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The Role of Similarity Measurement in an Agent-Based Supplier Selection Framework

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ABSTRACT

Similarity measurement is a critical component in any case-based reasoning (CBR) system. CBR is a superior technique for solving new problems based on previous experiences. Main assumption in CBR relies on the hypothesis that states similar problems should have similar solutions. This paper describes a comparative analysis on several commonly used similarity measures (Canberra, Clark, and Normalized Euclidean distance) in retrieving phase of the case-based reasoning approach to facilitate supplier selection. In addition, the proposed agent-based supplier selection framework was designed to use customer's defined weights to evaluate the price, volume, quality grade, and delivery date of supply materials, and also provide them with alternative products which are closest to their first order if it was out of stock. Finally, based on the proposed framework, a numerical example of the used approach is illustrated.

Keywords: Supplier selection, intelligent agent, customer knowledge management, case based reasoning, similarity measures

INTRODUCTION

In general, knowledge management has been of interest to companies because they realize that it can contribute to their competitive advantage. Therefore, in emphasizing on knowledge as a key competitive factor in the global economy, these companies may be overlooking a major element, i.e. customer knowledge. This means the knowledge that a customer has about the issues that are related to the products or services that he is interested in buying. Since the firm has a better understanding of the customer's expectations and needs, it will be able to improve customer service and thus

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achieve customers' satisfaction and retention. Better relationships with the customer can lead to increased sales and then new customers (García-Murillo & Annabi, 2002).

A supply chain is a network of organizations and their associated activities like procurement, manufacturing and distribution that work together to produce value for customers (Wang *et al*., 2008). Competitive advantage in tomorrow's environment will go to those enterprises that can consistently anticipate and implement customer-winning supply chain competencies (Ross, 2003). On the other hand, selecting the suitable suppliers has influence on the short- and long-term profits or losses of companies which spend a significant amount of their time and money on purchasing parts. Various selection criteria, weighting methods, and intelligent models have been used to support the supplier selection of organizations (Chang-Joo & Chung-Hsing, 2011). However, the failure of coordination between manufacturers and suppliers results in excessive delays and ultimately leads to poor customer services (Lee *et al*., 2001). Then, there is a need for an automated and integrated system framework. This paper aims to present such a framework for cooperation and information exchange that can receive orders and preferences from customers, generate production plans and material requirement specifications, check the inventory, make a build or buy decision, call suppliers for proposals, as well as receive and evaluate material offers, select the best suppliers, negotiate with them, and satisfy the requirements of the negotiating parties. These can be useful for all the stakeholders, especially customers who are more crucial for any company's survival.

RELATED WORK

The benefits of adopting agent technology in SCM (Supply Chain Management) systems have been recognized in an increasingly wide variety of applications. The agent technology facilitates the integration of the entire supply chain as a networked system of independent echelons (Gjerdrum *et al*., 2001). Agents are also capable of solving the problem of matching supply to demand and carrying out information exchange, uncertainty resolution, and preferences revision (Blecker & Graf, 2003). Due to the large amount of data collected and it is hard to remember every customer's preferences, agents can play a key role to collect and analyze this information, and then customers could be recognized later and presented by a series of alternatives that suit their preferences (García-Murillo & Annabi, 2002).

A number of researchers have attempted to apply agent technology to manufacturing integration, supply sourcing, supply chain management, negotiation, information transfer and knowledge sharing within a supply chain. Among other, Saad *et al*. (1995) proposed a Production Reservation approach by using a bidding mechanism based on the Contract Net protocol to generate production plan and schedule. Meanwhile, Barbuceanu and Fox (1997) proposed organizing supply chain as a network of cooperating agents, each performing one or more supply chain functions and coordinating their actions with other agents (Barbuceanu and Fox, 1997). Maturana *et al*. (1999) developed a hybrid agent-based mediator-centric Framework, called MetaMorph, to integrate partners, suppliers and customers dynamically with the main enterprise via the Internet and Intranets (Maturana *et al*., 1999). Min and Bjornsson (2000) presented a conceptual model of agent-based supply chain automation, in which a project agent gathers actual construction progress information and sends them to subcontractor agents and supplier agents, respectively, over the Internet (Min and Bjornsson, 2000). Jiao *et al*. applied multi-agent paradigm to collaborative multi-contract negotiation in a global manufacturing supply chain (Jiao *et al*., 2006). Wentao designed an agent-based negotiation model for the sourcing of construction supplies based on a new parallel bargaining protocol and Bayesian learning model (Wentao, 2008).

