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An utility range-based similar product recommendation algorithm for collaborative companies

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Abstract

In this paper, we present a similar product finding algorithm for the collaborative business companies that share the product taxonomy table and have exchangeable products information. The main idea of the proposed algorithm is to compute the aggregated utility ranges over specification values of products in the same product class of the companies and find similar ones between the products. Experimental results from a laboratory application are provided in terms of user satisfaction rates. Their comparative implications with a distance measure-based recommendation algorithm are suggested. The experiment confirmed that our algorithm could be used as a solution for similar product recommendation when a buyer's residence site was different from a receiver's one and the buyer had his/her own incomplete information about the weights of product specifications.

Keywords: Product recommendation; Similar product; Collaborative business; Product taxonomy; Utility

1. Introduction

Electronic commerce is an Internet application and it depends on key infrastructures such as information technology and telecommunications, social/cultural, commercial, and government/legal. In particular cultural elements such as language, education level, beliefs, and value systems influence technological innovations and entrepreneurial spirit. An online survey conducted by International Data Corporation (IDC) suggests that over 76% of Chinese respondents prefer to browse the Internet in their local language, and not in English. When viewed as a global distribution system, international social/cultural barriers remain. Just as many companies have made serious blunders when marketing in other countries, the lack of boundaries and the complexity of global consumer access magnify these complexities beyond anything previously encountered (Javalgi & Ramsey, 2001). Cultural factors inhibit the diffusion of electronic commerce. They comment that cultural values, including different traditions and habits of trading will impact the speed of e-commerce diffusion. Clearly, cultural issues including beliefs, languages, and value systems seem to present barriers to information sharing (Steinfield & Klein, 1999). In order for companies targeting global consumers to overcome the barriers, they allow the consumers to browse the Internet in their local language. Local companies need to have a collaborative strategy of performing vicarious delivery transaction for ordered goods at another area.

The electronic markets offering full support for all market transactions provide the following services or phases; knowledge exchange, articulation and management of intensions, negotiation and contracting, and settlement in the form of payment and delivery (Grieger, 2003; Schmid, 1997; Schubert, 2000; Slabeva & Schmid, 2000). Usually the online shopping takes a place within a same country. When a consumer who lives in Korea wants to buy a product at Internet shopping mall and present it to a relative who lives in America, there are two ways to do. First way is to access a Korean online shopping website that is written in Korean and then make the company deliver to America. If the consumer who lives in Korea orders the items from the Korean merchant's WWW page and makes the merchant ship the goods to America, he or she must pay for the extra shipping cost (Kalakota & Whinston, 1996).

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The merchant has to perform such business processes as delivery by airline or ship. Second way is to access an American website at his or her relative's area and make the company deliver it within the same country. The consumer does not need to pay for extra delivery from Korea to America. In order to use the web site at another country, there are such limitations as language, shopping culture, and so on (Javalgi & Ramsey, 2001; Steinfield & Klein, 1999).

Another method considered in this paper is based on a shared product taxonomy table between collaborative companies. Business opportunities of this method are in managing the product information (Adomavicius & Tuzhilin, 2001; Brew, 1991; Cho, Kim, & Kim, 2002). It is important to register and recommend similar products among the collaborative companies to the customer. The researches of comparison shopping agent are similar to this research (Doorenbos, Etzioni, & Weld, 1997; Iyengar & Dias, 1998; Yang, Choi, Kim, & Ham, 2000). BargainFinder and Jango are the examples of first-stage comparison shoppers that specify the functions that agents must have in order to be applied to Electronic Commerce, and both employ the manual rule extraction method. Shopbot (Doorenbos et al., 1997) suggests an automatic rule extraction technique by analyzing and learning the shopping malls. There are lots of researches related to the similar product registration. Most of traditional researches of the clustering algorithm are interested in the traditional recommendation problem which is to find *k* nearest products considering same and equal weighted product specifications from the large database (Shyu, Haruechaiyasak, & Chen, 2003; Sarwar et al., 2000; Sarwar, Karypis, Konstan, & Riedl, 2001). The researches are based on similarity measures such as cosine coefficient and distance between products.

