as the shared process where several companies are involved in [17]. In this section, an example of inter-organizational workflow is described in some detail. This example will be used later to illustrate our approach. [Figure 1] is a supposed book order process in the e-business environment.
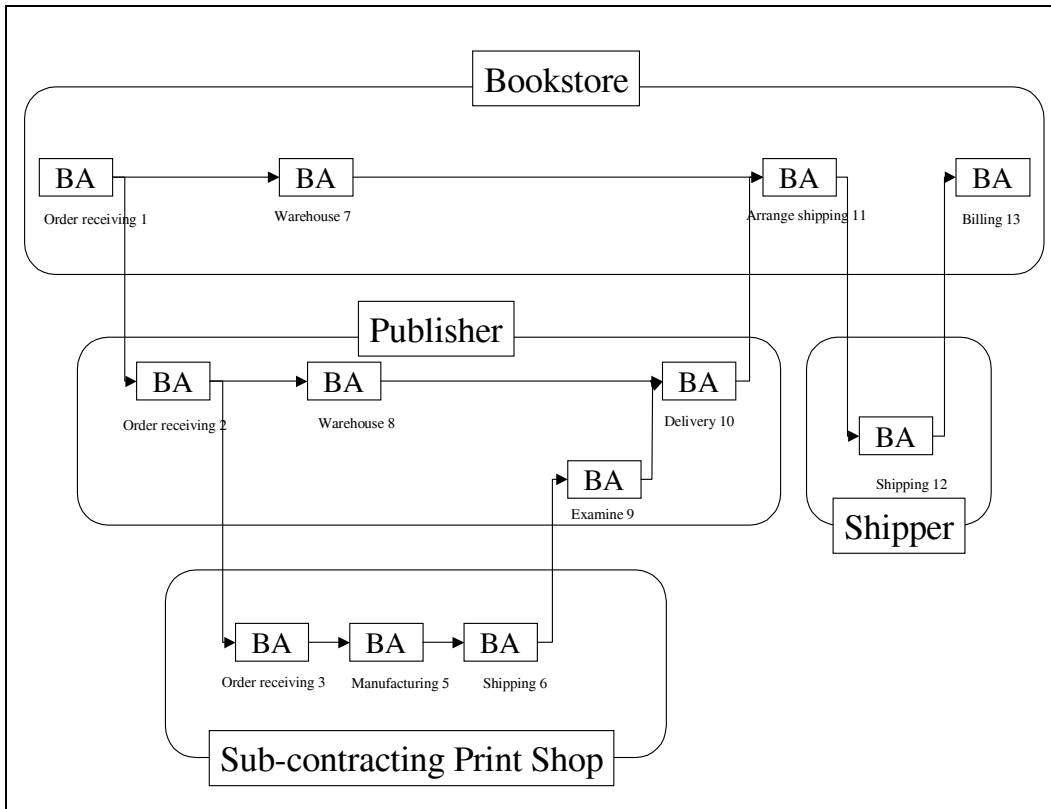
[Figure 1] Inter-organizational process of book order

Consider that a customer places an order for books with Internet bookstore, such as Amazon.com. The bookstore checks the stock of ordered books and in tern places orders for shortage of books with the publishers. At this time, the control of the whole inter-organizational process is handed over to the publisher. The publisher checks its own publishing schedule and updates the publishing schedule. The update of publishing schedule includes placing orders for required raw materials, such as printing paper. After finishing the publisher's internal process, the control is returned to the bookstore. The bookstore determines the shipper and requests delivery. The shipper then coordinates the delivery according to its schedule. Finally, the completion of delivery triggers the last of internal process of bookstore.

This simple example describes the normal process of book order. Of course there is no problem if the process is followed the process just as described above. But there is no means to deal with any situations of unexpected exceptions. For example, the customer may cancel or change his issued order when the order is conveyed to the publisher. The publisher may not be able to print the books as committed or the shipper may not be able to deliver on time. Actually considering cancellation policy of Internet bookstores, they allow cancellation only before the process control is handed over to outer companies, such as publishers or shippers. In the customer's perspective, the cancellation for the perceived single book order process is limited because the process is performed by multiple participating companies.

This limitation wastes customer's time and money and increases customer's dissatisfaction. In the bookstore's perspective, this limitation increases the returning rate and diminishes the profit. So the cancellation option should be possible until the cancellation cost is smaller than the returning cost (including the wasted time value).

