Agents and workflow engines for inter-organizational workflows in e-government cases

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Abstract

Purpose – The paper aims to propose a web-based “intermediation hybrid architecture” for a workflow management system that integrates services by exploiting and combining the advantages of strict centralized topologies that use workflow engines, with totally distributed systems which use agent technologies.

Design/methodology/approach – The proposed operational and technical architectures define the combination of a workflow engine and a software agent platform for the appropriate management of inter-organizational workflow processes. The proposed system is called “hybrid intermediation portal.”

Findings – The hybrid system was used in e-government cases for the management of cross-border workflows that span across multiple European chambers of commerce and industry. That demonstrated the usefulness of the specific approach in the inter-organizational workflow management domain.

Research limitations/implications – The approach presented in this paper was implemented and validated in real e-government cases that proved the advantages of the potential commercial use of the system. Several limitations were located due to the lack of a wide use of web services within governmental organizations.

Practical implications – Concerning security issues, it would be necessary to integrate appropriate security mechanisms without constraining the technical and functional characteristics of the software agents involved.

Originality/value – The contribution of the paper concerns the evolvement of the agent-enhanced workflow management systems in order to tackle the intelligence issues and the credibility problems concerning the overall control of dispersed inter-organizational processes.

Keywords Business environment, Communication technologies, Computer networks

1. Introduction

With the development of the world wide web and its establishment as the most important platform through which data and services are accessible for humans and programs, a new challenge raised concerning not only the management of workflows within an organization (intra-organizational workflows), but also the management and monitoring of business processes that span the boundaries of a single organization (inter-organizational workflows) (van der Aalst, 1999; Dayal et al., 2001).

It is true that the major problems in the inter-organizational domain are related to the dynamic and distributed nature of the internet environment. Such an environment creates the necessity of constantly altering, modifying and updating the related business processes, a fact that makes the creation and monitoring of systems that operate with respect to these dynamic conditions a very demanding task.
This paper proposes the development of a web-based software system, flexible enough to undertake successfully the management of inter-organizational workflows. It is called “hybrid intermediation portal” (HiP), since it is based on a multi-agent system combined with a workflow engine. The proposed operational and technical architectures of HiP exploit and combine the advantages of strict centralized topologies with totally distributed systems that use agent technologies.

It is true that nowadays, more fluid business processes are needed, such as in e-commerce, or e-government. This is stressed out in the scenario presented in Section 5, where we focus on cross-organizational services addressed to companies that require interaction with public administrations other than those of the country of origin. The services offered by government, national and regional administration agencies as well as commerce and industry chambers include simple informational and complex transactional services (issue of a legal document) with particular bureaucratic, disintegrated and dispersed characteristics. Those characteristics create the need for adaptive workflows flexible enough to constantly alter the responsible actor in each task (human interaction-totally automated response to a request), or even the process logic itself (e.g. task redesign in case a new law dictates the need for the acquisition of a new document for the registration of a foreign branch). In such situations, it is not always possible to predict in advance all the parameters that may be important for the overall processes.

The main contribution of our so-called “hybrid intermediation architecture” is that it upgrades the agent-enhanced inter-organizational approaches made so far by alleviating the restraints in the intelligence of the agents, using two agent layers with one workflow engine for creating a single one-stop point for electronic services. Our purpose is to fulfill the increased needs of the inter-organizational domain.

In Section 2, we refer to the issues that are located in the inter-organizational workflow management domain. The hybrid operational and technological approach are described in details in Sections 3 and 4, respectively, where Section 5 presents the implementation of HiP in a specific e-government scenario. In Section 6, a brief review is presented of related work that tries to tackle the special problems of the e-business inter-organizational domain, while Section 7 concludes the paper and discusses directions of future work.

2. Issues in inter-organizational workflow management domain
The business process analysis from several industrial, commercial and research areas helped in the identification of the special characteristics of processes that span across organizations:

- A number of organizations are involved in these business processes and each of them tries to maximize its profit during an inter-organizational workflow (Jennings et al., 1998).
- Organizations are naturally dispersed among different areas, countries or even continents, creating problems.
- Inside an organization there is a decentralized ownership of tasks, information and resources regarding the business processes.
- Different groups inside an organization act autonomously in order to control how are the resources consumed, from whom and with which cost and time limits.
- Nowadays, business processes are dynamic and unpredictable. Many detailed time plans are often reversed due to inevitable delays and incidents.
The main issue concerning the inter-organizational workflows is that in a certain extent the involved organizations are obliged to share process descriptions, types and workflow instances. The problem is that these kinds of data include important details of their internal business processes, their action plans and their tools and resource usage that are considered to be classified information of competitive value. So, their distribution should be avoided. Nevertheless, at the same time businesses need to participate in virtual enterprises and inter-organizational workflows in order to advance their productivity, their quality and their capability to get involved in bigger projects. We identify three main categories of issues that prevent the satisfying development of workflow management systems that can be used for inter-organizational business processes:

(1) **Organizational issues.** The way that the products, tasks, business rules, structures and allocation of responsibilities are described is quite different among enterprises. This is a fact that makes it very difficult for an enterprise to successfully dictate its business (sub-) processes that the suppliers must use or even more to integrate to its internal legacy systems foreign workflow logic. This is exactly why the agreements between organizations prove to be much too expensive since it is difficult to be established and cross-checked.

(2) Issues concerning the task definition and management. In workflow management level, the abstraction of a workflow element and its asynchronous re-insertion often causes severe problems in the whole workflow.

(3) Systemic and technical issues concerning the statistics record and the distributed tasks monitoring with a centralized approach.

We can understand that the traditional solutions which are focused simply on the provisional modelling of processes are no longer sufficient due to the fact that the traditional workflow management systems have rigid, centralized architectures which do not operate across multiple platforms.

On the other hand, employing a distributed network of autonomous software agents that can adapt to changing circumstances would result in an improved workflow management system as it was argued in the agent-based workflows in Borghoff *et al.* (1997) and Debenham (1998) here the software agents take full responsibility for process provisioning, enactment and compensation. Their consolidated use instead of web services is a fact based on the agents’ intelligence and capability to communicate and react to stimulations. But even in these approaches the lack of a credible centralised control creates problems in the real commercial exploitation of the totally decentralised agents’ architectures.

### 3. Operational architecture

Considering both the complex workflow-oriented interactions among the services, and the complex interactions of agents internal to architecture in an inter-organizational environment, we propose a web-based “hybrid intermediation portal” that can integrate the services offered by any organisation or government administration agency in the context of inter-organisational processes. Our aim is to tackle the special needs that arise in cases like the one described in Section 5 that require at the same time centralized control, distributed use, easy monitoring, flexible and intelligent workflow execution.

From the operational perspective, the HiP is established in the centre of a star-like topology, in which any service provider can participate by establishing one more
gateways for service offerings, while end-users get a single point of contact for acquiring the desired services. When a service request is posted the HiP handles all complexity of initiating, coordinating, controlling and monitoring service offering processes by combining the workflow logic with the intelligence of the appropriate agents. Theoretically, the inter-organizational communication still exists between the HiP and the service providers or the end-users but this time the burden is alleviated due to the structured intermediation.

The HiP is a support system for electronic service delivery that involves dispersed suppliers and end-users, trying to emphasize on the facilitation of locating services, on the service delivery speed and the user-friendliness. HiP comprises of seven discrete subsystems (Figure 1) that are presented below:

1. **Information management subsystem**, which provides the capabilities of forms processing and transfer/distribution of files.

2. **Communications subsystem**, which undertakes, on one hand, the communication between the workflow engine and the agent platform and on the other hand the communication between the system and the end-users.

*Figure 1. HiP’s functional architecture*
(3) **System management subsystem**, which gives to the end-user the opportunity to register with the system and the system administrator to manage and process all the data related to the end-users profiles.

(4) **Software agent management subsystem** that provides the means for agent’s invocation and activation, which is located in the related registry in order to undertake fragments of workflow instances.

(5) **Workflow management subsystem** that undertakes the modeling process and the automation of inter-organizational workflow instances.

(6) **User interface subsystem**, which facilitates and accelerates the system offerings, providing user-friendliness.

(7) **Access control subsystem**, which concerns the users’ registration and the authentication before they gain access rights to a specific service that they need to request.

4. **Technical architecture**

The operational model is based on a solid technical architecture which is shown in Figure 2. Each provider offers a set of services that can either be described together with associated information flows and communication channels, using appropriate online forms which then will be used by the workflow modeler as a guide to create and implement the service within our system, or can be implemented directly in case of a web service. In that way, the HiP can identify the service providers competent to serve an incoming request and employ appropriate communication channels.
The workflow engine keeps the overall process logic which selectively passes to the responsible agents enabling in such way the centralized control and monitoring. In irreversible failure cases the engine is responsible for calling back all the agents and restarting the workflow process.

