Winter 12-5-2004

A Personalized Recommender System Based on Explanation Facilities Using Collaborative Filtering

Do Hyun Ahn

Hee ae Lee

A Personalized Recommender System Based on Explanation Facilities Using Collaborative Filtering

Do Hyun Ahn, Hee ae Lee

School of Business Administration, Kyunghee University Seoul, 130-701, Korea
adh@khu.ac.kr, leeheeae@hanmail.net

ABSTRACT

Collaborative filtering (CF) is the most successful recommendation method, but its widespread use has exposed some limitations, such as sparsity, scalability, and black box. Many researchers have focused on sparsity and scalability problem but a little has tried to solve the black box problem. Most CF recommender systems are black boxes, providing no transparency into the working of the recommendation. This research suggests an improved CF recommender system with explanation facilities to overcome the black box problem. Explanation facilities make it possible to expose the reasoning and data behind a recommendation. Therefore, explanations provide us with a mechanism for handling errors that come with a recommendation. Furthermore, it is proposed to use web usage mining and product taxonomy to enhance the recommendation quality for e-commerce environment. For such purposes, it is developed a recommender system named WebCF-Exp, Web usage mining driven Collaborative Filtering with Explanation facilities. To test the performance of WebCF-Exp, EBIB research internet shopping mall and explanation interfaces are developed. Experiments are conducted with the data provided by EBIB Research Internet shopping mall.

Keywords: *Collaborative Filtering, Recommendation system, Explanation, Internet shopping mall*

1. INTRODUCTION

The continuous growth of the Internet and e-commerce has allowed companies to provide customers with more choices on products. Increasing choice has also caused product overload where the customer is no longer able to effectively choose the products he/she is exposed to. A promising technology to overcome the product overload problem is recommender systems that help customers find the products they would like to purchase. To date, a variety of recommendation techniques have been developed. Collaborative Filtering (CF) is the most successful recommendation technique, which has been used in a number of different applications such as recommending movies, articles, products, Web pages, etc. [1,2,3,7,10,11]. However, its widespread use has exposed some limitations, such as sparsity, scalability, and black box. Many researchers have focused on sparsity and scalability problem but a little has tried to solve the black box problem. According to Herlocker et al.[6], most CF recommender systems are black boxes, providing no transparency into the working of the recommendation.

This research suggests an improved CF recommender system with explanation facilities to overcome the black box problem. Explanation facilities make it possible to expose the reasoning and data behind a recommendation. Therefore, explanations provide us with a mechanism for handling errors that come with a recommendation. Furthermore, it is proposed to use web usage mining and product taxonomy to enhance the recommendation quality for e-commerce environment. Web usage mining populates the rating database by tracking customers' shopping behaviors in the Web, thereby leading to better quality recommendations. The product taxonomy is used to improve the performance of searching for

nearest neighbors through dimensionality reduction of the rating database. For such purposes, it is developed a recommender system named WebCF-Exp(Web usage mining driven Collaborative Filtering with Explanation facilities). To test the performance of WebCF-Exp, EBIB (e-Business & Intelligence Business) research internet shopping mall and explanation interfaces are developed. Experiments are conducted with the data provided by EBIB Research Internet shopping mall.

The remainder of this paper is organized as follows. Section 2 reviews the past researches related to recommender systems and explanation. Section 3 and section 4 provide our research framework and system architecture. Section 5 describes experimental evaluation and section 6 finally provides some conclusions and future works.

2. LITERATURE REVIEW

2.1 CF-based Recommender Systems

CF-based recommender systems recommend products to a target customer according to the following steps [11]: (1) A customer provides the system with preference ratings of products that may be used to build a *customer profile* of his or her likes and dislikes. (2) Then, these systems apply statistical techniques or machine learning techniques to find a set of customers, known as *neighbors*, which in the past have exhibited similar behavior (i.e. they either rated similarly or purchased similar set of products). Usually, a neighborhood is formed by the degree of similarity between the customers. (3) Once a neighborhood of similar customers is formed, these systems predict whether the target customer will like a particular product by calculating a weighted composite of the neighbor's ratings of that product (*prediction problem*), or generate a set of products that the target customer is most likely to purchase by analyzing the products the neighbors purchased (*top-N recommendation problem*). These systems, also known as *the nearest neighbor* CF-based recommender systems [2,10,11] have been widely used in practice. However, its widespread use has exposed some limitations, such as sparsity, scalability, and black box.