Typically, supplier selection is a multi-criteria decision problem (Weber *et al*., 1991; Ghodsypour & O'Brien, 1998). The suggested methods in the related literature can be classified into two categories, namely, mathematical programming models and weighting models. The mathematical programming model has a problem in dealing with qualitative criteria that are very important in decision making (Ghodsypour & O'Brien, 1998). Chang and Chung (2011) developed a multi-criteria decision making (MCDM) model for a manufacturing company to select suppliers based on customer order dependent weighting method to determine the weights of the supplier selection criteria. This was achieved by modelling the relationship between the customer order factors and supplier selection criteria, using a knowledge base with if-then rules (Chang-Joo & Chung-Hsing, 2011).

However, most of the above works have not applied the case based on reasoning method with customers' defined weights in the supplier selection and find alternative supplies due to the stock out. Failure to account for that may either lead to unsatisfied customer demand and loss of market share. Therefore, in order to keep customers and the multi-criteria decision making nature of supplier selection, first, this paper aims to present an agent-based supply chain framework in support of selecting the best suppliers by means of the proposed case-based reasoning approach. CBR is in the subset of weighting models. This framework is going to evaluate material offers, negotiate with suppliers and customers on the price and terms of quotation in the negotiation process and make successful agreements with the final supplier. In addition, this framework also wants to take into consideration customers' knowledge and provide them with alternative supplies, which are closest to their first order, if the manufacturer is unable to supply it. Then, the performance of the supplier's selection process will be improved to reach a real "win-win" situation and the mentioned problems like unsatisfied customers and then losing them can be reduced.

AN AGENT-BASED SUPPLY SELECTION FRAMEWORK

The proposed agent-based supply chain framework can generate a flexible, reconfigurable and coordinated approach for supplier selection process, both across enterprises and within an enterprise. In this framework, there is a FIPA-compliant (The Foundation for Intelligent Physical Agents) multi-agent system composed of a seller agent, a design agent, a procurement agent, a buyer agent, and a case-base for keeping suppliers records. Each agent performs one or more supply chain functions independently and coordinates its actions with other agents. This framework is illustrated in Fig.1 and the major components of the proposed framework are described below. Besides in this section, the order management and the supplier selection mechanism, along with Case-Based Reasoning (CBR) approach, will be defined later.

Seller agent provides an intelligent interface for the customers to place their personal orders. It is responsible for acquiring orders and preferences' weights from customers, handling order modification or cancellation. *Design agent* is responsible to gather all the incoming orders from the seller agent and eliciting relevant information regarding customer's preferences. Another task of this agent is product planning and placing Material Requirement Specification (MRS) into case structures and also sending them to *Procurement agent* and receives offers from it. *The Procurement agent* decomposes MRS into specific categories to generate and advertise Call For Proposals (CFP) through the *Buyer agent* as an intelligent interface to all the potential suppliers. Buyer agent is responsible for the general negotiation process that is divided into three consecutive phases: inviting, bidding and awarding. Whenever an order comes to a buyer agent, it invites potential suppliers to bid by sending a CFP to seller agents of suppliers. Then, it will collect and evaluate all the bids based on *Suppliers' Case-Base* and choose the one with maximal utility as a winner, and thus the winner supplier is awarded the contract. A few rounds of conversation may take place, where several proposals and counter-proposals are exchanged. The negotiation will end when one party accepts or rejects the other party's proposal, or when any party terminates the negotiation process on its own (Jiao *et al*., 2006). *Suppliers' Case-Base* keeps supplier information files as cases and gathers information on the past and new suppliers in order to identify alternative suppliers. This information includes the name of each supplier, a list of the available materials and their attributes, the supplier's delivery history, the supplier's quality records, the supplier's overall desirability, and general information about the supplier's plant and management.