The similar product recommendation problem in this paper is different with traditional recommendation problems in two aspects. One is that the collaborative companies share their product information for sales and delivery using the product taxonomy table. The companies share the table that contains exchangeable similar product lists at same classes. The other is that the problem assumes that the products at same class are specified by the same set of product specifications and customers or product managers have their own weight of the features. The weight information is given by them. In some practice, however, it is no simple matter to actually measure the exact values of weights. Rather, product managers or customers give only certain linear relations which express imprecise information about the weights of features.

We suggest an interactive algorithm for finding similar products when the weights of feature are not same and are given by the imprecise information. The main idea of the proposed algorithm is to find the utility range of products in a product class of the companies and register them as exchangeable similar products. The companies then allow consumer to shop and purchase the products at their own residence site and deliver them to another sites. The rest of paper is organized as follows. Section 2 describes the collaborative business process for a similar product recommendation. Section 3 suggests a procedure for the similar product recommendation and computational experiments, and results are included in Section 4. Section 5 concludes the paper.

2. Similar product recommendation problem for a collaborative electronic commerce

In the collaborative electronic commerce, three kinds of components exist: purchaser site, delivery site, and transaction server. The purchaser and delivery sites have its web sites and product catalogs and transaction server has a shared product map database between the collaborative sites. The server finds same or similar products with the product that a customer wants to buy and save transaction records such as purchasing information, delivery information, and so on. The records will be used to allocate profit to each related entities according to their activities (Fig. 1).

In the collaborative electronic commerce, the overall process consists of four sub processes as shown in Fig. 2.

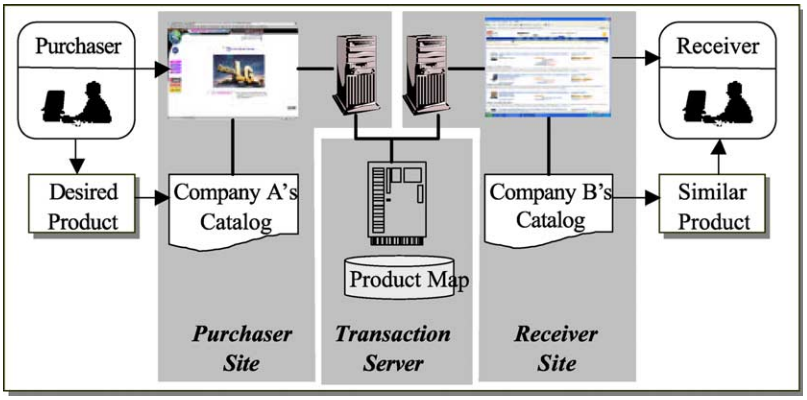

Fig. 1. Three components of collaborative business model.

