Ontological Approach Towards E-business Process Automation

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Abstract

This paper discusses the interoperability of e-business processes by using an ontology approach with description logic and agent systems to achieve e-business automation. An innovative e-business process modeling framework is proposed that outlines the building blocks required for Internet-based e-business in order to enable e-business process automation. The framework helps in understanding the role of many proposed standards with respect to the building blocks and in identifying both overlaps and gaps among them. The domain knowledge of e-business processes is conceptualised as an e-business process ontology that enables agents' communication in e-business application sharing and reusing. Several agent-based automation mechanisms are discussed based on the ontology that provides implementation guidelines to e-business process automation.

1 Introduction

Internet-based e-business is possible because a set of widely established standards guarantees interoperability at various levels. However, e-business has been primarily designed for direct human processing. The next generation of e-business process platform aims at machine-processable information that enables various e-business process models. The tasks of such an e-business platform are challenging. Semantic web and Web services are the two among recent developments of e-business process approaches, which enable intelligent services, and offer greater functionality and interoperability than current stand-alone services.

Web services are software components that use standard Internet technologies to interact with one another dynamically. In this model, businesses offer Web services that applications running in other businesses could invoke automatically, which require extensive integration and development efforts to build the bridges between systems. Semantic

web, on the other hand, aims at establishment of a different level of interoperability that not only defines a syntactic form of e-business, but also a semantic content. The potential benefits of these technologies are obvious, Web services provide a platform of e-business, and Semantic web supports the intelligent business transaction mechinism to achieve processes automation. Note that W3C standardisation efforts like RDF/RDFS and OWL facilitate semantic interoperability, and several leading organisation proposals offer XML-based Web service specifications and standards that provide the build blocks for the Internet-based e-business. While technology development of Semantic web and the convergence of Web services are long term efforts, it is possible to achieve e-business process automation based on existing technologies by identifying their overlaps and gaps to reach a common understanding about e-business from the Artificial Intelligence perspective. This paper is motivated by these technologies for Internet-based e-business processes without attempting ambitiously to propose another standard of e-business. Rather, it proposes an innovative e-business process modelling framework with respect to various proposed standards and their building blocks that ontologically represents e-business processes and semantically infers among different business process standards to achieve automation.

In the proposed approach, we start with the goal of understanding e-business processes in existing e-business standard proposals. The semantic meanings and relations of these processes are exploited and constructed as an e-business process ontology. Technically, description logic is considered for describing the ontology. Furthermore, agent systems, equipping with part or full of the domain ontology and inference mechanisms, are considered as a business process platform to achieve e-business process automation. Due to space limit, we concentrate on the approach itself rather than the implementation details in this paper. Please refer to our other papers [13, 22, 23] for more information. The rest of the paper is organised as follows. In Section 2, we give a background about ontology, description logic and

agent systems, and indicate the achievables of these techniques in knowledge representation, processing and communication in e-business environments. In Section 3, we propose an e-business process modelling framework that outlines the building blocks required for e-business automation. In Section 4, agent-based communication mechanisms are discussed for e-business processes. In Section 5, we summarise our approach and indicate challenges ahead of us as future work.

2 Background of Relevant Technical Issues in E-Business Process Automation

In this section, we will review techniques of ontology, description logic and agent systems for e-business processes. In particular, we will discuss the uses of these techniques in e-business process automation, and explain the requirements of e-business process modelling.

2.1 Ontology and Description Logic for E-Business Processes

Ontology is defined as an explicit specification of conceptualisation for the purpose of enabling knowledge sharing and reuse [8]. It is a description (like a formal specification of a program) of concepts and relationships. The aim of an ontology is to capture certain characteristics of the world by defining meta-concepts and meta-relations and filling each catalogue with terms and relations. Ontologies for business process are crucial to run business in today's dynamic, complex and heterogeneous e-business environment. Although a few proposals such as SUMO (http://ontology.teknowledge.com/), Enterprise Ontology (http://www.aiai.ed.ac.uk/project/enterprise/), TOVE (http://www.eil.utoronto.ca/enterprise-modelling/tove/), and MIT Process Handbook (http://process.mit.edu/), etc. bring freshness to the state of the art in ontologies, some of them are defined in highly conceptual abstraction outlining few activities of processes, others focus on detailed elements of business modelling. None of them deal with e-business processes from the run-time perspective of what the essential characteristics of Internet based e-business are and how an e-business process is run for the promised profits. Therefore, it is necessary to develop relevant techniques that are specifically tailored to e-business such as the ontology of e-business processes. Ontology as a computation model of some portion of the world seems fitting in well with the aim of providing a shared virtual world in which distributed organisations can ground their beliefs and actions [10, 18]. It can be used as a guideline to describe requirements and business concepts [12]. Actually, ontology is nothing really new, it has been a topic in knowledge engineering (KE) [17, 19, 16, 3] and AI [6]

for a while, especially in Multi-Agent Systems (MAS) to facilitate coordination and cooperation between software agents [5, 21].