2.2 Web Usage Mining

Web usage mining is the process of applying data mining techniques to the discovery of behavior patterns based on Web log data for various applications. The overall process of Web usage mining is generally divided into two main tasks: data preprocessing and pattern discovery. Mining behavior patterns from Web log data needs the data preprocessing tasks that include data cleansing, user identification, session identification, and path completion. Mobasher et al.[9] presented a detailed description of data preprocessing methods for mining Web browsing patterns. The pattern discovery tasks involve the discovery of association rules, sequential patterns, usage clusters, page clusters, user classifications or any other pattern discovery method. Lee et al.[8] provided a detailed case study of clickstream analysis from an online retail store. To measure the effectiveness of efforts in merchandising, they analyzed the shopping behavior of customers according to the following four shopping steps: product impression, click-through, basket placement, and purchase. It has been recognized that Web usage mining gave better recommendation quality in the CF recommendation procedures [1,3].

2.3 Product Taxonomy

Product taxonomy is practically represented as a tree that classifies a set of products at a low level into a more general product at a higher level. The leaves of the tree denote the product instances, SKUs (Stock Keeping Units) in retail jargon, and non-leaf nodes denote product classes obtained by combining several nodes at a lower level into one parent node. The root node labeled by All denotes the most general product class. For example, Figure 1 shows product taxonomy for a internet shopping mall, where "SKU00", "SKU09" and "SKU10" are classified into "Outwears", and etc. A number called level can be assigned to each node in the product taxonomy. The level of the root node is zero, and the level of any other node is one plus the level of its parent. Note that a product class at a higher level has a smaller level number. The product taxonomy of Figure 1 has four levels, referred to as level 0 (for root), 1, 2, and 3. Recently, the usage of product taxonomy in data mining has been emphasized by many researchers [3,5,7] since it reflects domain specific knowledge and may affect the results of the analysis.

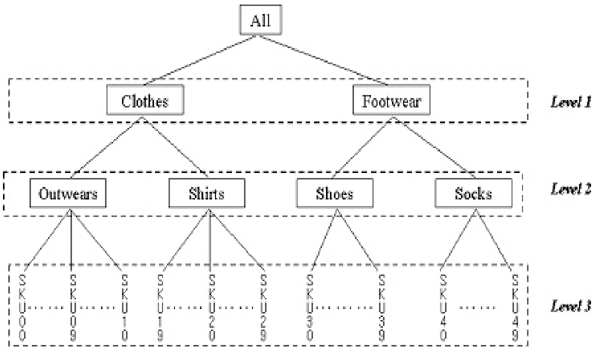

Figure 1. Example of product taxonomy

2.4 Explanation

Most CF recommender systems are black boxes, providing no transparency into the working of the recommendation. Therefore, a user is given no indicators to consult to determine when to trust a recommendation and when to doubt one. The problem has prevented acceptance of CF-based recommender systems in all but the low-risk content domains. Explanation facilities make it possible to expose the reasoning and data behind a recommendation. Therefore, explanations provide us with a mechanism for handling errors that come with a recommendation. Building an explanation facility into a recommender system can benefit the user in many ways. It removes the black box from around the recommender system, and provides transparency [4,6]. According to Herlocker et al.[6], some of the benefits provided by the explanation facilities are:

- Justification: User understanding of the reasoning behind a recommendation, so that he/she may decide how much confidence to place in that recommendation.
- User Involvement: User involvement in the recommendation process, allowing the user to add his knowledge and inference skills to the complete decision process.
- Education: Education of the user as to the processes used in generating a recommendation, so that he/she may better understand the strengths and limitations of the recommendation capability of the system.
- Acceptance: Greater acceptance of the recommender system as a decision aide, since its limits and strengths are fully visible and its suggestions are justified.

3. METHODOLOGY

WebCF-Exp is a CF-based recommender methodology based on Web usage mining, product taxonomy, and explanation facilities to improve the recommendation quality and system performance of current CF-based recommender systems. The overall procedure of WebCF-Exp consists of two main methods as shown in Figure 2: recommendation method and explanation method. The input data consist of Web server log files, product database and purchase database. The endmost output is the personalized product recommendation list with explanation facilities.