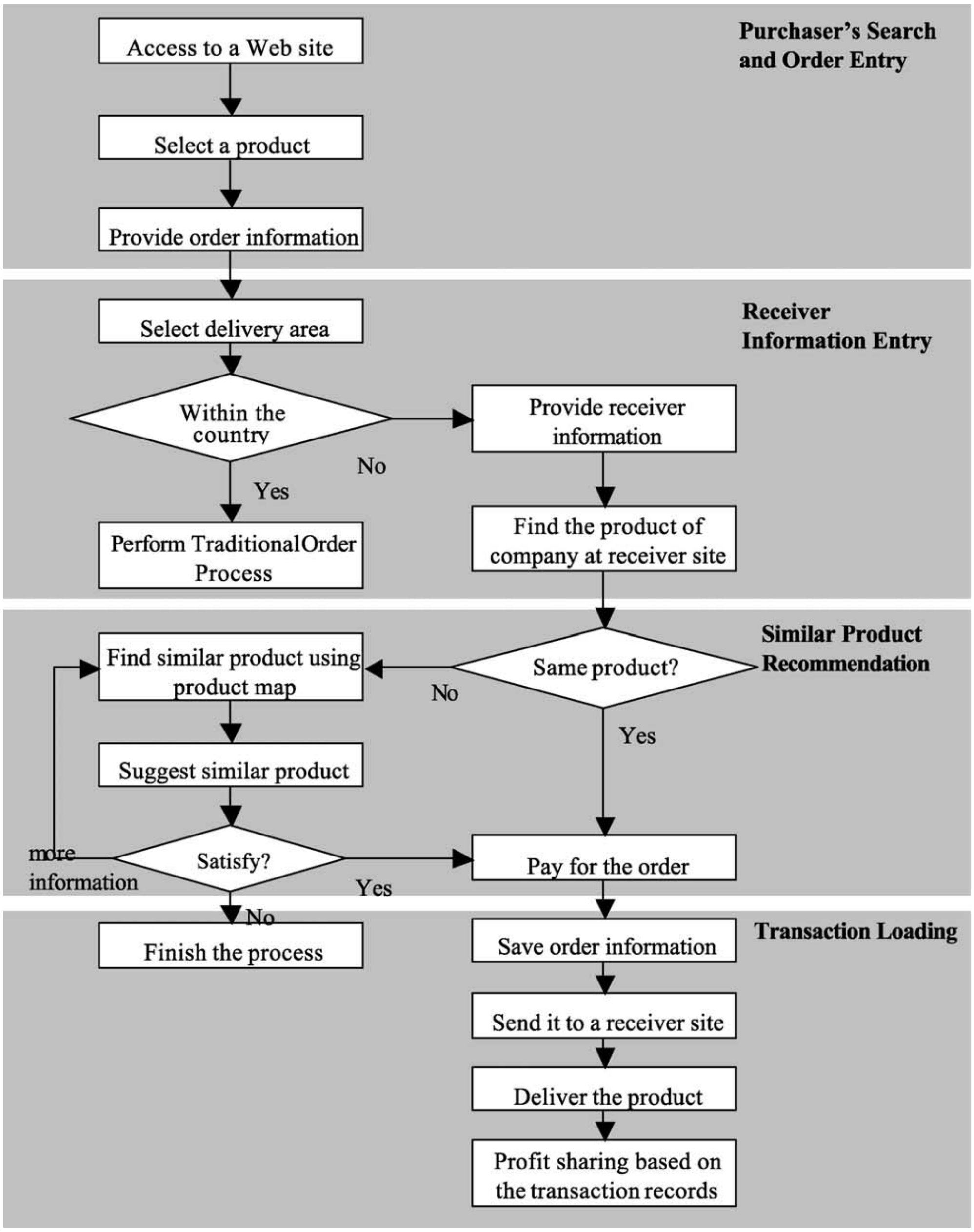

Fig. 2. A process for the collaborative electronic commerce model.

2.1. Purchaser's search and order entry

An user who wants to give a present at Internet shopping mall accesses a website at his or her own residence areas. The user surfs the web and finds a product in a product catalog. If the user searches for the desired product, the user would provide the mall with product order information.

2.2. Receiver information entry

The purchaser selects a delivery address type of whether a receipt address is within the residence area. If the receiver address is within the purchaser's country, a traditional delivery process is performed by the purchaser site. If the purchaser country is not same as receiver one, a transaction server finds a collaborative company close to the receiver address and search a same product among the catalog of the company. The server finds companies in the nearest order. If the server finds same product, the delivery site get a delivery order from the server. Otherwise go to next process.

2.3. Similar product recommendation

The transaction server searches similar products at the product map of a shared product database. The product map is a product relationship matrix that defines the exchangeable relations between products of the collaborative companies. They share orderable products and their customer orders any product among their shard products. The product map helps the company to drive down delivery cost and reduce prices to its customer. Furthermore, it increases cooperation between the companies as they strive for quick deliveries and low inventories. A detail algorithm for finding the similar product is presented in Section 3.2.

The server shows the user a set of k similar products with the item he/she has just selected. If the user is not satisfied with anything of interest, he or she does not purchase it on-line and the transaction is finished. If the user does find alternative product of interest, he or she elects to purchase it on-line, make an order, and provide payment information. Lastly, the consumer selects the means of payment.

2.4. Transaction loading

The consumer sends the merchant a complete order including receiver's address. The merchant requests payment authorization from the consumer's bank and sends the customer a confirmation of the order shipment and payment. The merchant saves the transaction and makes the collaborative company at the receiver area ships the goods to the recorded address. The server saves the transaction. The company at the receiver's area ships the goods in the shipment method as requested by the purchaser.

3. Similar product recommendation procedure

3.1. Mathematical problem definition for similar product recommendation

In this section, we formally define the similar product recommendation problem. The goal considered in this problem is to find the most similar product with the product of collaborative company. The selected product is being owned by purchaser site (shortly, A company). Suppose that the company has total of K classes or categories. Each class is characterized by a set of product specifications. Then a new product is assigned to a class having a same set of product specifications. The product at the kth class has a set of M product specifications. We define the following terminologies.