The use of ontologies in this context requires a well-designed, well-defined, and Web-compatible ontology language with supporting reasoning tools. The syntax of this language should be both intuitive to human users and compatible with existing Web standards (such as XML, RDF/RDFS). Its semantics should be formally specified since otherwise it could jeopardise the shared understanding. Finally, its expressive power should be adequate. Description logic is an ideal candidate for ontology language in defining integration and maintenance of ontologies because it provides both well-defined semantics and powerful reasoning mechanisms.

Description logics (DLs) are a family of logic based knowledge representation formalisms which are based on concepts (classes) and roles [9, 2]. The key feature of DLs is well defined semantics which ensures correctness of reasoning tasks. DLs have been influential in development of Semantic web. It is expected that Web standard ontology languages will be DL based. With this in mind, we choose DLs as knowledge representation formalisms for business processes.

The basics of DLs are mainly characterised by a set of constructors that allow to build complex concepts and roles from atomic ones, in which concepts correspond to classes (interpreted as sets of objects) and roles to relations (interpreted as binary relations on objects). In DLs, knowledge base (KB) is composed of TBox $\mathcal{T}$ and ABox $\mathcal{A}$ which represent terminological knowledge and assertional knowledge respectively. An interpretation $\mathcal{I}$ is a model of KB, namely $< \mathcal{A}, \mathcal{T} >$. Subsumption, Satisfiability, Consistency and Instantiation are issues involved in DL reasoning.

2.2 Role of Software Agents for E-business Processes

Software agents are able to act with no intervention by other entities such as humans or computer systems, having control over its own actions for achieving the given goals and tasks. Agents have been used to support virtual enterprises (VEs) in several applications [11, 1, 20, 7, 15, 4]. We recognise that all properties of software agents exist partly in reflecting a business entity, however, in terms of e-business process automation, the property of autonomy is the most interesting feature in designing agent based e-business process systems. a MAS is a computational environment that is well suited for analysing coordination problems involving multiple agents with distributed knowledge and relying on communication framework - the Internet, because it is developed aiming at the distributed, heterogeneous and autonomous properties of a system for real world

problems. Thus a MAS model seems to be a natural choice for e-business process automation, which is intrinsically dealing with coordination and coherence among multiple actors. In [14], we have experienced ontology and agent technologies in VE's formation with proposing a knowledge model and utility functions, which show these technologies the potential and usefulness in complicated business case studies.

The benefits of adopting the agent technology for e-business process automation are achievable. The inherent autonomy of software agents enables the different business entities on the Internet to retain their autonomy of information and control, and allows them to automate part of their interaction in the management of a common business process. The abstraction offered by MAS deals with the business automation by requesting that all parties involved subscribe to a common terminological computational model - the ontology, and they agree upon that the semantics of business process information is unique and universal within the scope of a relevant domain. We intent to model the Internet-based e-business processes by using the ontology approach, and develop an agent based process framework to achieve e-business process automation.

3 E-Business Process Modelling Framework

Several leading organisations have provided their standards focusing on e-business processes at different levels from Web service descriptions to e-business document formations. By revealing these standards, we found that there are several building blocks required to depict e-business processes, and form an e-business process modelling framework. Figure 1 shows an e-business process modelling framework, and gives some XML based e-business standards and their specifications to which the blocks are fitted into. Under this e-business process modelling framework, six building blocks are investigated from the available standards and their specifications focusing on the different perspectives of e-business processes. Each building block emphasises on one aspect of e-business processes, which needs to be investigated in detail. Basically, the framework describes processes required for e-business.