The characteristics of inter-organizational workflow are summarized as follows. First of all, the participating companies are autonomous and decentralized. It differs from the established assumption that one main process and other subsidiary processes join the master/slaves relationship. Any company has no right to verify or to control other's processes. Each participating company can control only its own internal process and inter-links outer process via limited messages equally. As seen above example, bookstore cannot directly order publishers or shippers to cancel their internal processes.

Next, participating companies use heterogeneous models and systems for internal process management. This characteristic makes the inter-organizational workflow a very troublesome and difficult issue. The standardization organization, such as WfMC, tries to define a common reference model and interface standards. But this effort is limited because of variety of legacy systems and newly supported services.

For all that, participating companies collaborate with each other for common goal. They are not in a competitive mood, but cooperate for the common goal such as order fulfillment. The inter-organizational workflow should be functioned as a seamlessly integrated

workflow. In order to attain this requirement, the inter-organizational workflow should be adaptive and flexible to the various exceptions and changes that are brought by customers or external environment.

As seen above, the current situation of inter-organizational workflow is just a linking of autonomous workflows for normal execution. The inter-organizational workflow defines the mapping relationship of input/output information and signals between workflow. There is no way to handle abnormal situation. Especially in the e-business environment, exceptions and changes occur frequently and the effect of them is not only on the process of origin but also on the other companies' processes. Even though the current situation is only an intermediate stage, the ultimate goal should be a virtual enterprise that is the seamless integration of e-business.

3. Related Researches

Many works for workflow modeling are based on the input-process-output(IPO) approach [13]. It provides the task-oriented view on the workflow, that is, a workflow is considered as a set of interrelated tasks which processes inputs and produces outputs. This approach is good for modeling structured workflow such as business trip approval process and purchasing process. On the other hand, the language/action approach is also used for workflow modeling [12]. It focuses on the conversations between workflow participants, and has merits for modeling unstructured workflow such as project planning. Some researchers employ object-oriented approach for workflow modeling and enactment [10]. Bose presented five classes of objects as key constructs: roles, organization structures, procedures, transitions, and documents. In his model, workflows are executed through message passing between participating objects of the workflow. Both of Chang and Scott and Jennings et al. suggested agent based approach for workflow management. In their architecture, autonomous and problem solving agents interact through their own protocol to achieve the workflow management goals.

The issue of flexible workflow management has been addressed in Casati et al., Reichert and Dadam, Dellen et al., and Bogia and Kaplan [5]. Casati et al. suggested a set of primitives that allow for the modifications ofworkflow schema, and introduced taxonomy of policies to manage the evolution of running when the corresponding workflow schema is modified. Reichert and Dadam defined a complete and minimal set of change operations that support users to modify the structure of running workflow while maintaining its structural correctness and consistency. Dellen et al. suggested the CoMo-Kit system in which it is possible to refine and extend the software process model during the process execution using the dependency management and the change notification mechanism. In these studies, managing the changes such as adding or deleting tasks and changing predefined task sequences are the main concern without considering mechanisms to handle changes in the organizational structure and business rules.

Basu suggested intelligent e-service as the future of workflow in e-business environment [1]. It contains negotiation, complex querying, and exception handling, etc. Aalst, et. al. suggested a public and private workflow for inter-organizational workflow modeling [14]. This formal modeling permits verification of soundness of inter-organizational workflow. But this model requires full information of the inter-organizational workflow before the execution, which is unrealistic in reality. Moreover, this formal model can't reflect the frequent changes or exceptions in e-business environment. Joeris used reactive task agents for flexible inter-organizational workflow [6]. But suggested multi-agent system is not compatible with existing workflow management systems. WfMC suggested the workflow reference model and 5 types of interface [18] [19] [20]. But they defined minimal standards so using only these interfaces for implementing adaptive inter-organizational workflow has limitations.

4. Inter-organizational Workflow Model

The proposed inter-organizational workflow model is based on the following two basic assumptions. First, there is no global and perfect view of inter-organizational workflow. Any one of participating companies doesn't have to play the central role of managing the inter-organizational process and doesn't have the right to do so. Each participating company sees the inter-organizational workflow in its own view point. One inter-organizational workflow can be defined differently depending on who defines the inter-organizational workflow. Each company performs its internal process and interacts with other companies for inputs and outputs as defined in the local viewed inter-organizational workflow. The global view is only attained via coordination of local views of participating companies.

