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An ontological intelligent agent platform to establish an ecological virtual enterprise

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ABSTRACT

A virtual enterprise (VE) is a dynamic alliance of companies collaborating for the accomplishment of a specific business goal. To establish a VE, it is very important for the VE initiator to select appropriate partners. General criteria such as price, lead time, quality, etc. are the major concerns for most VE initiators. However, in today's environmentally conscious society, environmental issues such as enterprise green image, product eco-design, etc. are increasingly receiving attention. Thus, it is worth to research on how to select the appropriate collaborative partners to establish an ecological VE.

The objective of this paper is to establish a multi-agent system platform for individual companies to form an ecological VE based on ontology theory and intelligent agents. The ontological approaches include shared ontology construction, ontology matching, ontology integration, ontology storage and ontology reasoning. In the generalized case that the VE initiator is a manufacturer and the collaborating partner are suppliers, the multi-agent system comprises three types of intelligent agents, namely, knowledge manager agent (KMrA), manufacturer agent (MA) and supplier agent (SA). MA and SA represent the capabilities and interests of the VE initiator and the VE partners, respectively. KMrA is in charge of functioning sub-tasks of the ontological approach. To select partners for the ecological VE, the VE initiator will also consider the environmental criteria, in addition to the general supplier selection criteria such as price, quantity, quality and lead time. The environmental criteria may include factors such as environmental management, green image, green product and pollution control. The complete set of selection criteria, including the environmental criteria, are categorised into quantitative or qualitative criteria. The formation of ecological VE is then divided into two stages, that is, candidate supplier selection based on qualitative criteria, and ultimate supplier selection based on quantitative criteria. A simplified example is introduced to illustrate and justify the proposed ontological approaches and intelligent agent platform.

1. Introduction

A common business phenomenon in today's global economy is to outsource manufacturing, logistics and back-office activities to domestic and foreign suppliers and service providers. It is now an emerging trend for companies to collaborate as a virtual enterprise (VE) to fulfil a particular business opportunity. VE is a temporary network of enterprises, whereas the VE initiator collaborates with its partners to share skills, resources, costs and benefits to achieve market opportunities and gain more value for products and services (Pallet & Sandoval, 1998). For individual companies, adopting a VE can enable them to focus on their core competencies, and rely on their partners to provide other essential assistances. Therefore, it is important for a company to select appropriate partners to create the VE. In general, criteria such as price, lead time, quality, etc. are major concerns for VE initiators.

With the growing awareness of environmental issues globally, governments and industry have recognized that they have vital roles in supporting and assuring sustainable development. For governments, laws and regulations have been issued to reduce and control greenhouse emissions, energy consumption, and environmental pollutions, etc. For industry, corporations are under tremendous pressure to comply with corporate social responsibility (CSR) requirements and to integrate environmental and social concerns in product design and manufacturing. In consideration of the environmental concerns, companies worldwide have begun to adopt green supply chain management (GSCM) practices. In this regard, the concept of GSCM has to be considered in VE initiatives. That is, in the formation of a VE, the initiator should not only consider the general criteria, but also should consider the environmental impacts of their partners.

Many researchers have proposed to use ontology-based intelligent agent system to support the formation and operation of VE

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(Garcia-Sanchez, Valencia-Garcia, Martinez-Bejar, & Fernandez-Breis, 2009; Lo, Hong, & Jeng, 2008; Malucelli, Palzer, & Oliveira, 2006; Soroor, Tarokh, & Shemshadi, 2009; Wang, Nagalingam, & Lin, 2007; Wongthongtham, Chang, Dillon, & Sommerville, 2006). From the perspective of ontology, it is used as a conceptualization of specification owing to its powerful and expressive characteristics. It helps agents in representing domain knowledge, reaching mutual understanding, and querying knowledge repositories, etc. From the perspective of intelligent agent, it is largely applied in distributed and dynamic interactions in VE. Each VE partner is represented by an individual agent, enabled with certain capabilities to fulfil different VE objectives.

However, in current ontology-based intelligent agent applications, few of them have considered the environmental impacts during the VE formation process. Due to the complexity of environmental concerns and differentiation from the general criteria, it is worth to research the incorporation of environmental considerations in ontology-based intelligent agent systems.

To establish an ecological alliance, many researchers proposed mathematics, statistics and intelligence methodologies for green supplier selection (Awasthi, Chauhan, & Goyal, 2010; Kuo, Wang, & Tien, 2010; Lee, Kang, Hsu, & Hung, 2009; Lu, Wu, & Kuo, 2007; Sundarahani, Souza, Goh, Wagner, & Manikandan, 2010), such as multiple attribute utility theory (MAUT), analytic hierarchy process (APH), artificial neural network (ANN), Delphi, data envelopment analysis (DEA), etc. However, few of them have proposed a systematic green partner selection or ecological VE formation approach from the perspective of system platform.