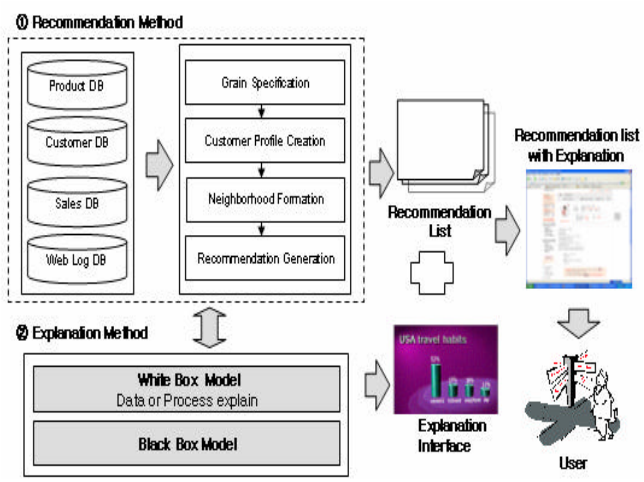

Figure 2. Overall procedure of WebCF-Exp

The recommendation method is divided into four phases: grain specification, customer profile creation, neighborhood formation, and recommendation generation. In the grain specification phase, all products in the database are hierarchically grouped based on the level of aggregation (called *grain*) specified from the marketing manager. Such a product grouping enables the following phases to handle products in the reduced dimensional space. Target customer's preference across products are analyzed and used to make customer profile in the customer profile creation phase. Tracking individual customer's previous shopping behavior in an e-commerce site is used to make preference analysis. The neighborhood formation phase is to form a similarity-based neighborhood between a target customer and a number of like-minded customers. Finally, the recommendation generation phase produces the top-N recommendations based on the shopping behavior of neighbors.

The explanation method consists of white box model and black box model. In white box model, we focus on techniques to justify that the recommendation is indeed performing each of the above phases to the satisfaction of the user and his/her current context. Let us examine each of the steps in more detail, focusing on two components that we need to explain: the process and the data. Often, there is not the opportunity or possibly the desire to convey the white box model. In such cases, the black box model is used to produce recommendations. In black box model, we focus on ways to justify recommendation that are independent of the mechanics.

4. WebCF-EXP RECOMMENDER SYSTEM

For the implementation of the proposed recommender methodology, a recommender system is developed using agent and data warehousing technologies. WebCF-Exp recommender system consists of four agents as shown in Figure 3: Web log analysis agent, Data transformation agent, Recommendation agent, and Explanation agent. Web log analysis agent manages Web log database through periodic collecting, parsing and analyzing Web server log files such as access logs, referrer logs, agent logs and cookie files. Thus, the users can easily access and analyze it like other operation databases. Data transformation agent creates and manages the data mart that provides data indispensable to accomplish recommendation tasks. Recommendation agent makes a personalized recommendation list for each target customer. Explanation agent provides interfaces which expose the reasoning and data behind a recommendation.

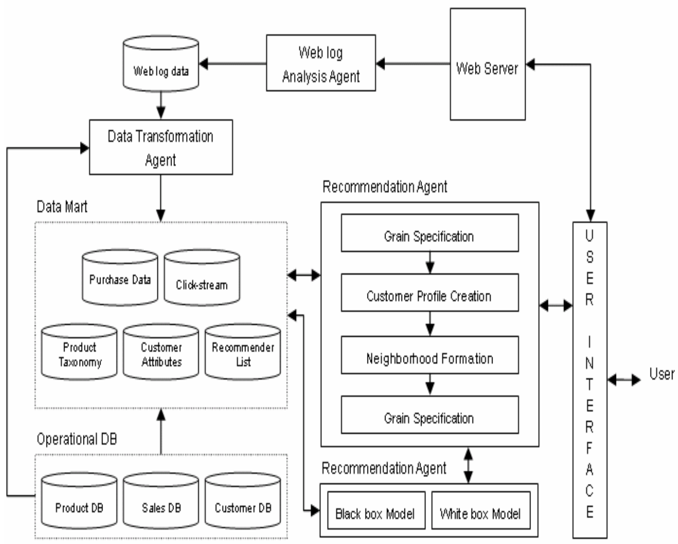

Figure 3. The architecture of WebCF-Exp recommender system

We developed twenty different explanation interfaces to test the recommendation quality. Figure 4 shows one of twenty explanation interfaces.

Figure 4. An example of explanation interface

5. EXPERIMENTAL EVALUATION

In order to evaluate the our suggested recommender system, we built the prototype of WebCF-Exp recommender system, EBIB Research online shopping mall and explanation interface. We also performed a survey to find the most suitable explanation interface for our recommender system and evaluate the effectiveness of explanation.