$I = \{i\}_{i=1,N}$: a set of N products at kth class
$J = \{j\}_{j=1,M}$: a set of M product specifications at kth class
w_i : importance of ith specification
x_{ij} : jth specification value of ith product
$x_i = \{x_{i1}, x_{i2}, \ldots, x_{iM}\}$ for $i \in I$: the specification values of ith product at the same class
$x_s^A = \{x_{s1}^A, x_{s2}^A, \ldots, x_{sj}^A, \ldots, x_{sM}^A\}$: the product that the customer has just selected at the A company's internet shopping site

Multi-criteria decision analysis is applied to this problem because the analysis deals with situations in which decision alternatives, such as products, are evaluated on a finite number of attributes, such as specifications. One of the best known and the most widely used ways to evaluate alternative $x = (x_1, \ldots, x_M)$ is to utilize the weighted additive decomposition

$$v(x) = \sum_{j=1}^{M} w_j v_j(x) \tag{1}$$

of a value function v. Here, v_j is the marginal value function of specification j such that $v_j : x_j \rightarrow [0, 1]$ and $w_j \geq 0$ is the weight which represents the relative importance of the jth specification. This evaluation function has been well examined in the literature (e.g. Dyer & Sarin, 1979; Keeney & Raiffa, 1976; Kim & Choi, 2001). Suppose that there is a finite set of all available products, $X = \{x_1, \ldots, x_i, \ldots, x_N\} \subset R^M$ and the collaborative company does not have the product x_s^A. The company then searches a similar product x_s, having the same or closest aggregated value.

$$v(x_s) = \sum_{j=1}^{M} w_j v_j(x_{sj}) \cong v(x_s^A) \tag{2}$$

Then this problem implies finding products having same or similar values as $v(x_s^A)$ among a set of available products, X, at the collaborative company. In this paper, we define the similar products, x_s and x_s^A, as the products that do not have a strict dominance relation and have the most similar utility values. The strict dominance concept is suggested by Park, Kim, and Yoon (1996). The condition is that if the minimal value of $\sum_{j=1}^{M} \times w_j[v_j(x_{sj}) - v_j(x_{sj}^A)]$ is equal to or more than $0, x_s$ strictly dominates x_s^A. If the decision parameters w_j and $v_j(\cdot)$ are all exactly or numerically assessed by the decision maker, finding x_s is done by simple calculation using (2). In some practice, however, it is no simple matter to actually measure the exact values of weights. Rather, the decision maker gives only certain linear relations which express imprecise information about the weights. Examples of imprecise weights are in the form of bounded descriptions; $w_s^- \leq w_s \leq w_s^+$ or $\rho_s^- w_1 \leq w_s \leq \rho_s^+ w_1$; and rankings; $w_1 \geq \ldots \geq w_S$. Use of linear programming approaches for some special and/or arbitrary forms of imprecise weights has been discussed in the literature; while identifying only non-dominated alternatives, methods for simultaneously dealing with dominance and potential optimality can be found (Eum, Park, & Kim, 2001). In this paper, we suggest the utility range concept which is described in Section 3.2.

3.2. An interactive procedure given exact specification values

The procedure is based on an utility range concept that an utility of a product can be represented by a range. We assume that a product utility value on a specification can be computed by the normalization formula (3). The weights of specification within a same class are in the form of constraints given by product managers. And, the aggregated product utility range of all specifications is computed by solving LP models having the constraints about the importance relationship between product specifications. Our procedure for finding similar products is composed of the following four sub-steps.

