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A Multi Agent-Based Service Framework for Supply Chain Management

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Abstract

Supply chain coordination has emerged as one of the major areas for companies to gain a competitive edge in a globalized world. Business organizations are increasingly located at the intersection of multiple supply chain networks. Managing such networks is hugely dependent on automation through combining advanced technologies such as software agent technologies, service oriented technologies, Internet of Things etc. This paper presents a multi agent and web service framework for Collaborative Material Procurement System (CMPS) in a supply chain. The information used in CMPS is used in two forms: business service rules and service description cases. It utilizes this hybrid information in order to form appropriate service, by using rule-based reasoning (RBR) and case-based reasoning (CBR). This paper outlines the CMPS architecture, designed to automatically retrieve software-based services for the agents that coordinate the supply chain form a service repository using a semantics-driven service similarity assessment algorithm.

Keywords: supply chain management; multi agent system;service oriented technology; rule-based reasoning; case-based reasoning; similarity assessment algorithm

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1. Introduction

Supply chains are an important part of every economy and every business. A supply chain is formed out of interconnected organizations and their associated business processes that work collectively, usually in a sequential manner, to enrich value for customers. Supply chain management (SCM) covers all business processes associated in procuring raw ingredients from suppliers, making the items of interest or services using raw ingredients and other relevant resources (e.g. staffs, utilities, infrastructures, machineries, and so on), and finally providing the items of interest or services to its customers [1]. It encompasses movement and storage of raw materials, work-in-progress inventory, and finished goods point-of-origin to point-of-consumption. The characteristics of supply chains differ hugely from industry to industry. In many industries, supply chains are challenged by their increasing complexity and the need for higher flexibility to meeting individual customer requirements (e.g. automotive industry, construction) [2], [3].

As companies increasingly use their supply chain to compete in the marketplace, the use of IT has noticeably increased in recent years. Supply chains use information systems to support their various business activities for internal operations (e.g. inventory management, order processing, human resource management, accounting systems). Companies can also use information systems to support external interactions with customers, suppliers, and business partners. In this way several companies within a common market segment jointly plan, and manage the flow of products, relevant customer relationship services, and information along the value system in a way that enhances customer value and maximizes the efficiency of the supply chain.

The emergence of web-enabled technologies, in particular service oriented architecture (SOA) [5] and semantically described services, allow supply chain partners to automate their interactions by providing automatic partner discovery and service chain composition. Such services can be utilized by autonomous software agent applications [6]. In this paper we propose a agent driven web service based supply chain and illustrate a collaborative material procurement system (CMPS) for a manufacturing supply chain. The proposed CMPS can assist the manufacturer, and global logistics service providers to reduce the uncertainty in distribution, and improve the supply chain execution time. Supply chain agents interact and cooperate with other agents, within and across organizations, in order to augment their individual knowledge, and to improve the performance of the whole supply chain [4].They can collaboratively execute the order fulfillment on the proposed CMPS platform to increase the accuracy and reliability of the manufacturing process.

This paper consists of five sections. Section 2 introduces the technological background information of multi-agent systems, web service computing, and its ramification in supply chain business process management related issues. Section 3 describes the architecture of the CMPS framework and an algorithmic similarity assessment of services in order to create a suitable service composition. Section 4 provides a business scenario for a manufacturing supply chain to illustrate the capabilities of the proposed architecture. The concluding remarks are presented in Section 5.

2. Technological Background Information

In this section we present a brief introduction to multi-agent systems, discuss the basic concept of semantic web service, and outline some of the research applications using these applications for SCM.

2.1 Distributed Multi-Agent Technology

Agent-based computing provides the theory and the practice of modeling, designing, and implementing real-world computer applications [6]. There are several proposed definitions for the term *agent.*. An agent is anything that can perceive its environment through sensors and act upon that environment through actuators [7]. Maes [8] defines agents as applied computer-based systems that inhabit some complex dynamic environment, sense and act autonomously in this environment, and by doing so realize a set of goals or tasks for which they are designed.

Wooldridge and Jennings [9] define agents as hardware based or (more usually) software-based computer systems that possess some important characteristics, autonomy, purposeful actions, and reactiveness, as follows:

- *Autonomy* refers to the agent's capability to make its own decisions.
- *Purposeful actions*: is the agent's ability to reason using the embedded domain knowledge in order to achieve their goals.
- *Reactiveness*: how the agent responds to external stimuli from their environment.

