Semantic Coordination of Web Services Based on Multi-Layered Repository

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Abstract

In late years, due to the significance of the Semantic Web technologies, it becomes important how quickly Web services can be coordinated by a certain task. This paper proposes a semantic integration of a web-based service for e-business agility. Our method rebuilds required heterogeneous repositories into a multi-layered repository based on ontologies. The proposed repository consists of component libraries and their use patterns from a level on a high abstraction such as B2B activities to the concreteness level of WSDL-based Web services. Our repository supports a development process of B2B coordination including both modeling B2B activities and business processes and deploying software components providing WSDL services. Finally, our proposed method of semantic integration devices a development methodology of on-line business as Web shopping, with the framework and the Web service components based on a free and/or commercial application servers.

Introduction

According to the recent trends of the Semantic Web technologies, the business requirement of the Web technologies is how rapidly to coordinate the business units provided as the web services. In order to achieve the rapid coordination with the Web-based environment, it is very significant to integrate the business semantics as a customer's needs and the ideas introduced by latest technologies. In fact, there is a significant gap between the customer's aspects of service requirements such as product semantics and the practical aspects of EC-enterprises such as WSDL-based Web services.

From the standpoint of the above context, a lot of research and development projects, which support the development of business applications, have been activated. Due to the boom of the Internet, a lot of XML based language specialized for business specification have been proposed such as ebXML [13] and BMPL [14]. Though these languages can describe some aspect on business modeling, it still remains hard to represent the business activities on an abstract level for the reuse of business models.

On the other hand, a lot of software libraries for building EC applications have been proposed. Most of them are originally developed as repositories for the agent applications and extended to ones for the business applications. Furthermore, the special platform for the development of enterprise applications is provided. Those libraries and platforms offer the strong framework for the construction of real applications. There are, however, no clear relationships between software components and business models.

Owing to the difference of purposes and viewpoints among those technologies, the integrated support is hardly performed in the coordination and the re-engineering of Web-based services on the existing domain. Furthermore, if we try to build up the application on the area of e-commerce, a lot of specific know-how on building software application, such as securities, credit, trading, and so on, should be come up together..

So, in order to achieve the unified support in the construction of business coordination and applications, we have to deal with the following heterogeneity as the research issues:

1. Conceptual diversity of B2B activities such as enterprise organization, business activities, software components, service primitives, and so on,
2. Expressive variety of component repositories available to access and involve through the Web such as UDDI registry, WSDL specification, enterprise data stocks, software library resources, and so on.

In this paper, in order to provide the unified support of e-commerce coordination on both B2B model level and software service level, we propose the development methodology of Web service coordination based on ontologies with reusable repositories such as e-business process handbook and software libraries.

In order to coordinate the e-business models on B2B model level, we propose a semantic integration of e-business models with reuse of existing models called best practices. To implement business models on a specific domain, we rebuild the heterogeneous repositories into multi-layered repositories on different-grain-levels: the business activity repository on the level of business activities and the business service repository on the level of software applications. The former one is for modeling business activities from business models on B2B levels, and the latter one is for constructing Web service application from the business models by using software components of J2EE. As the main characteristic of this work, we provide XML-based repository applicapable for B2B modeling and Web service deployment by employing primitives of PSMs (Problem Solving Methods), which provides the correspondence between the models and applications.

Coordination of Business Models

In this work, we employ the repository of B2B activities and case studies that is provided by the e-business Process Handbook of MIT, called Process Handbook for short, as a library classifying business activities. Because Process Handbook is provided as English documents, there still remains an issue in the extraction of a required process due to the difference of the viewpoints and the representation between business descriptions as natural language texts and process repositories available for software development. In order to bridge the difference, we construct the business activity repository by employing WordNet as a general lexical repository. First, the business activity repository is provided as a key structure bridging the business documents and Process Handbook. Then, the wrapper framework is constructed as an extract method of required activities from a repository of Process Handbook.

Building Business Object Ontology

In order to classify the noun concepts extracted from Process Handbook, we employ the WordNet as a general ontology that contains over 17,000 concepts. However, if we utilize WordNet as it is, the number of candidate explodes because of the variety of the word's meaning and the ambiguity of the word in a document. When the abstraction degree of a business plan is high, a verb concept of an activity in the business plan is often vague for specification makers due to the difference of viewpoints on the definitions. In contrast, a noun concept of the activity is comparatively clear and appears regularly in the document.