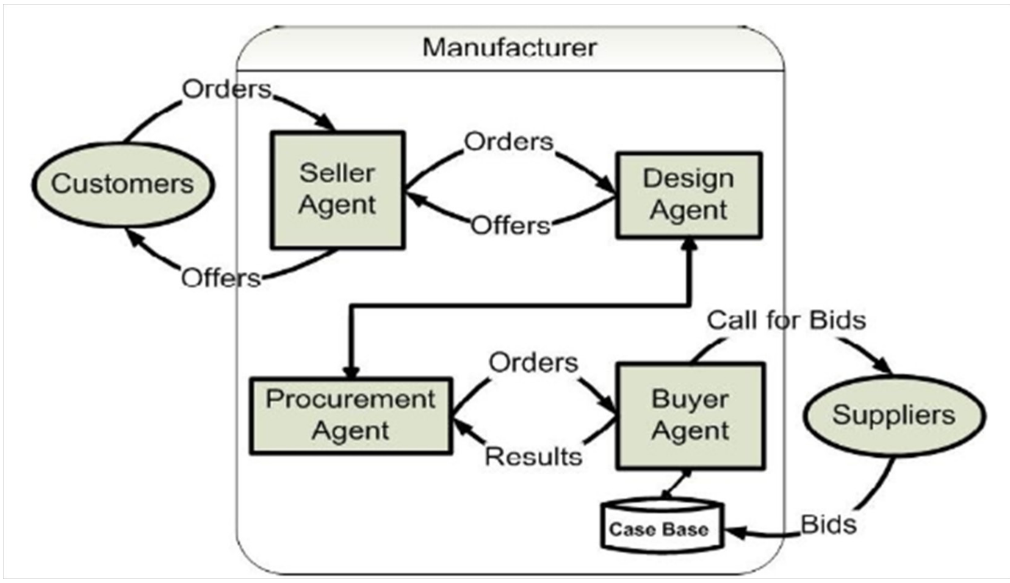

Fig.1: Multi-agent based supply chain framework

Order Management and the Supplier Selection Mechanism

Here, the major activities of the proposed framework are briefly described for a better understanding:

1. The customer places an order through the seller agent to the design agent.
2. The design agent will formulate the MRS and make a case structure of CBR approach for the ordered product and then send it to the procurement agent.
3. The Procurement agent checks the inventory regarding stocked finished products and raw materials based on the MRS structure. If the stock has enough resources, then there is no need for supplying.
4. Otherwise, the procurement agent must manage supplying sufficient raw materials from the suppliers.
5. The procurement agent advertises its outgoing orders with CFPs through the buyer agent for all the potential suppliers.
6. After receiving the CFPs, the potential suppliers make the decision of bidding and then bid on the case base of buyer agent.
7. After receiving all the bids, the buyer agent will evaluate the suppliers in consideration of price, due date, quality grade, volume, and so on, and then choose the most suitable suppliers.
8. If some or all supply materials of the customer's first order are found during the supplying process, the procurement agent will try to generate alternative product recommendations based on the received bids and offer them to the customers.
9. If the customer accepts the new offer, the buyer agent will then choose the suppliers who bid the alternative product's materials.
10. The buyer agent proclaims the award of bid and gives necessary replies to the un-chosen suppliers.
11. The supplier who has won the bid carries out manufacturing to fulfil the incoming orders.
12. The supplier delivers its finished products to the manufacturer.

Case-Based Reasoning (CBR) Approach

One of the most important contributions of this paper is that it shows how buyer agents can check orders with received bids from its associated case-based and responds to requests from the procurement agent. After receiving all the bids and storing them in the case base, the buyer agent retrieves from the case base cases that are identical or at least most similar due to the features of the new order's case. According to Maturana *et al*. (1999), the process of CBR strategy includes four steps (retrieve, reuse, revise and retain), which constitute the CBR cycle but the revised and retrained steps are not inculded in the scope of this paper. However, before the cycle can be run, another step, case description, should also be performed for both case base construction and application of case knowledge. Here are the explanations for each step that starts with Case Description:

1) Case Description: The CBR mechanism starts with the description of a new order which corresponds to a new case. Case description concerns with deciding what contents are to be stored in a case. It is important for the new case to be adequately described so that the retrieval of appropriate previous or newcomer's cases from the case base is possible. By considering order constraints which contain MRSs for ordered products, this research adopts the case structure as shown in Table 1 to describe each case. Product ID numbers, a certain product for its own and required materials; Product name indicates the name of the product; Price indicates the offered price to customers or suggested by customers in an incoming order; Volume shows the requested quantity of ordered products from customers or bidding quantity from suppliers; Quality Grade specifies the requested quality for each material; Delivery Time is the requested time by customer for each order. For suppliers, it indicates the possible delivery time for their bids.