An integral part of this architecture is the agent platform that facilitates the agent-enhanced functionality. The agent repository (yellow pages) and the agent management system are functional modules of any interoperable agent platform. The agent homogeneous layer consists of the message transport system which is also called agent communication channel (ACC) and the directory facilitator (DF). ACC controls the exchange of messages within the platform. The DF is the agent which searches the default yellow page service in the platform. In a multi-agent environment, each agent is assigned specific tasks. These tasks are published through the yellow pages which sustains a global registry of all agents.

According to the architecture a major task that is undertaken by an agent is the workflow block logic discovery. It is a function that refers to the discovery of the process logic of a specific workflow block from a given log. Event handling is carried out by the workflow event handler (WEH) agent. The agent’s behavior is to process any asynchronous events that may be evoked by the runtime environment of the workflow engine. For our purposes, we extend the functionality of the specific agent as it is basically the main responsible software component that is used for combining the agent platform with the workflow engine functionality by managing the exchanged XML-messages, interpreting them and invoking the competent agents in each case. The event is categorized and redirected to the dispatcher agent WS or TA. The dispatcher agent WS performs web services orchestration which is necessary for cases where the service provider side can support this kind of technology. In this case, the specific agent identifies and uses the registered web services (UDDI) according their stated function and invokes them suitably passing the necessary parameters in order to complete a certain task without human intervention. The dispatcher agent TA has the very important task of recovering from the yellow pages and orchestrating the invocation of a number of task agents that each one performs a segment of the overall requested service.

The workflow redesign refers to the business process reengineering which in our system becomes faster and less prone to errors due to the fact that it is made possible by altering only the specific “workflow block” that needs modification. Each time a WEH agent is invoked does not need to know if an alteration in the workflow block has happened, because anything concerning the process logic of the block that will be handled is acquired on invocation. This is a fact that makes the runtime reengineering possible in cases where the responsible for the altered block WEH agent is not yet invoked.

A dedicated agent, the data handler agent, is responsible for interacting with third party data sources. These sources vary from databases and LDAP servers to explicit UDDI servers. So, data handler agent has a complex parallel behavior that manifests SQL based/LDAP queries. The UDDI interface which is separate to the DF registry, serves the functionality of discovering a web service in case that dispatcher agent requests for one. Finally, the user’s interaction is accomplished by the web content publication agent. This agent is responsible for generating dynamic content. In Figure 3, we present the functionality of the described parts of the HiP in detail.

In previous work (Verginadis et al., 2004), the notion of workflow block was introduced as a non-trivially recurring group of consecutive (in the sense of control flow)
workflow nodes, with well defined (preferably single) inputs and outputs and meaningful application-level semantics that can be isolated as an autonomous segment of a container workflow. Starting from a workflow model described in XML Process Definition Language (WFMC, 2001) and based on such “workflow blocks,” a number of WEH agents are invoked to perform firstly workflow block logic discovery. The agent acquires the workflow logic of the specific block (XML parsing), which understands and decomposes it, based on a common ontology the Process Interchange Format (Jintae et al., 1998). The decomposition is performed as the WEH agent detects the simple tasks that are included in the “workflow block” and for each task searches and invokes the appropriate task agent. Secondly, they perform duplication, in case a certain block must be executed more than once with different parameters (service provider, information). Finally, they deliver consistent results gathered from the task agents.

The task agents are responsible for performing the subtasks that the WEH agent instructs. The intelligence of the specific agents is not restrained although they undertake only tasks semantically simple and indivisible. They react based on strict instructions but they communicate and move autonomously in order to identify the competent service providers (depending on their availability, their estimate response time) for fulfilling their goal. The group of the possible appropriate service providers for a specific service is already known in the system, as they have registered their services during the workflow modeling procedure or in the UDDI registry.

Concerning the implementation of this technical architecture (Figure 4), we used the OpenSymphony workflow engine which is an open source Java-based WFMS that can export in XML schema any information related to the description and invocation of a service. As an agent platform, we used the Java Agent Development Framework, which proved to be stable enough for our research effort, accompanied by a useful graphical tool which we used for the monitoring of agents’ enactment, mobility and exchange of messages.
The implementation is concluded using an SQL server for storing the data, an iPlanet LDAP Server and the appropriate web servers (apache tomcat and resin). At this point, we stress out that the use of two separate web servers for the workflow engine and the agent platform, respectively, proves the capability of the HiP system for totally distributed use even of its core technical components that can be located in physically dispersed computer systems. In the next section, we present the implementation of HiP based on our proposed architecture.