A system that consists of a group of agents that can potentially interact with other is known as multi-agent system (MAS).

2.2 Semantic Web Services

Web services, as it is defined by the World Wide Web Consortium (W3C), is a set of software protocols designed to support interoperable machine-to-machine interaction over a network. Service interacts with each other, fulfilling tasks and requests that, in turn, carry out parts of complex transactions or workflows. XML-based standards provide a meta-language to express complex interactions between clients and services or between components of a composite service transported over HTTP (Hypertext Transfer Protocol). SOAP (Simple Object Access Protocol) is an XLM-based mechanism for exchanging structured data among network applications while WSDL (Web Services Description Language) defines an XML-based grammar for describing network services. WSDL describes what functionality a service provides, where the service is located, and how to invoke the service while UDDI (Universal Description, Discovery and Integration) is used for listing what services are available.

UDDI specification provides a platform-independent way of describing services, discovering business services, and integrating business services, dynamically. This dynamic service provision can take place in a flexible manner where the role of the service providers and consumers are interchangeable. In order to use web service model – the service provider registered the available services in the UDDI registry. A client can search a needed web service from the UDDI registry where the UDDI will provide the location of the wanted web service to the client. Afterwards, the client will use the location of the service to request for the WSDL file. Upon receiving such a request, the service provider will return the WSDL file which contains detail information about the service. The client will then request for the service via SOAP [10] messaging and the service provider will perform the requested service and return the results to the client via SOAP messaging.

There are two major issues in relation to service discovery: (a) efficient location of the web service registries that contain the required web services and (b) efficient access to such services that meets quality of service (QoS) standards. With ever increasing number of useable web services it is troublesome to find a service with required functionality and appropriate quality characteristics. The main reason for this problem is that standard web services technology is not semantic-oriented. Many methods have been repored to add semantics to web services description to help discovery and selection of relevant web services (e.g. DAML-S [11], WSDL-S [12], WSML [13], OWL-S [14]).

Ontologies have been used by researchers [15], [26] in order to provide a machine-processable semantics of information sources that can be communicated between different web service applications. In simple, ontology defines the common words and concepts (meanings) used to describe and represent an area of knowledge, and standardize the meanings. Ontologies are used by people, information-bases applications that need to exchange domain of information that explain a specific concept to each other to sharing at special domain in computerized systems. In our work, we propose the use of ontologies to describe semantically the various parameters and characteristics of the client request and the web services.

2.3 Supply chain automation

The problem of automating supply chain related information system has long been a principal issue of both academia and industry. There are three important approaches in the development of current supply chain operation related information systems: Multi-Agent System [18], [19], [20], [25]; Semantic web service based system [21]; and combined Agent and web service based system [23], [24].

Each approach focuses on enriching some aspects of the traditional supply chain information systems. Multi-agent based systems have tried to adopt a cooperative approach in partly automated supply chain operations are of limited use as a software-based decision making tool. Such an automated tool would do very step-by-step business operations. The academic literature shows that projects using the MAS in the supply chain confront essentially three main problems: modelling, design and operational control. These problem areas raise a variety of research issues which researchers [18], [19], [20], [22] are addressing. Multi agent systems have proven quite helpful in the study of partial automation of supply chain operations [20], [21].

In [20], Sadeh et al. propose multi-agent approach called MASCOT (Multi-Agent Supply Chain Coordination Tool) for coordinating supply chain planning and scheduling. It helps the decision making processes in supply chain planning and scheduling. In another reported research [21] presents a multi-agent system for multilateral negotiation protocol for electronic markets (e-markets) using domain ontology. They, however, only gave a rough introduction and did not describe how to use the semantic web in SCM.

Lee proposed an architecture for semantic web [21], according to which contents in documents are stored in XML and RDF formats. There are modules for rules, logic and other inference methods to support the semantic induction. The ontology vocabulary provides a flexible linguistic matching when different terms are used.

Hendler [24] reported web services, which included techniques of web ontology language (WOL) and web agents. The agent systems solve problems of business-to-business electronic commerce related transaction related machine-to-machine interaction.

In this paper, we propose hybrid architecture to design an intelligent system with semantic web and multi agents in a supply chain management scenario and to overcome the above problems.