Business Documentation: This block describes all business documents required in business transactions and processes. It includes technical business documents as well as legal agreements under which entities conducting business reside. The technical business documents between the entities include the exact details of how the parties use their information technology infrastructure to transact the business at hand. The legal contracts include agreements on the terms and conditions of business exchange. There are various business documents such as transaction forms that are required to
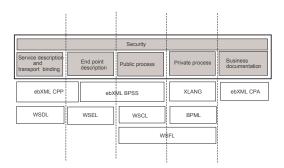

Figure 1. Building blocks of e-business process modelling framework

be understood by business entities in order to exchange business information.

Enterprise Private Process: In this block, internal executable business processes are described. It includes the processes of the enterprise value creation, as well as processes that support Web service's public collaborative processes. Accessing a private process is to obtain services provided by the enterprise, thus understanding an enterprise process is a critical issue for business coordination and interoperability.

Public Collaboration Process: It describes the sequence or choreography of the operation the Web service supports. The processes in this block are critical for e-business automation as the business concepts of private processes will commonly be invisible to the public, but the interface processes in this block are the only resources available to the outside for application calling.

End Point Description: It describes aspects such as quality of service, service location, provider information, and service cost that can influence a customer's decision to use the Web service.

Service Description and Transport Binding: This block provides metalevel data for services and their operations; transport binding that ties abstract service descriptions to specific physical addresses statically at build-time or dynamically at run-time.

Security Issues: Security requirements include a combination of features of authorisation, authentication, confidentiality, nonrepudiation, and audition. Any exchange of business information may require all, some, or no security features.

The framework only shows what the building blocks for processes are required for conducting business on the Internet. E-business is about business process automation for

which the standards and their specifications are engineered. However, because of many standards available, only partial e-business automation, so called business islands, can be achieved which means only the organisations that commit to a standard can automate business among them but not others. Thus integration of these standards has to be investigated in order to achieve business globalisation based on the backbone of the Internet. For the purpose of e-business process automation, the integration may be implemented in several ways including:

- Building bridges between these standards vertically and horizontally

- Building specification agreement among standard proposals for convergence

- Building a repository by including all standards available and their specifications

- Building ontology repository - the ontological approach

Among these integration approaches, each of them has its advantages and drawbacks. Building a bridge between two standards practically is feasible but only expands the islands. Once we intend to build many bridges among all available standards then the difficulties of off- and on-line development and management can be severe problems. The convergence approach is significant for e-business automation but it will be a long term effort of engineering. A repository of standards is to classify the available standards and group specifications of standards into the building blocks such as the modelling framework proposed. The repository then can be queried and retrieved for software components required. However dynamic management for characteristics of the repository is so complex that prevents it from being used in reality. Recently from the AI perspective, the ontological approach has been considered in dealing with heterogonous problems. Unlike the others that are working on specified standards alone, the ontological approach for e-business standards integration is based on the knowledge engineering methodology that exploits the common characteristics of e-business processes in terms of concepts, attributes and relations among the concepts and attributes. In Section 2, we discussed the aspects of ontology in e-business processes. Apart from the knowledge engineering efforts on the off-line and flexible yet robust on-line management features are appealing for e-business process automation, which will be our e-business research focus.

Under the proposed modelling framework, five building blocks with security issues concerned across each block are grounded for the e-business process ontology investigation. We believe that these blocks are the basic requirements of e-business process automation enabling. The onto-

logical approach based modelling framework is to conceptualise each building blocks from the knowledge engineering perspective. For each building block, the concepts and their relationships are studied, and organised into a tree-like matadata structure. It is possible to build such an ontology that conceptualises each building block since the existing e-business process standards and their specifications provide rich resources for constructing the ontology with available techniques such as DLs to describe the concepts and relations. Building such an ontology needs considerable implementation efforts but provides substantial benefits in e-business process automation. In Figure 2, the conceptual e-business process hierarchy shows the structure of the e-business process ontology.
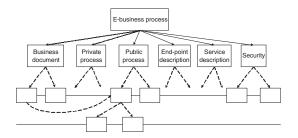

Figure 2. Hierarchy of e-business process concepts

In Section 2, the technical background of constructing such an ontology was discussed. Description logic is one of the theoretical foundations grounded for many tools, such as RDF/RDFS, OIL and others for a given domain conceptualisation. It is also possible to using declarative programming languages such as Prolog and others for reasoning. Protégé-2000 is such a constructing environment that provides many editing interfaces and plug-in facilities for constructing e-business process ontology. Figure 3 shows a screen shot of an e-business ontology under development.