5. Implementation of the hybrid architecture in e-government

The overall objective of this section is to present the web-based, agent-enhanced “hybrid intermediation portal” that integrates the services in the context of inter-organizational processes. The services that were integrated during the first implementation of HiP include transactional services (issuing certificates for setting up a company, getting and processing Carnet ATA’s and certificates of origin) and informational services (getting info on: market, economy and regulations, trade fairs and exhibitions, companies, exporters and products, business opportunities and partner search, setting up a company and branch registration in a foreign country). The workflows for providing these services were modelled within the CB-business R&D project (Verginadis et al., 2003). The implementation of these workflows included the real service offerings to businesses by governmental administration agencies as well as chambers of commerce and industry of Bulgaria, France, Greece, Romany and Spain.

We demonstrate (Figures 5 and 6) how our system and its internal components work in the real service that concerns the electronic acquisition of a legal document.
Figure 5. Sequence Diagram 1

Figure 6. Sequence Diagram 2
(Certificate of Branch Registration of a foreign company) from a Chamber of Commerce and Industry (CCI) (Spain). The businessman (Greek) can request a service after he views the available service content provided by the Web Content Publication Agent. The workflow engine according to the appropriate workflow model, identifies the competent agents that are needed and initiates, controls and monitors the process. The WEH agent, is responsible for interpreting the XML messages from the workflow engine and for mobilizing the responsible dispatcher agent depending on whether or not the CCI provides the requested service as a web service. If this is the case then the dispatcher agent WS performs web service orchestration and delivers the legal document to the end-user. Else wise, the dispatcher agent TA identifies and invokes the capable agent to perform the certain task from the agent repository. The latter migrates to the service provider/s side/s in order to request the legal document providing the necessary data and at the same time any additional certificates or documents necessary. The latter documents frequently must be acquired by a different service provider (Greek CCI) than the one that produces the Certificate of Branch Registration (Spanish CCI). This is undertaken by the responsible task agent. Another task agent will attend, so that the requested document reaches the end-user.

The following screenshots of the HiP system present how the end-user can be informed about his/her requested services (Figure 7), how the service provider is being notified for a new request (Figure 8) and finally how the produced legal document can be downloaded (Figure 9). In Figure 10, we show the communication between the responsible agents that were invoked in order to satisfy the request for electronic acquisition of the branch registration certificate of a Greek company in the Spanish CCI.
Figure 8. List of Requested Transactional (service provider view)

Figure 9. End-User Downloads Results
6. Related work

The workflow management systems for inter-organizational business processes are categorized depending on the way that the processes are managed into:

1. Workflow engine-based systems. They normally use one or more commercial or open source Corba- or Java-based workflow engines.

2. Systems that take advantage of the software agents technology (Shepherdson et al., 1999; Yang et al., 2001; Yuhong et al., 2001) and are subcategorized into:
   - **Agent-based systems.** In these systems, software agents are used in order to model, enact, monitor and execute business processes. Basically, agents take full responsibility for process provisioning, enactment and compensation.
   - **Agent-enabled systems.** In these systems, software agents are used in order to accomplish interoperability between geographically distributed workflow management systems. Agents appear as brokers that can invoke workflow instances in different workflow dispersed engines.
   - **Agent-enhanced.** In these systems, software agents execute simple tasks that are fully controlled by workflow engines. These systems are achieved by combining a layer of agents with a commercial workflow engine. The agent layer is given responsibility for both the provisioning and compensation phases of business process management, whilst the underlying WFMS handles process enactment.

3. Web services based systems that take advantage of the WSDL, UDDI and SOAP technologies.
In efforts like (Zeng et al., 2001) agents are incorporated as formal methods for process enactment. They adopt formal approaches to the service composition, but as agent-based approach lacks of the advantages of centralized monitoring and coordination. Hetal et al. (1998) use three-tiered agent architecture for workflow enactment comprising an agent-enabled approach that has the disadvantage of restraining the agents’ abilities since they can only invoke distributed workflow instances acting just as brokers.