Based on the above two concerns, this paper fills the research gap in providing an ontological intelligent agent platform to establish an ecological VE to justify that within the proposed platform, both the general and environmental criteria could be considered and dealt with.

In the rest of this paper, Section 2 reviews some ontology-based intelligent agent applications and common environmental criteria. Supplier selection criteria, platform architecture and agent interaction protocols are presented in Section 3. Section 4 introduces the ecological VE formation procedures, i.e. ontology reasoning based candidate supplier selection, and case based reasoning oriented fuzzy set theory (CBR-FST) based ultimate supplier selection. Section 5 presents conclusions and future studies.

2. Related works

2.1. Ontology based intelligent agent applications

Many researchers have applied ontology-based intelligent agent systems for VE formation and operation. Malucelli et al. (2006) developed an ontology-based services agent to detect lexical and semantic similarity of two concepts to solve agent heterogeneity problem during e-commerce negotiations among different enterprises. Wongthongtham et al. (2006) made use of a shared ontology to enable agents to have meaningful communications, such as representing knowledge from the service providers, system authentication for user security access control, manipulating and maintaining the software engineering knowledge, etc. In Wang et al.'s (2007) virtual computer integrated manufacturing application, ontology was to facilitate agent communication and strategy representation for manufacturing resources planning and scheduling. Soroor et al. (2009) developed their ontologies for data and semantic integration to help agents in understanding services offered and terms during the real-time coordination, such as holding reference and standard models, integrating semantics of multiple data sources, translating data between different models, etc. Lo et al. (2008) adopted their ontology for knowledge retrieval and reasoning, such as exploring more functions for e-fashion, and querying products, specifications, etc., and also enabling a shared semantic interoperable environment for the multi-agent platform. The functions of ontologies in Garcia-Sanchez et al.'s (2009) application are fourfold, i.e. being a universal vocabulary for a semantic interoperable environment; representing web service capabilities and processes for agent communication; extracting local domain-related knowledge and representing negotiation protocols and strategies.

To sum up, to effect the intelligent agent applications in the collaborative environment, ontology can help in representing and storing domain knowledge, enabling a semantic interoperable environment, reasoning and querying the knowledge repositories and maintaining a secure system access, etc.

2.2. Environment management system criteria

Environmental management system (EMS) criteria have been adopted in green supplier selection applications. Lu et al. (2007) pointed out that materials, energy use, solid residue, liquid residue, gaseous residue, and technology are very important. Lee et al. (2009) evaluated their suppliers based on green image, pollution control, environmental management, green product, green competencies, total product life cycle cost, technology capability, etc. Kuo et al. (2010) introduced EUP, RoHS, ODC, ISO 14000 and WEEE to select their suppliers. In Awasthi et al. (2010), criteria including clean technology, clean materials, environmental efficiency, and pollution control were considered. Sundarahani et al. (2010) proposed an analytic method to measure the carbon footprint across a supply chain and pointed out that carbon emission was the major threat.

Many of the studies follow one or more common EMS criteria when determining their environmental partner selection criteria. For instance, ISO 14000 series, REACH, RoHS, and WEEE, etc.

In the global economy, enterprises are required to follow local environmental management laws and regulations in their partners' regions and countries, typically, laws and regulations administrated by the US environmental protection agency (EPA). In reality, companies are also required to follow their partners' self-developed environmental standards. For example, IBM forces their suppliers to complete a product content declaration form to document compliance to their environmental requirements, namely, IBM Engineering Specification (IBM ES 46G3772), containing restrictions on materials and certain chemicals used in manufacturing, such as battery collection programs, energy efficiency, etc.

3. Ontological intelligent agent platform

3.1. VE structure and supplier selection criteria

Fig. 1 depicts a simple VE structure with the VE initiator acting as the centralized decision maker. In this example, the VE initiator

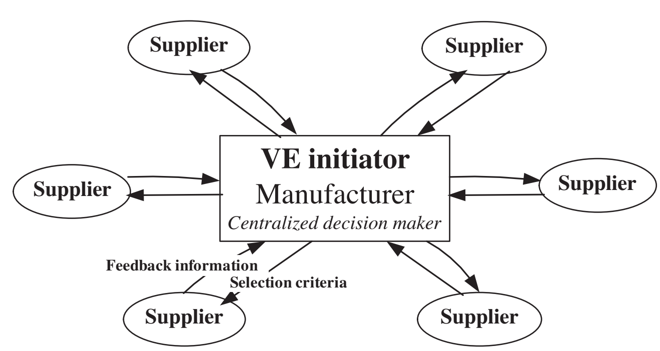

Fig. 1. Centralized decision making VE structure.