Step 1: Gather and normalize product specification vales

In this step, a product manager gathers information of specification values of the products at the collaborative company. We define the utility of a product specification as the normalized value computed by following formula and the utility is between 0 and 1.

$$v_{ij} = \frac{\max_i x_{ij} - x_{ij}}{\max_i x_{ij} - \min_i x_{ij}} \text{ for specification j with better for larger}$$

or

$$v_{ij} = \frac{\min_i x_{ij} - x_{ij}}{\min_i x_{ij} - \max_i x_{ij}} \text{ for specification j with better for smaller} \quad (3)$$

Step 2: Compute the utility ranges of current products

This step is used to compute the utility range of products at kth level. The utility of ith product is the weighted sum over all specification utilities, that is, $\sum_{j=1}^{M} w_j v_{ij}$. It is very difficult to find exact weight values and compute the product utility. The weight information represents the relationship between specification weights with the five forms of incomplete information provided by an user. We define the relationship set as Φ_w which is a set derived from the manager's incomplete information regarding the relative importance of specifications. We can get the utility ranges of ith product, $[v_i(\min), v_i(\max)]$, by following formula.

$$\begin{aligned} v_i(\min) &= \min \sum_{j=1}^{M} w_j\, v_{ij} \ \text{ subject to } \Phi_w \text{ and} \\ v_i(\max) &= \max \sum_{j=1}^{M} w_j v_{ij} \ \text{ subject to } \Phi_w \end{aligned} \quad (4)$$

Finally we can get the expected utility, $E[v_i]$, by computing an average value of $v_i(\min)$ and $v_i(\max)$.

Step 3: Classify the products by the utility ranges

In this step we subdivide the products at the same class into similar product classes using the expected utilities of products. From the expected utilities, we obtain the abstract difference values between products, $\mathrm{DE}[v_{\mathrm{sm}}] = |\bar{v}_s - \bar{v}_m|$, where, $\bar{v}_s$ and $\bar{v}_m$ mean, respectively, average utility value of the selected product v_s and the others v_m. If two products do not have a strict dominance relation and the value is equal to or less than threshold value, δ, then sth and mth products are registered into product table as a similar product class. This procedure is performed over all products pairs as shown in Fig. 3. After having the similar product pairs, the sub-classes at kth class are identified.

Step 4: Recommend similar products

In this step, the t most similar products, $X^s = \{x_1^s, x_2^s, \ldots, x_t^s\}$ are retrieved such that $\mathrm{DE}[v_{s1}]$ is the lowest, $\mathrm{DE}[v_{s2}]$ is the next lowest, and so on. The similar products are suggested to a user. If the user is satisfied with the result and selects a product to be purchased, the transaction

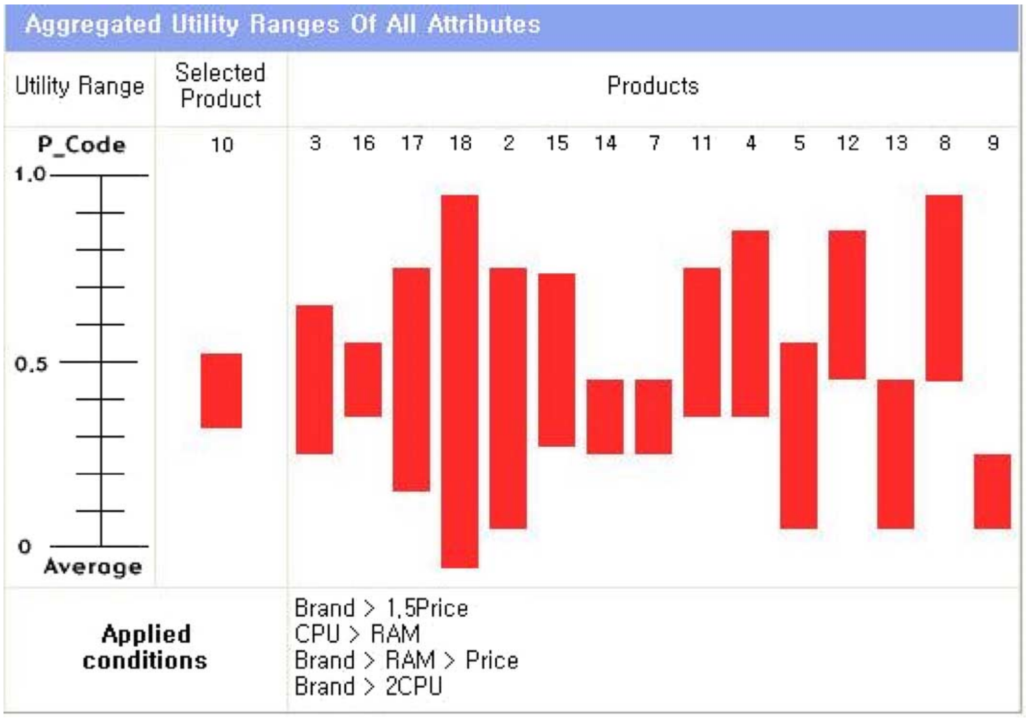

Fig. 3. Comparison screen of utility ranges for the selected product and the others.

loading process will be performed. Otherwise, the user will modify the information, Φ_w, regarding the relative importance of specifications. Then, return to the utility ranges computation in step 2 and repeat the same process until a satisfactory result is obtained or the user stops the process.