There are several research efforts that belong to the agent-enhanced approaches that present similarities to our work like in Yuhong et al. (2001). These agents correspond to activities one by one losing their intelligent notion and resembling to pieces of ordinary software. One notable effort in this area of distributed workflows is that of Yoo et al. (2001). Their agent-enhanced approach comprises a workflow engine which uses also blocks, with one agent layer. The main differences with our hybrid intermediation architecture is firstly that their maximal sequence model perceives the workflow blocks only as a group of sequential workflow tasks without any semantic connection between them, in contrast to workflow blocks in (Verginadis et al., 2004) and secondly the use of agent technology is constrained in only one layer of “non-intelligent” agents that just obey the workflow engine.

Efforts like CB-business project (Verginadis et al., 2003), where an intermediation scheme was developed for services offered by governmental and business service providers across the European Union, are examples of totally centralized approaches orchestrated usually by a workflow engine. The exact opposite approach can be found in research efforts like in Blake and Gomaa (2005) and Jennings et al. (1998) where totally distributed approaches to inter-organizational workflows using the agent technology for modeling, invoking and executing workflows, were argued.

It became obvious that the totally centralized approaches proved to be not flexible enough, in cases where business process reengineering and task reconfiguration is a constant necessity. On the other hand, the totally distributed approaches of agent technology can fulfil the special dynamic requirements of the e-business and e-government domain, but they lack of a credible overall control.

Specifically, the review work in the field concluded in the identification of several disadvantages of the centralized approaches:

- The coordination of geographically dispersed business processes from a central point creates a dependency between the management of workflows and the connection to the involved organizations. A possible functional interruption of the central system or a problem in the communication lines would result the failure of the whole inter-organizational workflow.

- Since the autonomy of the involved organizations is a central issue in the inter-organizational domain, a strict centralized control of all the running processes cannot be accepted.

- The involved organizations often use heterogeneous workflow management systems that are necessary to be interoperable during the management of inter-organizational processes.

- Lack of immediate reaction (O’Brien and Wiegand, 1998). These systems need a prescribed representation of the business processes and all of their possible deviations which is not easy in a distributed environment.
We found out that the agent-enhanced systems present all the advantages that make possible the appropriate enactment and management of inter-organizational workflows. Their main advantages are concluded from the:

- Exploitation of the special characteristics of software agents (distribution, autonomy, social association with other agents, environment awareness).
- Exploitation of the characteristics of workflow engines (stable and composed coordination, central control, easy process monitoring).

7. Conclusions
The HiP that has been introduced above has a potential to achieve operational integration of inter-organizational service offerings alleviating issues of this domain (Table I). Our effort upgrades the agent-enhanced inter-organizational approaches made so far by alleviating the restraints in the intelligence of the agents. Having as purpose to fulfill the increased needs of the inter-organizational domain, we have achieved the combination of a workflow management system and an agent platform. We used agents that can be registered or imported into a repository that basically contains reusable, easy to modify or correct, autonomous software components. These components can be located and connected accordingly. We managed to sustain central control of the workflow processes, providing easy monitoring of the workflow instances. At the same time, the distributed and flexible use was made possible by the proper integration with two layers of intelligent agents.

Concerning the future work, we find it necessary to evolve our system in such way in order to be able to execute workflow models that are described using ontologies. The usage of a general ontology for describing inter-organizational workflows would be a good step for reducing organizational costs, as the employment of specialists who understand and can describe the business models for each case will no longer be necessary. For an upgraded implementation of HiP it would be useful to combine a general business ontology with an (semi-)automated process for extracting specific ontologies that are useful for understanding and describing inter-organizational workflows per case. There are already research efforts that propose the use of ontologies in the workflow modeling process. Beco et al. (2005) suggests even an extension of Ontology Web Language (OWL) into OWL-WS (OWL for Workflows and Services) for covering the description needs of particularly dispersed grid services.

It is also important the technological evolvement of HiP, using artificial intelligence technologies for the integration of agent’s autonomy and intelligent behaviour (Russell and Norvig, 2003). Such an evolvement would cause the quantitative reduction

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Table I. HiP comparison
of the software agents needed to be initiated for the execution and management of inter-organizational processes.

Finally, we would like to stress the security issues that arise in the totally dispersed environment of inter-organizational workflows. Specifically, for the commercial exploitation of a system like HiP, it would be necessary to integrate appropriate security mechanisms (Alfalayleh and Brankovic, 2004) that would provide the necessary privacy and protection levels without constraining the technical and functional characteristics of the software agents involved.

References


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