3 Architecture of the Framework

Although semantic web services facilitate interoperability amongst supply chain participants, they do not have enough degree of autonomy nor capacity to adapt in a dynamic way to the changing situations. In such situations, the intelligent agents can contribute to give the systems a high degree of autonomy and dynamicity. In conformity with this, we put forward a framework which intelligent Agents and the Semantic Web Service (SWS) work in collaborative fashion.

CMPS framework consists of two main types of agents: Consumer Agent (CAgent), and Service-Provider Agent (SPAgent); and service selection functionality, as shown in Figure-1. In the following section we describe the various components briefly.

- The Consumer Agent (**CAgent**): The consumer agent allows the entry of service request to the CMPS. It plays an important role to trigger appropriate service discovery process.
- The Service-Provision Agent (**SPAgent**): This group of agents are responsible for service provision within CMPS. The detail description of these agent groups is beyond the scope of this paper.
- The Central Service Base (**CService**): The central service base contains service descriptions, case-based reasoning (CBR), and Rule-Based Reasoning mechanisms based [17] on OWL ontologies, as a reference to develop the various logistic service related local ontologies and semantic descriptions of the different web services. In this project, we have used web service selection mechanism based on a hybrid reasoning (e.g.

CBR and RBR) mechanism. The framework also utilises OWL semantic descriptions extensively for implementing both the components of the CBR engine and the matchmaking profile of the web services.

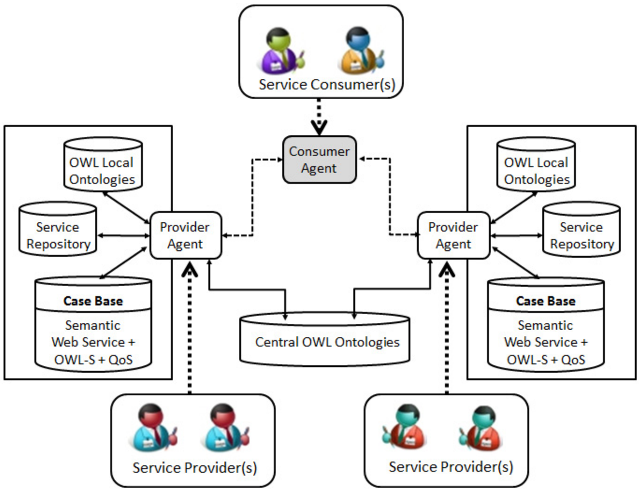

Figure-1 A diagrammatic architecture of CMPS

In the next section, we explain the purpose of the service similarity algorithm in this framework.

4. Service Similarity Assessment Algorithm

In this section we present an overview of how an ontology can help with annotating web services with semantics. Then we present what a semantically described web service consists of, how ontologies are used in CMPS implementation purpose, and the patterns that make it possible to publish and search for semantic web services described in either of the OWL-S and WSDL-S using Protégé [16].

4.1 Semantic Service Ontologies

The ontology used in CMPS can be considered to be a *world ontology*. We argue that there should be world ontology for seamless integration of heterogeneous business processes over the web. World ontology is characterised by describing virtually the whole world items of interest in a day-to-day business work. It helps to have a non-redundant definition of every concept. Moreover, such world ontology should be very comprehensive by nature and should be created by gathering information from multiple domain experts to ensure its correctness. Since world ontologies are still at the stage of development, we have used instead a *domain ontology*, that addresses only the problem domain.

By using a domain ontology, it is possible to define patterns for publishing and searching for semantically described web services. A typical manufacturing/logistics classification ontology is shown in Figure 2.

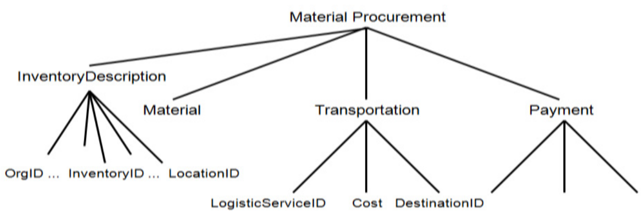

Figure-2 Shared domain specific ontology

Figure-2 shows an example of material procurement services in an inventory management system for a manufacturing enterprise. The interface descriptions (inputs and outputs of service operations) are shown here in the form of a tree, and are extracted from their WSDL descriptions in a UDDI repository. The terms shown at the leaves are part of some domain ontology. These include terms such as (LogisticServiceID, Cost, DestinationID) for manufacturing material transportation purpose.