Second, the model for inter-organizational workflow not only defines the normal sequence of inter-organizational process, but also manages the rules for handling exceptional situations. As explained in section 2, the inter-organizational process in e-business is exposed to many exceptions and changes and the inflexibility of inter-organizational process is the main obstacle of customer's satisfaction. The change or exception in the inter-organizational workflow effects not only on one participating company's process, but also on several companies' processes. Each participating company has its internal policies for exception handling on its internal process and makes decisions depending on the status of internal process at that moment. The exception handling of full inter-organizational workflow is achieved by coordinating the partial exception handling of participating companies.

The proposed inter-organizational workflow model is summarized as in [Figure 2].
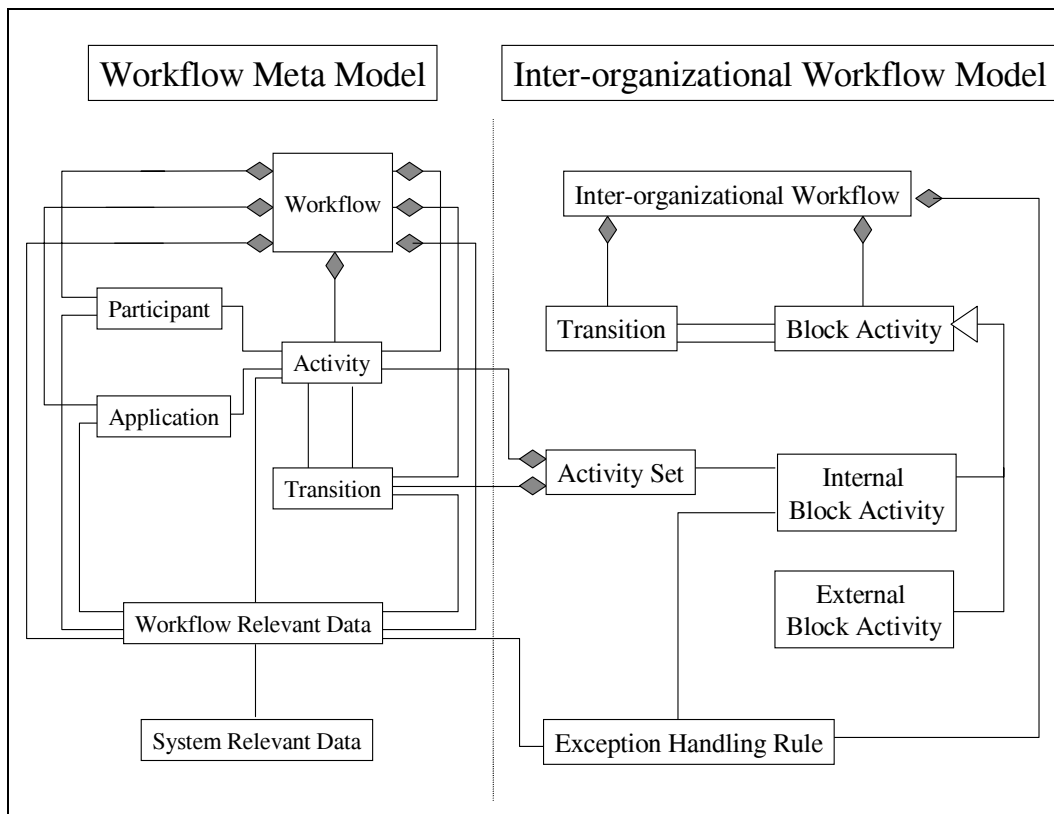
[Figure 2] The inter-organizational workflow model

In this model, an inter-organizational workflow is defined as an ordered sequence of 'block activities' in contrast to that the existing intra-organizational workflow is defined as a ordered sequence of activities. The 'transition' represents the precedence relationship between block activities. The 'resource' captures the information, documents, artifacts, etc, which are exchanged between block activities as inputs or outputs.