TABLE 1: Case structure and content

Case Attribute	Attribute Value
Product ID	Integer, from 01 to n
Product name	text
Price	Integer, from 1 to n
Volume	Integer, from 1 to n
Quality Grade	Integer, from 1 to 5
Delivery Time	Integer, number of days

2) Case Retrieval: Case retrieval is finding the most similar case from the case base according to the features of a new case. A CBR method seriously depends on this step to find the order's matches of incoming bids from suppliers. There are numerous similarity measures in use today. While different similarity measure employs different algorithms, they have basically the same in functionality, and these are to take two objects as input and output as a measure of their similarity. The existence of many similarity measures does not always give a clear choice of an appropriate measure for a particular application domain. Hence, it is often convenient to be able to experiment with different measures before a final version is decided upon (Long *et al.*, 2004).

In this paper, three similarity measures (namely, Canberra, Clark, and Normalized Euclidean distance) were used as similarity functions in the nearest neighbour algorithm, one of the widely used methods to identify the similarity between cases employed here to perform the retrieval task. For the nearest neighbour algorithm, the similarity of two cases was calculated according to (1), as follows:

$$similarity(O,S) = \frac{\sum_{i=1}^{n} w_i \times sim(O_i, S_i)}{\sum_{i=1}^{n} w_i} \tag{1}$$

In (1), *O* is the new order, *S* is the incoming bid from the suppliers, O_i and S_i are the features *i* of *O* and *S,* respectively, w_i is the weight of feature *i*, and $sim(O_i, S_i)$ is the similarity function of the feature *i*. The value of $sim(O_i, S_i)$ is calculated in three different ways; the normalized absolute difference of the individual level is called Canberra in the equation (3), the squared root of half of the divergence is called Clark in the equation (3), and Normalized Euclidean distance in the equation (4):

Canberra:

$$sim(O_i, S_i) = 1 - \frac{\left|O_{i_k} - S_{i_k}\right|}{\left|O_{i_k} + S_{i_k}\right|} \tag{2}$$

Clark:

$$sim(O_i, S_i) = 1 - \frac{\left|O_{i_k} - S_{i_k}\right|^2}{\left|O_{i_k} + S_{i_k}\right|^2} \tag{3}$$

Normalized Euclidean:

$$sim(O_i, S_i) = 1 - \sqrt{\sum_{k=1}^{m} \frac{\left(O_{i_k} - S_{i_k}\right)^2}{\sigma^2}} \tag{4}$$

The weights of the features, which have been obtained from the customers, are applied to select the closest suppliers' bid to the customer's order. The role of the supplier selection mechanism is to calculate the similarity of each feature of the bids during the supplier selection and also to rank the alternative suppliers.

3) Case Reuse: Once the same case or the most similar case to the incoming order is selected from the received bids, it will then be offered to the customer. For the same cases, the suggested case can be reused by direct copy. However, for most situations that have different values in their attributes, the seller agent can offer the retrieved case as an alternative to the customer who can either accept or reject it.

CASE STUDY

In order to illustrate the proposed method of this paper, the case study of Moxober, a leading mobile phone manufacturing company in Finland (which has also been used by Jiao *et al*., 2006) was also used for the current work. Fig.2 shows Moxober's product structure at three levels: component arts, subassemblies and the final product. Nearly all the components parts were produced by Moxober, but with the development of global economy and booming telecommunication market, it has changed to a global manufacturing strategy focusing on key technologies and its core competency while outsourcing major component manufacturing activities, such as the manufacturing of peripherals like batteries and chargers, memory chips and LCD panels.