In CMPS project, we have used a semantically described web service, where every operation has a semantic description of its inputs and outputs. This information is needed to find out whether a specific web service can be integrated seamlessly into a business process. The different parts of a business process have formal definitions; the most important of these are denoted by service templates (ST) and service objects (SO).

Based on the UDDI structure, in CMPS, a business service contains a *categoryBag* that holds a number of *keyedReferences*. Each *keyedReference* contains a *tModelKey*, a *keyName*, and a *keyValue*. The *tModelKey* contains a reference to a special tModel, which can be either UDDI: INPUT_CONCEPTS or UDDI: OUTPUT_CONCEPTS.

4.2 Service Matching Algorithm

In order to select appropriate service from service repository – CMPS uses different matching rules. When a match has to be checked, the input and output parameters of the web service operation must be identified. We explain the functionality of this operation by an example for a material transportation service. In completing the request, the logistic business process must be matched against a number of matching service objects. A service template for the "*request transportation*" business process is described in Table-1.

Table-1 A service template.

Request Transportation	Service Template
Sub Component	JourneyTime
Input	Date, Destination
Output	TransportationPlan

When the service template is composed as in Table-1, it needs to be matched against a number of service objects. This matching must be done on the basis of ontology descriptions. To do this matching process, an algorithm has been implemented in CMPS, as shown in Figure-3.

Algorithm 1 *Similarity* (ServiceTemplate, ServiceObject)

```
BEGIN
SimilarityScore double;
Set ST = ServiceTemplate, SO = ServiceObject;
  If (ST.input.concept = SO.input.concept)
        Return 1;
   Else
       If (ST.input.concept < SO.input.concept)
        Return 1;
    Else
       If (ST.input.concept > SO.input.concept)
         Return(SO.input.characteristic.count( ) / ST.input.characteristic.count( ));
      Else {
            characteristicList CL1, CL2, CL3, CL4;
            CL1 = ST.input.characteristic.addAll( );
            CL2 = SO.input.characteristic.addAll( );
            CL3 = intersection (CL1 , CL2);
            CL4 = union(CL1, CL2);
             SimilarityScore = SQRT (((CL3.count( ) / CL4.count ( ))
                                  * (CL3.count( ) / CL2.count())));
            Return SimilarityScore;
           }
END
```

Figure-3 Similarity scoring algorithm

4.3 An Ontology Matching Example

To explain the concept of the matching operations in CMPS, we consider Date input in service template (ST) and service object (SO) and the respective score based on the algorithm of Figure 3 is shown in Table-2.

Table-2 Matching scores

	ST	Input	SO	Input	Score
1	TransportST	Date	TransportSO	Date	1
2	TransportST	Date	RoadSO	CalendarDate	1
3	TransportST	Date	AirSO	TimePoint	0.25
4	TransportST	Date	SeaSO	Time	0.189

The above characteristics matching calculation of four different cases are based on the following equations:

Eqn_1 = Characteristic (Date) = {absolute_time, year, month, day} and Size = 4
Eqn_2 = Characteristic (Time) = {absolute_time, hour, minute, second} and Size = 4
Eqn_3 = Characteristic (Date) ∩ Characteristic (Time) = {absolute_time} and Size = 1
Eqn_4 = Characteristic (Date) ∪ Characteristic (Time) and Size = 7

The match score mentioned above, in Table-2, considers the case where the similarity between two concepts should be calculated. These cases correspond to situations where parameters of a categoryBag are void, or not known in the domain ontology. These matching mechanisms are encoded in our knowledge base as rule forms and service descriptions are stored as case form. CMPS uses such cases and rules in order to retrieve appropriate services.

5. Concluding Remarks

This paper proposes a software architecture for supply chain process integration that is based on multi-agent and service oriented computing and employs RBR and CBR for service matching. The paper has shown how a complex business integration problem can be enhanced using domain ontology. The novel contribution of this work includes: hybridization of two knowledge-based paradigms, namely, semantic web and agent technologies to automate supply chain coordination operations; and use of an algorithm to measure the similarity between service descriptions using domain semantics to find matching services in the service repository to support the current supply chain operation.

One of the limitations of the approach described in this paper is regarding the difficulty of creating and maintains a web service repository. This would have to be maintained by multiple supply chain participants in order to remain up to date and useful. This however is mainly an organizational, rather than a technical problem. Further research will extend the current ontologies to support the diverse business domain in manufacturing and logistics.

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