So, in order to classify the noun concepts appearing in Process Handbook, we choose the major concepts with respect to the degree of abstraction and frequency by using WordNet. As the criteria to select a major noun concept, we pay attention to roles of input-output objects in the definition of Process Handbook. Based on the above standpoint, we construct the business object ontology in the following way:

1. Concentrating the case-study models of e-business and extracting the taxonomy,
2. Counting the number of the appearance of each noun concept,
3. Comparing the noun hierarchy of WordNet and the taxonomy obtained and adding the number counted for the similar concepts,
4. Choosing the main concept with high scores as upper concepts and building upper ontologies by giving all the nouns the formal is-a relation, and
5. Merging all the noun hierarchy extracted from the whole Process Handbook in the same way.

According to the WordNet's structure, we define the substructure of concepts obtained above as an upper ontology, provided that the priority of the meaning is given to business domain over the relation of WordNet. Furthermore, when we fix the upper ontology for constructing business domain ontology, concept drift, that is a kind of semantic shift on a specific domain, often occurs and causes inefficiency on building ontologies. Due to reduce the cost of construction, we employ the methodology for resolving the concept drift [4]. Fig. 1 shows the structure of the business object ontology obtained.

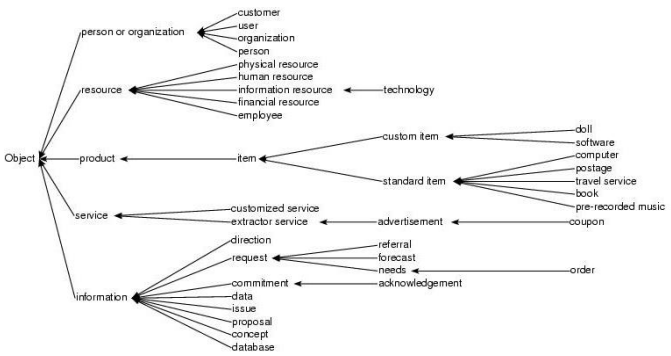

Fig. 1 Business Object Ontology (a part of it)

Constructing Model Repository of B2B Activity

In order to perform the semantic integration of business models, we need to access the repository of business practices and models. When we obtain the best practices for the reuse of management level knowledge, however, higher concepts including the trading structure of business

models would be preferred as the key idea to extract management level models. In order to bridge the gap between management level concepts and business activities defined by process handbook, we have analyzed the case studies of Process Handbook and classified the business trading structures as shown in Fig. 2, which is provided as B2B Activity Repository.

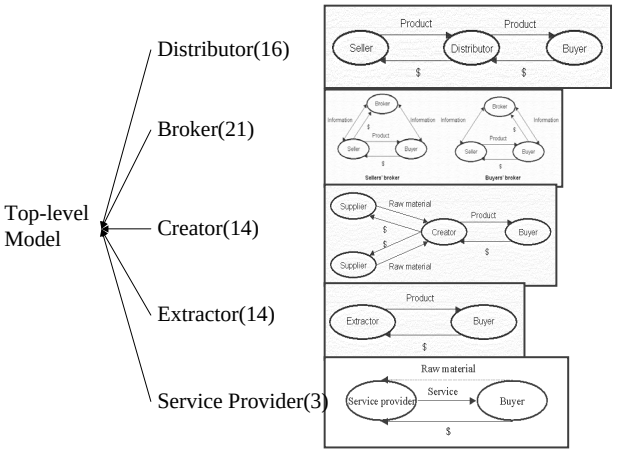

Fig. 2 B2B Activity Repository

Determining Business Activities

When obtaining the definition of the B2B activity corresponding to a business document such as a customer's request, it is difficult to utilize the hierarchical structure of the process handbook because of the gap between web-based activities and words of process handbook. In order to consider the inherent structure of concepts found in dictionaries (like the e-business Process Handbook of MIT) that has been developed by the theories in economics, we employ the business object ontology, as an upper ontology, which bridges the variety of words in documents and nouns in Process Handbook. In order to identify business activities from a sentence given by a user, we devise an extraction mechanism as a wrapper for Process Handbook based on the business object ontology.