4 Agent Based E-Business Process Automation

In Section 2, we pointed out the common aspects of e-business processes by using software agents that represent business entities in doing business. The functioning of e-business process automation is strictly dependent upon agent's commitment of the e-business process ontology in part or full. If agents have uncommitted decision with no consideration of the roles they play, the e-business process would not work properly and would soon collapse. Thus, there is a need for a set of rules that works as a "contract" among software agents, constraining their behaviour in order to safeguard the interests of the e-business process and
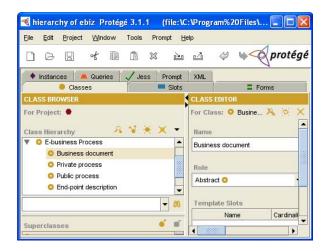
Figure 3. E-business process ontology in processing

consequently the existence of e-business itself. These rules can be seen as ontology commitment that an agent makes with respect to others, so the implementation of a mechanism for the construction and the management of commitment seems to be a natural choice to deal with agent's autonomy in e-business processes. Let us have a closer look at what commitments are and propose some guidelines on how they can be implemented and utilised in e-business process automation enabling. Actually, we consider the ontology commitment of an agent as a concept that underlies the whole multi-agent environment of e-business processes. More precisely, that an agent makes its commitment to the ontology is the inter-agent state, reflecting the process relation between two agents, that binds an agent, relative to another agent to the fact that it will take some action within a determined time interval.
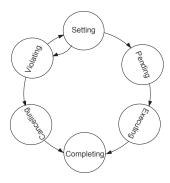

Figure 4. Agent's commitment states and transmission

In e-business processes, agents perform nothing but in-

formation sharing, including the contents, condition and state of information that communicate between two agents. The contents and conditions are part of the e-business process ontology as discussed in the previous section. The states of agent's commitments to the e-business process ontology, however, are logical transition steps of how the agent interprets information shared between itself and others. We define the states of an agent under a MAS environment for e-business processes using an abstract state machine, which fully describes the agent's state cycle for statical setting and dynamic running as shown in Figure 4, where

- Setting: in general, an agent does not know other agents' commitments. In this state, the agent makes a request to other agents for a commitment.

- Pending: if the setting state is completed for successful commitment, the agent immediately changes to the pending state that the agent becomes committed to execute all the tasks, and ready to execute the content of its commitment.

- Executing: the agent is committed to the ontology, and executes what is expressed in the ontology.

- Completing: the agent completes its commitment either successful or unsuccessful.

- Violating: the agent has failed in completing its duties so that the commitment has been violated, and needs further message exchange to create another commitment for ontology agreement.

- Canceling: the commitment is cancelled and is no longer relevant to any agent.

Agents, by consulting the knowledge base, i.e. the ontology, logically translate information from one form of data set to another that meets the process logics. Note that most standards written in XML enable the interoperability. Figure 5 shows how an agent maps the massages with its internal commitment states.
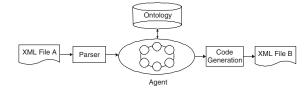

Figure 5. An agent's mapping process

Let us now examine how the ontology commitment can be used in e-business process automation. We assume that the ontology of e-business processes be partially or fully available to agents. Thus without human interfering, the

agents are able to interpret the process requests, and to invoke the required applications, to return results requested, that enable the automation of e-businesses. Many types of process automation mechanisms are possible regarding to using the ontology and agents. In the following, we briefly discuss four potential automation mechanisms.

Centralised process: A central agent, who presumably commits to the ontology, provides services that interpret the incoming requests, invokes applications and returns the results of the applications, to agents participating in the business but allocated in different locations. The central agent acts as ontology server to other agents in the sense of coordination. The process workflow is organised and managed by the central agent, as shown in Figure 6.
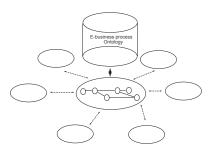

Figure 6. A centralised e-business process communication structure

In this model, while other agents have no restriction on using a standard as long as the specification used is conceptualisable with respect to the ontology, the central agent must understand the specifications used by all other agents for process coordination. By conceptualisable specification we mean that the concept set of the specification is a subset of the ontology. The central agent does most of tasks in interpreting requests, mapping massages and invoking the applications required. The workflow of the business process virtually is organised and coordinated by the central agent. The life-cycle of the process workflow is maintained by the central agent until the business transaction is completed.