4.1 Internal and External Block Activities

The concept of 'block activity' is used as the basic unit for modeling inter-organizational workflow. Block activity is classified into two types by their control authority; internal and external. Because internal and external are relative concepts, inter-organizational workflow model of each participating company is different with one another. This local view of inter-organizational workflow is the appropriate modeling mechanism for autonomous workflows. Participating companies don't have to open their detailed process definitions nor permit access control to their confidential processes. They only abstract their process into a number of block activities and inform the information about them to other participating companies.

The internal block activity refers a separately defined set of internal activities, which have high coherence and share common inputs and outputs. The activities of the referring activity set are already defined in the internal process definition, such as organizational workflow model. The internal block activity is the boundary of independent and autonomous execution of internal process. The control of inter-organizational workflow is transferred to the pertinent company while its internal block activity is executed. Each internal block activity has inputs and outputs for their execution, which are defined in the resource part of inter-organizational workflow model. Participating companies define and manage exception handling rules for each internal block activity. Exception handling rules are defined

The external block activity refers an external process and is perceived as a black box with pre-defined inputs and outputs. But this black box is not a fixed environmental variable, but a negotiable entity. If the effects of some exception handling rules come over to this type of block activity, the appropriate request for exception handling should be passed to the pertinent company and the result should be checked before the actual exception handling.

4.2 Exception Handling Rules

An exception handling rule is composed of three parts; request type, condition, and result. There are six generic 'request types'; cancel, suspend, resume, roll-back, expedite, and change. The first five is for the process control and the last one is for the information control. Every complicated exception can be interpreted into the combination of these six generic request types. Detailed description for each request type is summarized in the [Table 1].

[Table 1] 6 generic request types for the exception handling

Control	Request type	Description
Process	Cancel	Cancel the currently executing process
	Suspend	Suspend the currently executing process temporarily
	Resume	Resume the currently suspending process
	Roll-back	Roll-back the currently executing process to a certain point
	Expedite	Expedite the currently executing process until a certain time
Information	Change	Change the value of inputs of currently executing process

```
<ExceptionHandlingRule Id="1" name="cancellation for publishing">
    <RequetType>Cancel</RequestType>
    <Conditions>
        <ActivityConditions>
            <ActivityCondition Id="activity23" state="unstarted"/>
        </ActivityConditions>
        <ArtifactConditions>
            <ArtifactCondition Id="publishing schedule" state="generated"/>
        </ArtifactConditions>
    </Conditions>
    <Results>
        <ActivityResults>
            <AcitivtyResult Id="activity22" state="unstarted"/>
<AcitivtyResult Id="activity21" state="unstarted"/>
        <ArtifactResults>
            <ArtifactResult Id="publishing schedule" state="not_exist"/>
        </ArtifactResults>
        <Costs>
            <Cost name="scheduleing cost" value="$4.5"/>
        </Costs>
    </Results>
</ExceptionHandlingRule>
```
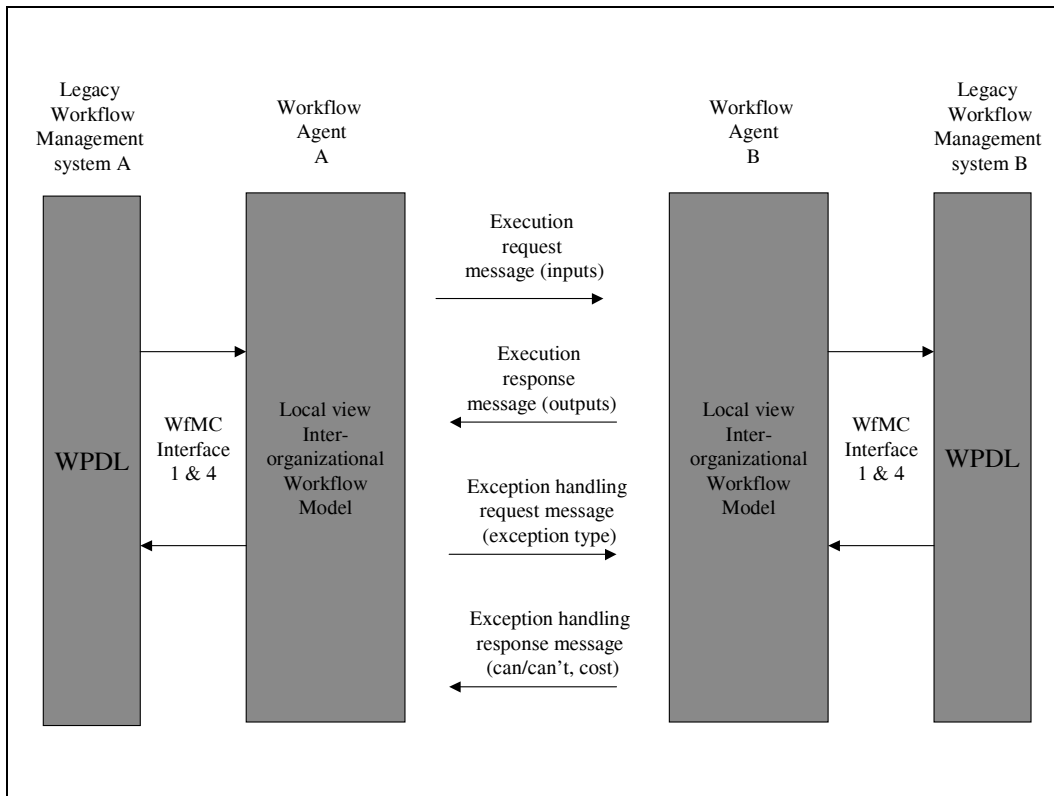
[Figure 3] Example representation of an exception handling rule

