AN ONTOLOGY-BASED INTELLIGENT SYSTEM WITH AHP TO SUPPORT SUPPLIER SELECTION

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Abstract

Due to the popularity of Internet and growing business-to-consumer electronic commerce, the alternative products or services whose information can be acquired through the webs also significantly increased. In this paper, an intelligent agent system, which was initially designed and implemented for the specific application of supplier selection, is proposed to act for consumers in the matters of gathering information of expected suppliers and making an optimal choice from these suppliers. This agent system is composed of two subsystems, product gatherer and decision maker, to address the two key issues, finding out right products and making a right choice. First, Web Ontology Language (OWL) is utilized to define the ontology, which is used for processing the semantic content of gathered supplier's information. Decision maker subsystem utilized the Analytic Hierarchy Process (AHP), which is a structured technique for dealing with complex decisions, to make an optimal decision to contribute to the improvement of consumer-oriented e-commerce services.

Keywords: Analytic Hierarchy Process, Decision Support System, Ontology, Supplier Selection

Introduction

The development of the Internet and WWW technologies has made a great impact on the life and business of humans, and consequently it has caused the electronic commerce (EC) applications to grow extraordinarily, especially for the business-to-consumer (B2C) applications. This rapid advancement of B2C business model brings consumers not only the convenience for completing a transaction but also the various product or service alternatives for making a favorite choice.

Because of the increase of similar product alternatives provided by the large number of websites, selecting a satisfying one may become a hesitating process for consumers. Making decision with many tradeoff considerations is the major cause of such a hesitation. The requirement of a consumer is

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not merely acquiring products information, but also getting the right and optimal one. An offer of help to consumers for completing the decision becomes necessary and critical. To solve the problem, it requires an intelligent decision-making process.

This paper proposes an architecture and an intelligent agent to help consumers make the purchase decision by conducting the World Wide Web Consortium and Analytic Hierarchy Process (AHP) (Saaty, 1980, 1994). There are two fundamental components, product gatherer and decision maker in the system. The first one is based on web service architecture and majorly responsible for completing supplier information aggregation from distributed database servers respectively offered by the corresponding suppliers. The other one acts as a decision support system by utilizing AHP process with the gathered supplier data.

Literature Review

The foundation of the Analytic Hierarchy Process (AHP) is a set of axioms that carefully delimits the scope of the problem environment (Saaty, 1986). It is based on the well- defined mathematical structure of consistent matrices and their associated eigenvector's ability to generate true or approximate weights (Merkin, 1979; Saaty, 1980, 1994). Some of the industrial engineering applications of the AHP include its use in integrated manufacturing (Putrus, 1990), in the evaluation of technology investment decisions (Boucher and McStravic, 1991), in flexible manufacturing systems (Wabalickis, 1998), layout design (Cambron and Evans, 1991), location planning of airport facilities and international consolidation terminals (Min, 1994) and also in other engineering problems (Wang and Raz, 1991).

The supplier selection decision is highly complex and purchaser's most difficult responsibility. Garfamy classifies the main supplier selection criteria as cost, quality, cycle time, service, relationship, organization (Garfamy, 2004) which every criterion is composed of different factors. Bhutta (2001) reviews the status of methodology literature in supplier selection, a total of 154 papers from 68 refereed journals are reviewed and classified into various categories such as Mathematical Models, Criteria, Case Study, Literature review, Conceptual. In this paper, an intelligent agent system was designed and implemented, which can gather information based on the Web Ontology Language (WOL) and utilized the Analytical Hierarchy Process (AHP) to make an optimal decision for the selection of suppliers. The proposed intelligent agent system with utilizing Analytic Hierarchy Process decision mechanism acts as a Decision Support System (DSS) to assist consumers in decision-making, and furthermore it can contribute to the enhancement of consumer-oriented e-commerce services.

System Architecture

This section describes our proposed ontology-based intelligent agent system with analytic hierarchy process as a decision support system to support supplier selection for consumers. As shown in Figure 1. System architecture, which contains the front-end Client Tier (Web Browser), middle Application Tier (Web Application) and back-end Data Tier (Web Service). The consumers, which want suppliers, will expect to evaluate some criteria before making the decision. The system provides consumers with an opportunity to interact with the AHP DSS Agent by using the web browser such as Microsoft Internet Explorer or Mozilla Firefox. This agent will help users to collect the information from suppliers and recommend an optimal one according to user preference through the AHP process. The interaction between users and the agent will proceed via the HTTP protocol.