4. Experimental evaluation

4.1. Experiment

Using the procedure discussed in this paper, we carry out the experiments with the intent of answering two major questions:

1. What is different about the procedure in comparison to recommendation based on the Euclidean distance measure?
2. How do the different relationship sets of specification weights affect the similar product recommendation?

For our experiments, six user groups who are interested in buying the Pentium 4 2.0 GHz laptop computer participated in the experiment. We used six computer information from Korean L Internet shopping mall at the buyer site and 55 computer information from American B mall at the receiver site. Each group selected a laptop computer in the L mall at the buyer site. We explained the collaborative business model. They could not present the product selected at the L mall to the relative in receiver site as the B mall did not have same product. We were going to suggest similar products based on importance relationships of product specifications. They had to provide the incompletely specified information of specification weights. The computers are specified by RAM size (w_1), hard disk size (w_2), types of display (w_3), CD-ROM (w_4), brand name (w_5), and price (w_6).

We asked each group to enter an agreed set of relationship information between specification weights with the five forms of incomplete information. For example, the first group provided the following information (5). The group suggested that the weights of all specifications are equal to or greater than 0.1, and brand and price specifications are more important than RAM size, hard disk size, types of display, and CD-ROM. The following conditions of specification weights are summarized.

$$
\begin{aligned}
& w_5, w_6 \geq w_1, w_2, w_3, w_4 \\
& w_1 \geq w_2 \\
& w_4 \geq w_3 \\
& w_3 \geq w_2 \\
& w_5 + w_6 \geq w_1 + w_2 + w_3 + w_4 \\
& w_6 - w_5 \geq w_1 - w_4 \\
& w_1, w_2, w_3, w_4 \geq 0.1 \\
& w_1 + w_2 + w_3 + w_4 + w_5 + w_6 = 1
\end{aligned} \tag{5}
$$

The above group focused on the price and brand specifications. The group reviewed the result of similar products provided by our procedure and did not satisfy it.

The group revised the constraint as following.

$$
\begin{aligned}
& w_6 \geq 2w_1, 2w_2, 2w_3, 2w_4 \\
& w_1, w_2, w_3, w_4 \geq 0.05
\end{aligned} \tag{6}
$$

The rest of constraint is same as (5).

The group is satisfied with the current result and then performed a satisfaction rate survey. For convenience, the rest five groups suggested the most and next important specifications. The constraint set are assumed to have same format as formula (6). Second group suggested price and RAM size, third group price and type of display, fourth group brand and price, fifth group brand and type of display, and sixth group type of display and RAM size as shown the important criteria column in Table 1. After gathering the incomplete information of specification weights by each group, we calculated the utility range of 56 computers using formula (4) and obtained the abstract difference values, DE[v_{ij}], between a selected product and the others. We suggested three computers that are closest to the selected product as shown in Table 1.

To answer the first question, we provided users with the results of utility range-based approach and distance measure approach and gathered the response information of users' satisfaction rates as shown in Fig. 4. In the distance measure approach, we used same normalized utility values of specification values as our approach. We suggested three computers that are closest to the selected product among 55 computers. For the second question, we summarized the characteristics of the results from six utility range-based computations and distance measure-based approach.

4.2. Result and discussion

A *t*-Test model was used to analyze users' responses to the post-study questionnaire. The results of the user responses are shown in Table 2. Here, the satisfaction rate is used as a measure to compare the performance of the two approaches. From the table, it can be seen that the average satisfaction rate of utility range-based approach is higher than that of distance measure. Through the post-study questionnaire, we have known that it is because the utility range-based approach allowed users to suggest their opinions about the weight relationships of product specifications. This proves that the utility range-based approach is a viable solution to the problems currently encountered in similar product recommendation on the collaborative business model.