The wrapper tool is composed of the databases of the following information. First, the co-occurrence information of noun concepts in the definition of a business activity is obtained and classified with respect to the structure of the business object ontology. Then, the information is made accessible as the database of the co-occurrence. At the same time, the frequency information is also available in collecting the co-occurrence one. By using both of the co-occurrence and frequency information, the wrapper tool helps us to search the definition of activities in the space of Process Handbook. The proto-typing tool is shown in Fig. 3.

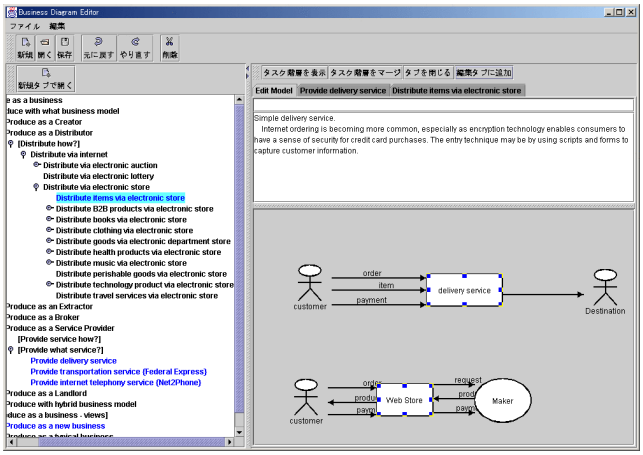

Fig. 3 The Wrapper Tool

Model Refinement of Web Service Applications

Building WS Object Ontology for Reuse of Libraries

In the same way of building the business object ontology, the WS (Web Service) object ontology (Fig. 4) is constructed as a domain independent ontology from the libraries intended to employ. The WS object ontology gives words for expanding domain ontologies such as building a set, picking up an atom of a set, indicating a calculation stage, data structures for implementation details and so on.

On the purpose of the developing business applications from the business model obtained above, a detailed definition of each activity of the model is required. In order to give the activities the operational information that is used for application development, we prepare the library of the application template, which defines the structure of the part of application in the fashion of the knowledge system development with respect to the WS object ontology. By constructing the web service repository with the reusable template of REPOSIT [5], Common KADS [6,7], JAT [8] and historical databases, the business application is obtained.

Model Refinement Based on Application Templates

As the same standpoint of Semantic Web vision, we consider the structure of Web service coordination based on the agent architecture to be composed by the inference engine to attain a task, the sensor to get the information of the outside such as behavior of customers and the effecter to carry out its business task. The sensor is characterized by the following three functions:

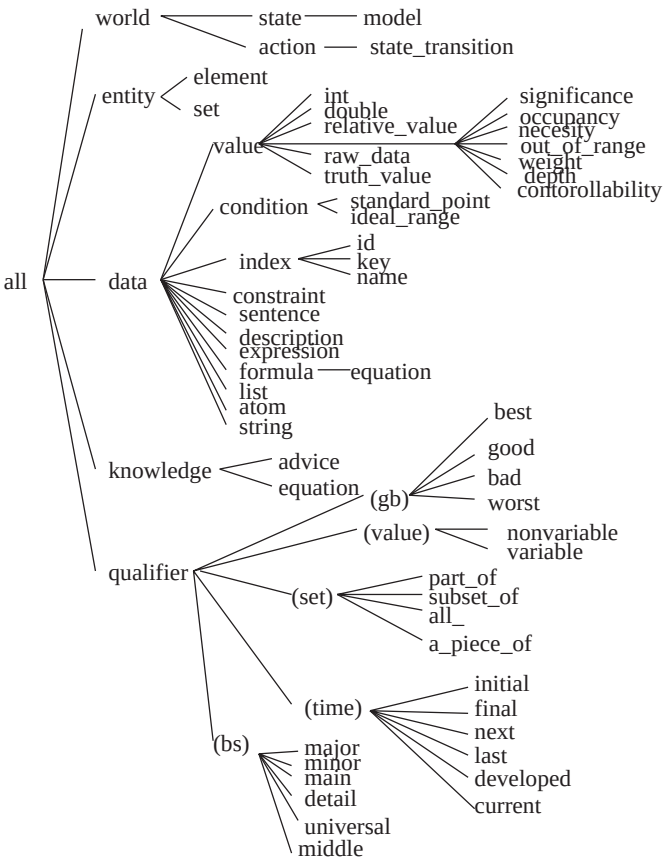

Fig. 4 WS Object Ontology

1. The function that accesses the inside and the outside resources of the business,
2. The function that examines the place and the contents of resources,
3. A function to acquire a message from the user and to interpret the message.