The 'condition' specifies the required status of inputs, outputs, and activities of referring activity set. The 'result' specifies the resulted status of inputs, outputs, and activities. The status for inputs and outputs is defined one of followings; not_exist, generated, and a specific value. The status for activities is defined one of followings; unstarted, running, suspended, completed, and aborted. And the incurred cost is also specified in the result part. The incurred cost can be used in the negotiation process as the criteria for a decision making about exception handling. [Figure 3] is the example representation of an exception handling rule.

5. Multi-agent System for Adaptive Inter-organizational Workflow

In order to be adaptive, the inter-organizational workflow should handle exceptions accordingly, even though the effects of the exceptions go over other participating companies' processes. Each participating workflows are autonomous, so the exception handling of inter-organizational workflow is only achieved by the coordination between participating workflows. Software agent has communication and reasoning capabilities for problem solving, so multi-agent system is a suitable mechanism for implementing this coordination. Each software agent represents its belonging company and interacts with legacy process management systems, such as organizational workflow management systems. So this multi-agent system is an additional layer on top of the legacy systems. The multi-agent system for inter-organizational workflow is depicted in [Figure 4]. Each workflow agent defines its own inter-organizational workflow model based on the model defined previous section. It also manages exception handling rules for each internal block activity.

Legacy Workflow Management system A

Workflow Agent A

Workflow Agent B

Legacy Workflow Management system B

WPDL

WfMC Interface 1 & 4

Local view Inter-organizational Workflow Model

Execution request message (inputs)

Execution response message (outputs)

Exception handling request message (exception type)

Exception handling response message (can/can't, cost)

Local view Inter-organizational Workflow Model

WfMC Interface 1 & 4

WPDL

[Figure 4] Multi-agent system for adaptive inter-organizational workflow

Each workflow agent separately defines local viewed inter-organizational workflow model and controls the normal execution of it. When the turn comes round, the workflow agent receives pre-defined inputs for its internal block activity from external block activities and conveys them to the legacy process management system. After finishing the execution of block activity, the workflow agent collects outputs and delivers them to the appropriate workflow agent of next block activity. The workflow agent also actively monitors exceptional situations and coordinates the exception handling. The workflow agent follows the coordination algorithm for exception handling as described in the [Figure 5]. The more detailed coordination process is presented in section 6 with example case that is explained in the next section.

1. *Depending where the exception is occurred*
   A. *If the exception is occurred in the internal block activity, detect the exception and decompose it with 6 generic type exception handling request*
   B. *If the exception is occurred in the external block activity, receive the exception handling request*
2. *Query the status of its workflow and update the fact base for reasoning the exception handling rules*
3. *Choose the currently executing block activity*
   A. *If the currently executing block activity is internal, fire the exception handling rules for that request type and adds results into the fact base*
   B. *If the currently executing block activity is external, request the exception handling to the workflow agent and wait for the response*
   C. *Find the next influenced block activity and repeat stage 3*
4. *If there is no more influenced block activity or the response is impossible, then response back the requester whether the exception handling can be successful or not*

[Figure 5] Coordination algorithm for exception handling

6. Example Inter-organizational Workflow

In this section, the Internet bookstore example is revisited. As described in section 2, there are 4 participating companies in this example; bookstore, publisher, shipper, and paper manufacturer.