In Moxober's supply chain network, customers and suppliers are spread worldwide. The mobile phone company plays the role of the manufacturer. Its direct suppliers, which are labelled as Supplier I, provide resources like software, PCB (Printed Circuit Board), LCD (Liquid Crystal Display), cover and peripheral. Its suppliers' suppliers (which are labelled as Supplier II) provided sub-resources like chip, board, interface, charger, and battery to the corresponding Supplier I. The next issue is to determine a specific configuration of the global manufacturing supply chain network for each individual customer order of a particular product model.

In this paper, the operation of this specific supply chain network is analysed by means of an agent-based supply chain framework and giving a numerical example for using CBR in the supplier selection process. In fact, actual employment of a supplier should be consistent with the product fulfilment process of a specific customer's order to achieve customers' satisfaction.

Now, suppose a customer's order is from Wenzhou China. This customer places his order through the seller agent of the mobile phone company. Through interaction, the customer can configure various ordering parameters such as product features like quality grade, quantity, price, and delivery date. The order information then goes to the design agent for product planning and determining a set of MRSs for each order along with the defined constraints. Then, the MRSs will be organized into three case structures for LCD, Cover and Peripheral, and then forwarded to the procurement Agent.

In order to accelerate the delivery, the procurement agent decides to allocate the final assembly of this order to the Xiamen plant in China - a process which involves the requirement specification of three material types, namely, LCD, Charger and Battery. The software design and PCB assembly operations are still held in Finland. The buyer agent will broadcast the material requirements to the potential suppliers who will bid on the platform of this agent to win the supplier selection procedure.

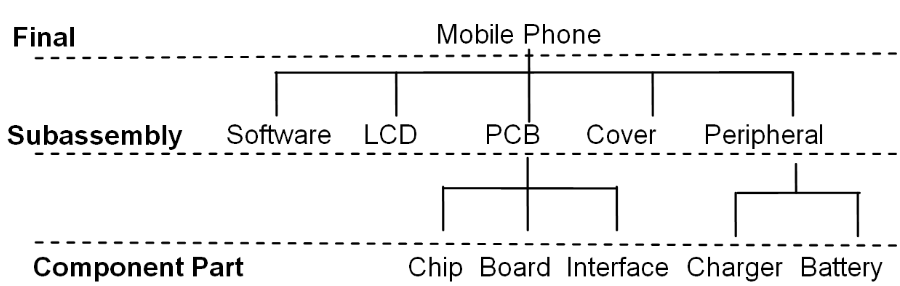

Fig.2: The BOM structures of Moxober mobile phones (Jiao *et al*., 2006)

Since that customer defines the range for his order, the best values which are the highest for attributes like volume and quality and the lowest for attributes like price and delivery date were used to find more suitable alternative products. For example, the best values of the price, volume, quality, and delivery date for MRS1 are:

$$Order_{high} = (01;013;\text{Charger};20;\&800;5;20)$$

Table 2 shows the case structure of an incoming order (ID=#13) related to MRSs, in addition to the defined weight by the customer for each attribute.

TABLE 2: Case structure values

Case Attribute	MRS1	MRS2	MRS3	W
Product ID	O1;013	02;013	03;013	-
Product name	Charger	Battery	LCD	-
Price	20-30	50-80	100-120	2
Volume	600-800	1200-1600	1000	4
Quality Grade	3-5	2-4	4-5	5
Delivery Date	20	15	12	4

Table 3 shows all the incoming bids received from the suppliers and the offered values for each attribute, including price, volume, quality, and delivery date.

TABLE 3: Incoming Bids

MRS	Bid	Volume	Price	Due Date	Quality Grade
MRS 1 Charger	Bid11:Supplier01	800	20	20	5
	Bid12:Supplier02	1000	25	18	4
	Bid13:Supplier03	800	20	18	3
MRS 2 Battery	Bid21:Supplier04	1000	65	22	4
	Bid22:Supplier05	1400	70	10	4
	Bid23:Supplier06	2000	45	18	3
MRS 3 LCD	Bid31:Supplier07	1000	120	11	5
	Bid32:Supplier08	1200	100	10	4
	Bid33:Supplier09	900	90	15	3