Before running AHP process to generate a recommendation of supplier alternatives, the AHP DSS agent will gather the information of suppliers from distributed database servers provided by different suppliers. For delivering data via a standard communication interface, the system utilizes SOAP (Simple Object Access Protocol) for the data communication between middle tier and back-end tier. This will require the database system that supports Web Service functionality. Microsoft SQL Server 2005, which has built-in web service, satisfies the requirement and is utilized by our proposed system.

On the other hand, data must be expressed in a structured and standard manner for the purpose of interoperability; therefore, Web Ontology Language (OWL) is used (Paolucci *et al*, 2004) to define the XML-based travel ontology in our system. Data or information of suppliers will be stored and delivered in an XML formation.

The proposed system is composed of two major subsystems in respect of system functionality; they are product gatherer and decision maker. Details of these two subsystems will be described as follows.

Product Gatherer Subsystem

This subsystem can be divided into two parts: data requester and data provider. The data requester, which is a component of the AHP DSS Agent, will raise a request to the data provider to ask the data of products and services offered by the suppliers in the near future. Naturally, not all suppliers but just the ones that satisfying the consumer's preference will be requested. The preference setting will be finished through the user interface web pages in the AHP DSS Agent. After receiving the request, data provider will query database and return the result data of suppliers as the corresponding response. Data request and response are finished under the Web Service-based environment; thus, data requester can acquire its required data via a Remote Procedure Call to the data provider. To do this, the SOAP standard protocol which is upper and based on the well-known XML technology and HTTP protocol should be used. Since Microsoft SQL Server 2005 provides built-in native XML Web Services with SOAP through its database engine (Andrew and Stephen, 2006), we utilized it as the database system in our proposed system.

The network communication between data requester and provider is via SOAP request and response packets. User's preference setting and return supplier's data should be respectively encapsulated in the SOAP request and response packets. We conducted the Ontology concept into the encapsulation; thus, ontology-based XML schema was used in the expression of preference setting and return data. Web ontology language was followed up in our system to pre-define the product or service ontology. Fundamentally, since Microsoft SQL Server 2005 supported the XML data type and related query methods in the database system, our system utilized this mechanism to store the suppliers data in the database for further queries and retrieves.

Data requester raises a request and gets return results via Remote Procedure Call which performs the detail data query process. It is implemented by the Stored Procedure which is a saved collection of Transact-SQL statements in the database system and is created by the CREATE PROCEDURE statement. In our system, we created and used stored procedure to perform the suppliers data query with indicated preference parameters and return result data for further decision-making process.

The other important task is to set up the database engine as a Web Service provider that can listen to SOAP requests. This requires the creation of an HTTP Endpoint beforehand. HTTP Endpoint is created for use with Microsoft SQL Server 2005 to listen to and receive requests on a TCP port (Ex: port 80) and start up the execution of indicated stored procedure. It can be created by the CREATE ENDPOINT statement in the database system.

An additional remark is that the only one data requester is built in the middle-tier AHP DSS Agent, but data provider exists in each joined suppliers. Therefore, AHP DSS Agent can send SOAP requests to many HTTP Endpoints that are distributed in respective database servers provided by the suppliers and can get various product or service data from these suppliers for further supplier selection decision. In current stage of our proposed system, the list of joined agencies is recorded within a table in the AHP DSS Agent. In the future work stage, the web service registration mechanism such as UDDI (Universal Description, Discovery and Integration) (OASIS, 2002) service will be conducted into our system.

Decision Maker Subsystem

Once the data of products and services is acquired, the next step is making a decision by selecting a preferred supplier for further purchase. Making decision by user individual self with many tradeoff considerations will be a hesitating process. Analytic Hierarchy Process is used in our proposed system to solve such a problem. It is a structured technique for assisting people to deal with complex decisions and following are the steps used in this process:

- ❑ Synthesis of priorities for all the criteria and measurement of Consistency Ratio (CR)
- ❑ Prioritization of alternatives as against all the criteria of vendor selection separately
- ❑ Synthesis of overall priority matrix of alternative suppliers

Synthesis of Priorities and the Measurement of Consistency

The pair-wise comparisons of the criteria of vendor selection problem generate a matrix of relative rankings for each level of the hierarchy. The number of matrices depends on the number of elements at each level. The number of elements at each level decides the order of every matrix of the next higher level. After all matrices are developed, eigenvectors or the relative weights (the degree of relative importance amongst the elements) and the maximum eigenvalue (λ_{max}) for each matrix are calculated. The λ_{max} value is an important validating parameter in AHP. It is used for calculating the consistency ratio (CR) (Saaty, 2000) of the estimated vector in order to validate whether the pair-wise comparison matrix provides a completely consistent evaluation. The consistency ratio is calculated as per the following steps:

Step 1: Calculate the eigenvector or the relative weights and λ_{max} for each matrix of order *n*

Step 2: Compute the consistency index for each matrix of order n by the formulae:

$CI = (\lambda_{max}-n) / (n-1)$

Step 3: The consistency ratio is then calculated using the formulae: $CR = CI/RI$

where Random Consistency Index (RI) variesdepending upon the order of matrix. Table 1 shows the value of the Random Consistency Index (RI) for matrices of order 1 to 11 obtained by approximating random indices using a sample size of 500 (Saaty, 2000).

The acceptable CR range varies according to the size of matrix i.e. 0.05 for a 3 by 3 matrix, 0.08 for a 4 by 4 matrix and 0.1 for all larger matrices, $n >= 5$ (Saaty, 2000, Cheng and Li, 2001). If the value of CR is equal to, or less than that value, it implies that the evaluation within the matrix is acceptable or indicates a good level of consistency in the comparative judgments represented in that matrix. In contrast, if CR is more than the acceptable value, inconsistency of judgments within that matrix has occurred and the evaluation process should therefore be reviewed, reconsidered and improved. An acceptable consistency ratio helps to ensure decision-

Table 1. Average random index (RI) based on matrix size (Saaty, 2000)

Size of the Matrix (n)	1	2	3	4	5	6	7	8	9	10	11
Random Consistency Index (R.I)	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51

maker reliability in determining the priorities of a set of criteria.

Prioritizing of Suppliers

The pair wise comparison of all criteria separately for each suppliers is executed in this step. For each criterion, a priority matrix is obtained for suppliers by following the same procedure described above.

Synthesis of Overall Priority Matrix

After the synthesis of priority matrices for the criteria of supplier selection as well as for the suppliers for every criteria, an overall priority matrix is synthesized. This priority matrix is obtained by multiplying the priority matrix obtained for each criterion for various suppliers with the priority matrix obtained by the comparison of criteria itself. The matrix thus synthesized will give the overall priority matrix suppliers using the criteria of supplier selection as criteria for the selection of suppliers.

Supplier Selection Using AHP DSS

Evaluation and selection of suppliers is a typical multiple criteria decision making (MCDM) problem involving multiple criteria that can be both qualitative and quantitative (Sonmez, 2006). Evaluation and selection of suppliers is a group decision making problem. This group has been formed with the experts from procurement, planning, marketing, sales, public relations, logistics, accounting and technical departments. The various criteria that are important for supplier selection, as evident in literature and from discussions with experts, are price, transportation cost, quality, quality certification, lead time, buffer stock needed, goodwill and reliability of the supplier, experience of the supplier in the same field etc. (Weber *et al*, 1991; Bajaj *et al*, 2005). Vendor selection problem solved in the paper based on the criteria of price of product (PP), transportation ease and cost (TC), quality certification of the supplier (ISO, ISI certification) (QC), quality of product (based on rejection rate) (QP), goodwill of the supplier (GW), reliability of the supplier (RV), experience of the supplier in the same field (EV), lead time (LT) and buffer stock of inventory required (BS).

Results

After the ratings have been obtained through the questionnaire for the supplier selection of a retail chain company, the average matrix for these ratings is shown in Table 2. The numbers in the Table 2 represent how much

Table 2. The average matrix for the criteria of vendor selection

Criteria	PP	TC	QC	QP	GW	RV	EV	LT	BS
PP	1	8	0.2	0.125	3	0.143	0.5	2	2
TC	0.125	1	0.143	0.125	0.2	0.143	0.2	0.333	0.333
QC	5	7	1	0.2	0.333	0.333	0.25	0.5	0.25
QP	8	8	5	1	1	1	1	3	3
GW	0.333	5	3	1	1	0.5	1	0.167	0.2
RV	7	7	3	1	2	1	2	3	3
EV	2	5	4	1	1	0.5	1	2	3
LT	0.5	3	5	0.333	6	0.333	0.5	1	1
BS	0.5	3	4	0.333	5	0.333	0.333	1	1

more important the row attribute is compared to the column attribute. For example, Price of Product (PP) is eight times more important than Transportation ease and Cost (TC). Similarly, Quality of Product (QP) is eight time more important than Price of Product (PP).