Decentralised process: In this model, the ontology is shared in part by the agents, who involve in a business process. Each agent has a partial process ontology that only relates to the closely-related agents interested in the business process. In order to find business partners to build an business process workflow, there is an agent acting as an initiator that provides such a service to set up the process workflow, while the maintenance and management of the workflow are done by the agents

involved in the business. The initiator agent does not engage in the business transaction process. Figure 7 shows such an automation mechanism.
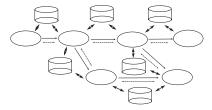

Figure 7. A decentralised e-business process structure

The life-cycle of the process workflow is dependent upon the business transaction completion. However, as agents share the processes only with their close business partners interested, they are not able to directly access the information of the process at other locations.

Distributed process: The most dynamic e-business process is a distributed process, where the ontology is fully shared by all agents involved in the business transaction. In this model, it is assumed that each agent equips with the ontology, so that the communication between them is open without intervention and restriction. Furthermore, because all agents in the business transaction commit to the ontology, they can access the business process information at any time, which the business process workflow can be efficiently managed and maintained. Figure 8 shows the distributed process mechanism.
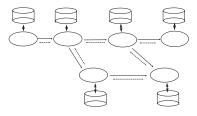

Figure 8. A distributed e-business process structure

As we mentioned in Section 3, we hope that there will be an convergent e-business standard, which has been worked on by several leading organisations. We believe that this is a long term effort. The distributed model takes the view of the standard convergence from the AI perspective which is similar to the standard convergence but requires e-business knowledge and software agents based engineering for the concrete ontology and agents systems.

Mobilised process: Unlike the process automation mechanisms discussed above, where a business transaction is done by the agents via massage passing, the mobilised process model takes the advantage of mobilised codes such as mobile agents that can enter the business process on demand just in time. In this model, there is an entity, which intends the business initiation, so called business initiator, committing to the ontology. By business initiator we means that the entity involved in the business and is the business process dominant. The initiator requests business services from other business entities to conduct the business. The other entities act passively by providing the services with no intention of knowing how the business process is running. Under such a model, the business entities send the delegated agents to the initiator for forming a business process. This model is shown in Figure 9.
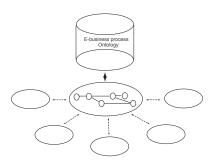

Figure 9. A mobilised e-business process structure

The ontology sharing process is at run-time. The agents access the ontology only after they enter the business process. Unlike the centralised process model, where the ontology is provided by the third party which is part of process but not in the business. In a mobilised process, the initiator provides the ontology to others and is involved in the business itself. There are several issues involved in this model. First an agent which enters into the business requires a learning process of understanding the ontology. The initiator can be a teacher to tell the entering agent how to access the ontology in order to communicate with others. Secondly, the security is an issue that needs to be fully addressed in this model, as the agent and its privacy are fully exposed to others. However, we believe that these issues can be technically resolved based on the current technology, and the e-business security issues are already a part of the e-business process ontology that is addressed in ontology construction.

The ontology sharing and agent systems developemnt for e-business are challenging research tasks. The use of ontology and agents enables the construction of e-business that automatically conducts e-business on the Internet. The e-business components can be duplicated and reused to reduce costs of e-business system development. The discussion on the proposed approach illustrates some promising potentials. However, the mentioned concerns in e-business process automation need to be further investigated.

5   Conclusions and Future Work

In this paper, we have discussed e-business process automation that facilitates the techniques of ontology, description logic and agents for e-business process knowledge representation and reasoning. Based on the current e-business process standards and specifications available, we have introduced an innovative e-business process modelling framework that group them according to their roles and functionalities in e-business processes. We have exploited these processes, and constructed ontologies for these processes. Several agent-based automation mechanisms have been discussed as possible ways to realise e-business process automation based on the proposed approach.

The approach discussed in this paper might potentially be an platform in language-independent interoperability that enables e-business process automation. However, to achieve full automation, concrete ontologies for e-business processes are required, and agents must be made intelligent enough to accommodate e-business scenarios in the real world. In addition to the modelling issues in e-business processes, Semantic web services need faster, less expensive, and more modular business modelling and code generation tools, such as workflow supported graphical tools. As pointed out, the approach is at an initial stage of development, which needs considerable implementation efforts. In particular, the construction of e-business process ontologies for each e-business process building block is currently our research focus.

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