Now, for the nearest neighbour algorithm, which is used to find the most similar bid, and the similarity of highest values of orders with each bid are calculated as follows. For example, the similarity of order 1 and supplier 1's bid for MRS1 are:

$$sim_{price}(O_{1_{High}}, S_1) = 1 - \left| \frac{20-30}{|20|+|30|} \right| = 0.8, \quad sim_{volume}(O_{1_{High}}, S_1) = 1 - \left| \frac{800-800}{|800|+|800|} \right| = 1$$

$$sim_{quality}(O_{1_{High}}, S_1) = 1 - \left| \frac{5-5}{|5|+|5|} \right| = 1, \quad sim_{delivery-date}(O_{1_{High}}, S_1) = 1 - \left| \frac{20-20}{|20|+|20|} \right| = 1$$

$$Similarity(O_{1_{High}}, S_1) = \frac{(0.8\times 2)+(1\times 4)+(1\times 5)+(1\times 4)}{2+4+5+4} = 0.973$$

Table 4 shows all the results of similarity function calculations for the highest values of the received orders and suppliers' bids for each MRS. The weight of each attribute is assumed to be both equal to 1 and with various weights from 1 to 5 for each attribute.

TABLE 4: The overall similarity function results

MRS	Bids	Utility (Jiao *et al*., 2006)	W=1 Canberra	W=1 Clark	W=1 Euclidean	W=1-5 Canberra	W=1-5 Clark	W=1-5 Euclidean
MRS 1 Charger	Bid01	0.68	0.922	0.986	-1	0.943	0.991	0.434
	Bid02	0.73	0.936	0.993	-1.499	0.936	0.993	0.037
	Bid03	0.75	0.846	0.970	-1.828	0.846	0.969	-0.414
MRS 2 Battery	Bid04	0.65	0.868	0.974	-1.499	0.872	0.974	0.058
	Bid05	0.72	0.916	0.987	-1.499	0.919	0.987	0.058
	Bid06	0.69	0.843	0.969	-1.828	0.843	0.976	-0.414
MRS 3 LCD	Bid07	0.77	0.989	0.999	-0.414	0.988	0.999	0.623
	Bid08	0.71	0.903	0.990	-1.828	0.902	0.989	-0.414
	Bid09	0.69	0.873	0.975	-1.828	0.870	0.971	-0.414

The results show that the weighted attributes do not play an important role in the awarding process of three similarity measures and the satisfaction of the MRS constraints. For instance, if w=1, the bid of supplier 2 with the highest similarity for MRS1 would be selected in both the Canberra and Clark measures and supplier 1 is selected in Normalized Euclidean distance measure. The only exception in the awarding process is for Canberra similarity measure when different weights are applied. Table 5 lists the winners of the awarding process in comparison to (Jiao *et al*., 2006) the utility values for each MRS. In Jiao *et al*. (2006) for MRS, S1 was selected; however in this paper, S2 is selected due to the proposed mechanism and considering the different weights for different attributes.

TABLE 5: Winners

MRS	Utility (Jiao *et al*., 2006)	W=1			W=1-5		
		Canberra	Clark	Euclidean	Canberra	Clark	Euclidean
MRS 1 Charger	S3	S2	S2	S1	S1	S2	S1
MRS 2 Battery	S5	S5	S5	S4, S5	S5	S5	S4, S5
MRS 3 LCD	S7	S7	S7	S7	S7	S7	S7

CONCLUSION

This paper presents an agent-based Supply Chain framework for supplier selection by considering the influence of different similarity measures in case-based reasoning process. The process involved selecting the best suppliers using the CBR method to match incoming orders with those of the received bids from the suppliers. In the proposed framework, customer orders have various weights in the CBR approach. Sometimes, the manufacturer is unable to supply and to provide their customers' first order. Therefore, the main contribution of this research is to take the customers' preferences into consideration and to provide them with alternatives which are most similar to their first order from various suppliers. The second contribution is to use the CBR approach in finding the most similar alternatives by using three different similarity measures, namely, Canberra, Clark, and Normalized Euclidean distance. During the ordering process, customers can define the features' importance of their orders by weight. Hence, in the case retrieval level, these weights can help to find the most similar bids and offer alternative products to the customers based on their desires. The results of the numerical example show that the proposed approach is robust enough to find the closest bid to the received order and rewards the winner supplier. The improvement and development of the prototype of the proposed framework should be submitted to further studies.

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