The maximum value of eigen vector for the above matrix, λmax = 12.63

Consistency index, C.I. = (λ_{max} -n)/(n-1) = 0.45

Random Index for the matrix of order 9, R.I. = 1.45

Consistency Ratio, *C.R. = C.I. / R.I.* = 0.3, which is greater than 0.1.

With the responses being taken over from a wide range of experts from various fields, the consistency ratio is found to be greater than the desired value. The pair-wise comparison of all the criteria of vendor selection problem generates a priority matrix as given in the Table 3.

Table 4 above shows that Reliability of the Vendor (RV), Quality of the Product (QP) and the Experience of the Vendor in the same field (EV) are top three in the supplier selection problems. After that, a priority matrix for the criteria of supplier selection, the priority matrices for these criteria have been obtained for different suppliers.

Discussions

From Table 4 we obtain that, the priority matrices for the criteria of Transportation ease and Cost (TC), Quality of Product (QP), Goodwill of Vendor (GV), Reliability of the Vendor (RV) and Experience of the Vendor in the same field (EV), supplier L is the best suitable, priority matrices for Quality Certification of the vendor (QC), supplier M and L are both equally preferable whereas for the criteria Price of Product (PP), Lead Time (LT), Buffer Stock of inventory required (BS), supplier S is preferable. Table 5 shows that supplier L will be the best alternative followed by supplier M and Supplier S. Therefore, AHP DSS suggests that Reliability of the Vendor, Quality of the Product and Experience of the Vendor the same field are top three criteria for the supplier selection problem and supplier L is found the best alternative as compared to supplier M and Supplier S.

Conclusions

This paper proposes an architecture that integrates an ontology-based web service and the Analytic Hierarchy Process (AHP) to provide consumers with the decision support service for supplier selection. Since making decision with many tradeoff considerations usually causes hesitation - in customers, our proposed intelligent system can help to solve this situation and offer a preferred and optimal choice suggestion to the consumers for further purchase. The system can be improved in the future work by introducing UDDI (Universal Description, Discovery and Integration) service registration mechanism into data gatherer subsystem for the process flexibility improvement of tourist data aggregation from travel agencies.

Table 3. The priority matrix for the criteria of supplier selection

S. No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Criteria	PP	TC	QC	QP	GW	RV	EV	LT	BS
Priorities	0.089	0.020	0.070	0.196	0.086	0.203	0.136	0.106	0.093
Rank	IV	IX	VIII	II	VII	I	III	IV	V

Table 4. The priority matrices for the criteria of supplier selection by AHP

PP					TC					QC				
Scale	Suppliers			Priority Matrix	Scale	Suppliers			Priority Matrix	Scale	Suppliers			Priority Matrix
	S	M	L			S	M	L			S	M	L	
S	1	3	4	0.608	S	1	0.333	0.2	0.104	S	1	0.2	0.143	0.111
M	0.333	1	3	0.274	M	3	1	0.25	0.231	M	5	1	0.2	0.444
L	0.25	0.333	1	0.121	L	5	4	1	0.665	L	7	5	1	0.444

QP					GW					RV				
Scale	Suppliers			Priority Matrix	Scale	Suppliers			Priority Matrix	Scale	Suppliers			Priority Matrix
	S	M	L			S	M	L			S	M	L	
S	1	0.2	0.143	0.072	S	1	0.167	0.2	0.084	S	1	0.167	0.167	0.076
M	5	1	0.2	0.232	M	6	1	0.25	0.288	M	6	1	0.25	0.277
L	7	5	1	0.696	L	5	4	1	0.627	L	6	4	1	0.647

EV					LT					BS				
Scale	Suppliers			Priority Matrix	Scale	Suppliers			Priority Matrix	Scale	Suppliers			Priority Matrix
	S	M	L			S	M	L			S	M	L	
S	1	0.143	0.143	0.067	S	1	5	7	0.696	S	1	5	5	0.571
M	7	1	0.2	0.270	M	0.2	1	5	0.232	M	0.2	1	4	0.184
L	7	4	1	0.663	L	0.143	0.2	1	0.072	L	0.2	0.25	1	0.094

	PP	TC	QC	QP	GW	RV	EV	LT	BS
S	0.608	0.104	0.111	0.072	0.084	0.076	0.067	0.696	0.571
M	0.274	0.231	0.444	0.232	0.288	0.277	0.270	0.232	0.184
L	0.121	0.665	0.444	0.696	0.627	0.647	0.663	0.072	0.094

Table 5. Overall priority matrix

S. No.	Suppliers	Priorities	Rank
1	S	0.236	III
2	M	0.265	II
3	L	0.483	I

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