Examining the products obtained from the utility range-based approach and distance measure-based approach helps us to show the distinct characteristics of two approaches. The first result was focused on price and brand specifications, and it showed the products that had the same or higher utility values of those specifications.

Table 1
Six results of similar product recommendation based on utility ranges

Important criteria[a]	Product name	RAM		HDD util	Display		Brand		Price util
		Spec	Util		Spec[b]	Util	Name	Util	Util
Selected product	NZ2SH4B	DDR256	0.67	0.67	1024 × 768	0.6	LGIBM	0.8	0.34
Price brand	Sens JB242	SDR256	0.33	0.67	1024 × 768	0.6	Samsung	0.8	0.4
	Sens THP4	SDR256	0.33	0.67	1024 × 768	0.6	Samsung	0.8	0.42
	PCG-GRT25	DDR256	0.67	0.67	1024 × 768	0.6	SONY	1	0.31
Price RAM	N7600.4	DDR256	0.67	0.67	1024 × 768	0.6	TG	0.2	0.47
	N7620.4	DDR256	0.67	0.67	1024 × 768	0.6	TG	0.2	0.47
	C2220	DDR256	0.67	0.67	1024 × 768	0.6	Fujitsu	0.4	0.42
Price display	Sens JB242	SDR256	0.33	0.67	1024 × 768	0.6	Samsung	0.8	0.4
	N7620.4	DDR256	0.67	0.67	1024 × 768	0.6	TG	0.2	0.47
	N7600.4	DDR256	0.67	0.67	1024 × 768	0.6	TG	0.2	0.47
Brand price	Sens 5B241	DDR256	0.67	0.67	1024 × 768	0.6	Samsung	0.8	0.36
	NZ3SH4B	DDR256	0.67	0.67	1024 × 768	0.6	LGIBM	0.8	0.37
	E7/518	DDR256	0.67	0.67	1024 × 768	0.6	Toshiba	1	0.23
Brand display	Latitude C840	DDR256	0.67	0.67	1400 × 1050	0.8	DELL	0.6	0.3
	Sens 5B241	DDR256	0.67	0.67	1024 × 768	0.6	Samsung	0.8	0.36
	NZ3SH4B00S	DDR256	0.67	0.67	1024 × 768	0.6	LGIBM	0.8	0.37
Display RAM	S7601.3	DDR256	0.67	0.67	1400 × 1050	0.8	TG	0.2	0.41
	S7581.3	DDR256	0.67	0.67	1400 × 1050	0.8	TG	0.2	0.4
	Sens 5B241	DDR256	0.67	0.67	1024 × 768	0.6	Samsung	0.8	0.36
Distance measure-based approach	Sens 5B241	DDR256	0.67	0.67	1024 × 768	0.6	Samsung	0.8	0.36
	PCG-GRT25	DDR256	0.67	0.67	1024 × 768	0.6	SONY	1	0.31
	E7/518	DDR256	0.67	0.67	1024 × 768	0.6	Toshiba	1	0.23

[a] All specification values and utility values of ODD in this table are Combo and 1's. Spec and Util mean respectively Specification value and Utility value.
[b] All specification types of Display in this table are 15 in.