The effecter is defined by two of the next:

1. The function to form and modify the inside and the outside resources of the business,
2. A function to make and to send a message to the custmer.

The framework of the combination with the above functions and the inference engine is organized as agent templates by referring to JAT (JAVA Agent Template) of the Stanford University. Furthermore, detailed templates, corresponding to eight types of communication models given by Common KADS, are formed as interaction templates with the user and resources (Fig. 5).

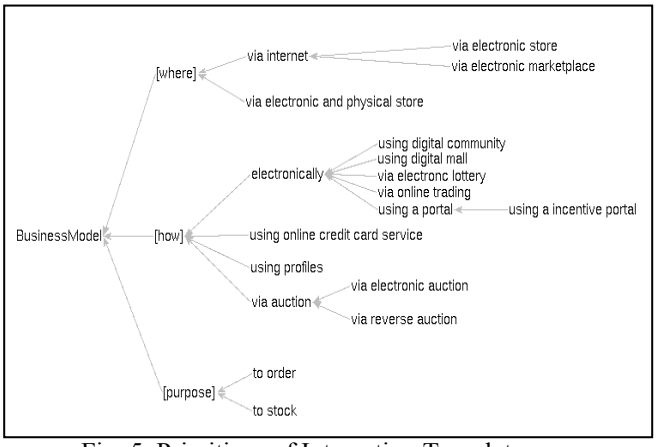

Fig. 5 Primitives of Interaction Templates

Building Tools and Mechanism for Semantic Integration

In order to perform semantic integration, we devised the tools for managing the top-level model of business practices, for editing and merging the definitions of business models based on business activities, and for mapping the business activities to the business software components.

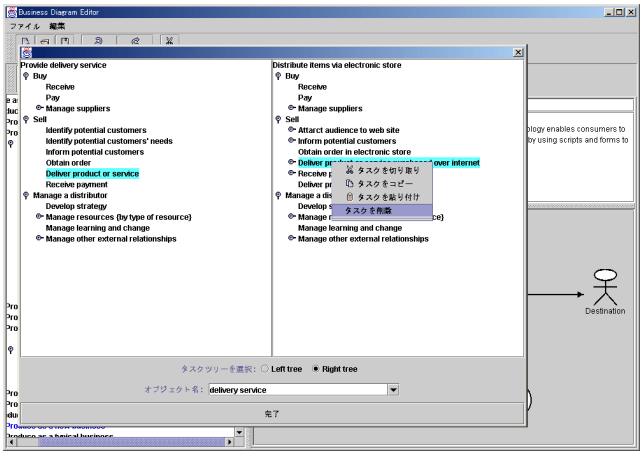

Fig. 6 Top-level View of Integration Tool

The tools shown above enable us to select business models in the left window, and to merge the model into the right window. Furthermore, in order to achieve the business model integration semantically, we developed an editor of business definition of activities, shown in Fig. 7.

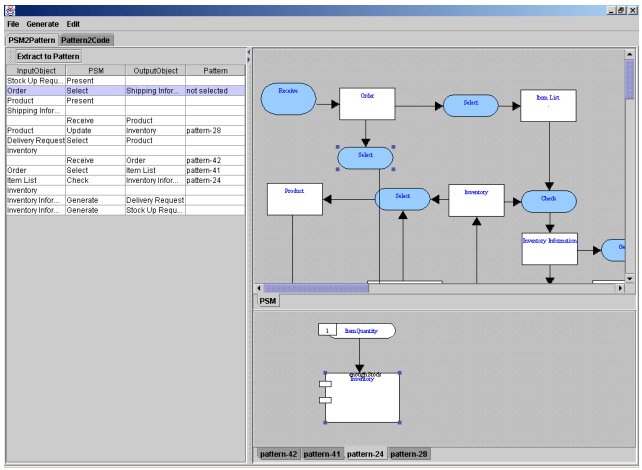

Fig. 7 Business Definition Editor

Transplanting Web Service Models to J2EE Architecture

As the final step of Web service coordination, the obtained refinement models are transplanted to the software application architecture. The architecture we employ is a J2EE platform, which consists of Web Container providing the interface to client applications and EJB Container managing the business logic as enterprise activities.