The bookstore's view for this example inter-organizational workflow is as follows. The customer's order is received and processed. Then orders for some out-of-stock books are issued to the appropriate publishers. While the publishers supply ordered books, the bookstore finds its own warehouse for stocked books. When all ordered books are prepared, books are checked and packaged for shipping. The shipper delivers ordered books to the customer. After shipping, bookstore's billing process is started.
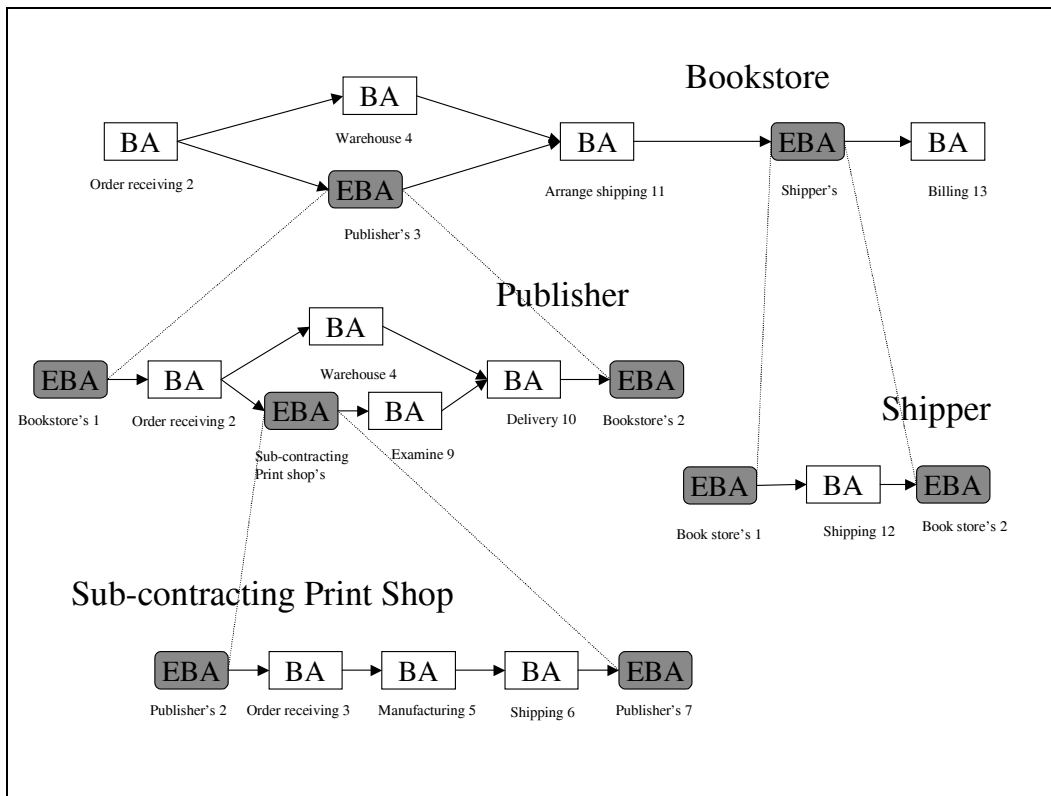
The publisher's view for the same process is fairly different. Publishers don't care who ordered their books or to where their books are delivered finally. They only fulfill the order from the bookstore. The publisher checks its warehouse stocks and re-schedules out-of-stock books. In tern, the subcontracting print shop prints and delivers books as the publisher's schedule. Then the publisher examines the delivered books. Finally, the publisher delivers ordered books to the bookstore and its role is over in this inter-organizational workflow.

In the shipper's view, the process is simple. The bookstore requests the delivery of some books to the customer. The shipment schedule is made and shipping is accomplished. Then the result is notified to the bookstore.

In the subcontracting print shop's local view, the publisher initiates the inter-organizational workflow. The publisher requests to deliver books to it as their schedule. The print shop follows some internal activities and finally delivers requested books. Then the publisher executes its remaining tasks.