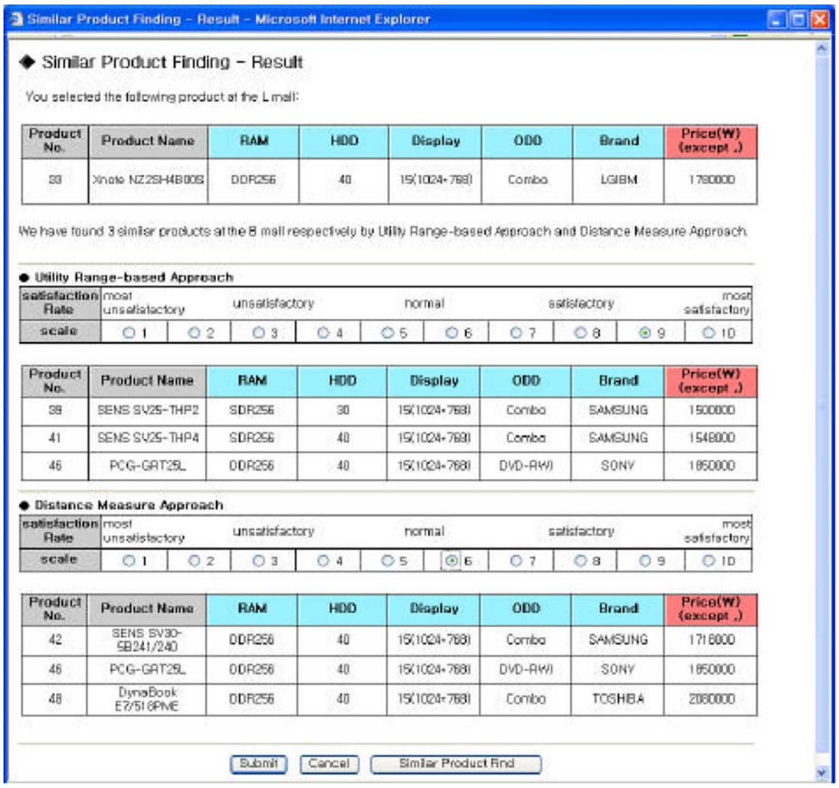

Fig. 4. Results and satisfaction rate survey sheet of similar product recommendations.

Table 2
Result of t-test for two approaches

Statistics

TYPE	Variable	N	Mean	Std dev	Std err
Utility range	Satisfaction rate	30	8.9	0.7589	0.1385
Distance measure	Satisfaction rate	30	6.9	1.125	0.2054
Rate	Diff (1–2)	30	2	0.9595	0.2477

t-Tests

Variable	Method	Variances	DF	t-Value	Pr > $\|t\|$
Rate	Pooled	Equal	58	8.07	<0.0001
Rate	Satterthwaite	Unequal	50.9	8.07	<0.0001

The utility values of RAM and type of display specification were relatively little considered. The second result based on price and RAM-oriented utility showed the products having same utility values of RAM. The utility values of brand specification were relatively little considered and compromised by much higher values of price than the selected product. In the third result focused on price and type of display specifications, the values of display specification are same and ones of price specification were a little higher than the value of selected product. The utility values of brand specification were relatively little considered. In the fourth result, brand and price specifications were focused and had similar values or compromising values. The values of RAM and display specifications were same. The fifth result was focused on brand and display specifications. In this result, the products compromising the values of brand and display specifications were selected. The values of price specification were a little lower than those in the other results. In the sixth result focused on display and RAM specifications, the values of display and RAM were similar to the selected product. The utility values of brand and price specifications were relatively little considered.

In the distance measure approach, the values of RAM, HDD sizes, and display specifications were same and the result was very similar to the fourth result focused on brand and price specifications. The values of brand and price specification were almost same and a little lower than selected product. In the approach, the products having similar values across all the specifications were selected. The users are interested in a set of specific specifications and the approach needs to be revised. For example, they have to provide exact weights of all specification to reflect their opinions. It is not easy to reflect users' opinions about the weights of product specification in a flexible way.

5. Conclusion and further study

In this paper, we explained a global electronic business situation that a purchaser residence area is different from a receiver's one. In order to do this kind of business, we suggested an interactive algorithm for finding similar products. This algorithm is based on the user's utility ranges of products. The users can easily enter their preferences of product specifications into incomplete information. Usually the users on the Web have their own preference system. The utility range-based approach suggested in this paper can get users' preference information in the form of incomplete information. It is very easy to reflect users' opinions about the weights of product specification in a flexible way.

To do this, the collaborative companies have to share product taxonomy table and register their own products and exchangeable products. After completing the integration of product categories among collaborative partners, the collaborative business process explained in this paper can be preformed. The goal of this process is to specifically classify products of trading partners into similar product sub-classes based on their specification values. This model helps local companies to perform a collaborative strategy of performing vicarious delivery transaction for ordered goods at another area. The business model suggested in this research makes the companies that are difficult to set up physical branches at every corner of the world to cooperate with another companies at the sites in a cost efficient way. The collaborative companies can globally expand their electronic commerce business without a heavy facility investment. The companies are able to give the customer easy access to their own country and save the delivery cost.

The complexity of developing and operating a global electronic commerce model calls for a collaboration platform between the companies that contains rules of similar product registration, profit sharing, and so on. Future research in this model should focus on an in-depth investigation of the required regulations and their economic justification.

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