In order to map the refined models and software architecture with respect to the Web service repositories, we've devised the proposed repository as the XML-based resources and made the correspondence between business activities shown as ovals in the Figure and the components of Web service, JSP Page and Servlet. We also define the matching relationship between WS objects shown as squares in the Figure and the components of Enterprise JAVA Beans. Connecting the components obtained by manual development, the final EC-Application system is obtained as the Web-based application.

In order to consider the validness and usability of proposed framework, we've implemented the above mechanism by JAVA-Swing into the proto-typing tool and applied it into the construction of WS applications from description documents provided by e-marketplace requirements.

Experimental Study

We've applied the proto-typing tool into case studies of constructing WS coordination from description documents.

In each case study, service requirement obtained from the Internet are used as a WS coordination requirement. We have compared among the models of case studies provided by Process Handbook, the ones manually developed and the ones built by the proto-type tool.

Table 1 shows the average of the resulted number of the business task and Web service modules in the development of 6 case studies.

	Our Environment	Manually Coordinated
Determined B2B Activities	87%	58%
Determined WS Modules	71%	32%

Table 1 Result of Experimental Studies

According to the result, approximately 87% activities of each case study model are determined from requirment documents. Our environment also enables us to search 71% of the WS modules, in the contrast with 32% of the manual development. By the contrast with the result of the manual development, our tool enables us to reduce the search cost of business model driven Web service coordination.

From the standpoint of the time-consuming cost of the development, each implementation with our environment has been completed around 18 hours after receiving the requirement specification. In the case of the manual development more than 48 hours are required.

This means that the cost of the WS coordination has been reduced as compared with the manual development, that reuse of the system has been performed about the common structure of business applications, and that main business structure could be reused if we have stacked and open some experience to the public at our library.

Discussions

The above result of the experimental study means that the cost of the WS coordination has been reduced more than 62.5% time consuming cost (from 48 to 18 hours) as compared with the manual development, and that performance of the search rate has been increased around 29 points (from 58% to 87%).

As comparison with related work, there are three main fields of research areas: clarifying specifications, building an application and reusing existing libraries.

First, numbers of work on analyzing business specification has been done by MIT, Edinburgh University and so on. Their work are very significant as a fundamental research, however, most of them are around abstract and general framework. Recently, Process Handbook is revised into e-Business Process Handbook and provides a hundred of specification as case studies. But most of them are just defined by natural language text. So, our work can be regarded as the integrated work to utilize the related work. Furthermore, because our repository is constructed as XML-based resources, varieties of the Semantic Web

modules can also access to our repository as well as Web services.

Second, a lot of works are carried out on building applications Including software engineering field\cite{9}, but they use the different type of tool and languages on the different phases of development. So, models and languages should be unified into on framework as we proposed.

Our framework is based on a standpoint that it is difficult to automate the whole business, but possible to do many part of it. Recently, a few of the researchers consider the modeling methodology of the whole enterprise structure as a multi-agent system\cite{10}. It is worth paying attention but still remain on the abstract structures of defining agent roles.

From the standpoint of business modeling, our environment enables various sorts of designers to discuss and to exchange knowledge and know-how about e-commerce application development. Because of the variety of purpose of the employment of the e-commerce application, such as management vision, workers view, system engineer's experiments, and so on, our environment would play a significant role of communications of the designers.

Conclusion

As conclusion, the computing environment, which supports dynamic coordination of e-business and Web services from customers' requirement, should be developed for the purpose to perform the re-engineering business processes according to the available Web services. From standpoint that the heterogeneous repositories should be integrated to achieve the unified support of the Web service development, we have proposed the framework of the extraction of the required information based on ontologies with reusable repositories such as e-business process handbook, Common KADS and REPOSIT. In order to construct the business models and to implement them as the actual business including software applications, we develop two repositories on different-grain-levels: the B2B activity repository on the level of business activities and the Web service repository on the level of Web-based services.

We have implemented the prototype system by JAVA and confirmed that it supports us in various phases of Web service development including business model coordination, detailed business model definition and an implementation of the Web service applications. Furthermore, we are re-organizing our product in order to open it to the public.

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