[Figure 6] represents four local views of participating companies. There is no global view, which covers all participating processes. Four companies participate in the same inter-organizational workflow, but each company only sees a certain portion of the full process. Even though the bookstore's view is the widest, it can't see the hidden process of subcontracting print shop. The suggested model reflects this substantial characteristic of inter-organizational workflow. The each local viewed inter-organizational workflow model abstracts the full process using internal and external block activities.

[Figure 6] Modeling of example inter-organizational workflow using block activities

book store agent 1A. Detect the cancellation exception from the customer and decompose it as the cancel type exception handling request 2. Query the status of bookstore's workflow and update the fact base 3B. Current executing block activity, 'publisher's 3' is external, so request the exception handling to the workflow agent of block activity 'publisher's 3' and wait for the response		
	publisher agent 1B. Receive the cancellation exception 2. Query the status of publisher's workflow and update the fact base 3A. Current executing block activity, 'print 10' is internal, so fire the exception handling rules for that request type and adds results into the fact base 3B. Current executing block activity, 'paper manufacturer's 9' is external, so request the exception handling to the workflow agent of block activity 'paper manufacturer's 3' and wait for the response	
		paper manufacturer agent 1B. Receive the cancellation exception 2. Query the status of paper manufacturer's workflow and update the fact base 3A. Current executing block activity, 'order receiving 3' is internal, so fire the exception handling rules for that request type and adds results into the fact base 4. There is no more influenced block activity, so response back the publisher agent that the exception handling can be successful
	publisher agent 3A. Current executing block activity, 'print 5' is internal, so fire the exception handling rules for that request type and adds results into the fact base 4. There is no more influenced block activity, so response back the bookstore agent that the exception handling can be successful.	
book store agent 3A. Current executing block activity, 'order receiving 2' is internal, so fire the exception handling rules for that request type and adds results into the fact base 4. There is no more influenced block activity, so response back the user that the exception handling can be successful		

[Figure 7] Coordination process between agents of example inter-organizational workflow

The exception handling of inter-organizational workflow is a practical problem especially in the e-business environment. Each participating company can't have the control over other's autonomous process. Each company only has the right to control its own internal process. So in reality, most of Internet bookstores permit users to cancel their orders only before the process is handed over to other company's control.

For example, assume that customer wants to cancel his/her order when the bookstore already handed over the order for the out-of-stocked books. In this case, the control is on the publisher, so the bookstore can't permit customer's cancellation request. The customer has no option, but returning the delivered package after the delivery. This inflexibility raises the customer's inconvenience and lowers the customer's satisfaction. Of course it brings high returning rate to the bookstore.

Using the multi-agent system as described in section 5, this kind of exception handling can be resolved. If each participating company models its internal policy for exception handling, the exception handling process can be checked by coordination between workflow agents. The coordination process of this example case is summarized in [Figure 7]. This posterior verification for

exception handling is different from the prior verification of other formal inter-organizational workflow modeling. The assumption that the information of all participating companies' processes is fully known before the execution is too strict. The decision according to the exception handling rules is dependent on the situations of the company, so the inter-organizational workflow can be more adaptive. This coordination can defer the deadline for cancellation and it must have a good effect on customer satisfaction and returning rate.

7. Conclusions

In this paper, a local viewed inter-organizational workflow model was suggested to achieve adaptive inter-organizational workflow. Especially in e-business environment, this model can play the role of intermediate stage. Each participating company has its own autonomous process. The coordination of this autonomous process is important for the inter-organizational workflow to be adaptive. The suggested model uses the concept of block activity. The inter-organizational workflow is abstracted into internal and external block activities. Internal block activity refers an activity set and also contains related exception

handling rules for that activity set. The external block activity refers the owner of that part of process. This modeling is relative and only reflects its local view point. The exception handling rule is defined using 3 slots; exception handling request, conditions, and results. There are six types of exception requests.

A multi-agent system based on the suggested inter-organizational workflow model is suggested and an example case of inter-organizational process is explained. Each workflow agent interacts with legacy workflow management system for querying the current internal status and communicates with each other workflow agents for normal execution and exception handling of inter-organizational workflow. The book order process example illustrates how the autonomous processes can be coordinated in the multi-agent system and how the adaptiveness is achieved.

Further research issues includes revising the suggest model to compatible with existing workflow models including WfMC's reference model. And experiment of the suggested multi-agent system with some commercial workflow management systems is under way.

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