5.1 Experimental Design

We conducted the experiment from October 2, 2003 to November 26, 2003, and analyzed the user data between November 18 and November 26, then evaluated the performances of the recommender system. We also surveyed the customers who received our recommendation and say the explanation interface at the same time. In order to make WebCF-Exp recommender system more understandable, we would explain the process of purchase and recommendation. Programs to perform all our experiments were implemented using Visual Basic 6.0. MS-Access was used to store and process all data necessary for our experiments. EBIB Research online shopping mall was made by MS-SQL Server 2000, WindowsNT2000 Web Server IIS5.0, and ASP(Active Server Page).

Study participants were presented with the following hypothetical situation:
You enter the site of EBIB Research online shopping mall and sign up. You have to submit such data as ID, name, e-mail, birthday, gender and address. When you finish, you will receive 1,000 dollars and can purchase what he want to have. After you log in the site, the server will collect all log data about you. Through the web log agent, the WebCF-Exp recommender system preprocesses web log files and maps click, basket and purchase with “goods_view.asp”, “cart_list.asp” and “cart_pay.asp” to extract data related customers’ shopping behavior.

Each user was then provided with a different explanation interface, and asked to rate on a scale of 1-5 how likely they would purchase the recommended goods. A successful explanation interface can make a customer more preferable to purchase the recommended goods, and feel the explanation useful and exciting. Therefore we should make it communicate and understand easily and help with the customer’s decision making if building an explanation facility into a recommender system. In our research we performed a survey to find the most suitable explanation interface for our recommender system and evaluate the effectiveness of explanation. There are two key research questions that we are interested in answering about the use of explanations with WebCF-Exp recommender system.

The first question is about the understandability and suitability.

Q1: Are the explanation interface understandable and effective?

The goods was explained by the explanation interfaces that we randomly choose from the 20 interfaces, and the question was rated on a 5-point Likert scale ranging from "very difficult" to "very easy."
The second question is about the usefulness of the explanation interface.

Q2: Can the explanation interface increase the acceptance of recommended goods?

The question was rated on a 5-point Likert scale ranging from "not at all" to "very much."

5.2 Experimental Results

(1)Quality comparison of WebCF-Exp and benchmark CF

To compare the quality comparison of WebCF-Exp with that of the benchmark CF algorithm, we performed an experiment to measure *precision* and *recall*. *Precision* and *recall* have been widely used in recommender system research [2,3,11]. Table 1 shows the *precision* and *recall* provided by two algorithms. Looking into the results shown in Table 1, we can see that WebCF-Exp is about 159% and 116% better than benchmark CF, respectively.

Table 1. Quality comparison of WebCF-Exp and benchmark CF algorithm

	WebCF-Exp	Benchmark CF
Precision	0.196	0.123
Recall	0.495	0.425

(2)The result of survey on explanation facilities

The first question is about the understandability and suitability. Table 2 shows mean response and standard deviation of users to explanation interfaces. Looking into the results shown in Table 2, explanation with simple graph and description is better than other explanation types.

The second question is about the usefulness of the explanation interface: Can the explanation interface increase the acceptance of recommended goods? Looking into the results shown in Table 3, the higher customer understands explanation interface, the more helpful customer purchase a product.

Table 2. The result of Q1

	Explanation Interfaces	Mean Response	Std Dev
1	Neighbor ratings (5 stars)	3.806	0.992
2	Discounted item (description)	3.609	1.060
3	The ratio of purchase (graph)	3.536	1.069
4	The ratio of basket (graph)	3.472	1.035
5	The 64% of recommended customers purchased this item	3.443	1.127

	(description)		
6	This item is similar to purchased items in the past (description)	3.417	1.229
7	The best item in the last week (description)	3.277	1.005
8	The ratio of click (graph)	3.261	0.993
9	The ratio of basket (description)	3.247	0.950
10	The preference on Product Taxonomy (graph)	3.217	1.260
11	The ratio of basket (table)	3.210	1.028
12	The ratio of click (table)	3.207	0.942
13	Detailed process (description)	3.173	1.104
14	Recommended by a famous magazine(description)	3.155	1.253
15	The ratio of click (description)	3.152	0.969
16	The preference on Product Taxonomy (table)	3.149	1.051
17	The preference on Product Taxonomy (desciption)	3.138	1.197
18	The ratio of purchase (description)	3.100	1.150
19	The ratio of purchase (table)	3.049	1.206
20	Recommender system confidence in prediction (description)	3.023	1.116

Table3. The result of Q2

	Explanation Interfaces	Mean Response	Std Dev
1	Neighbor ratings (5 stars)	3.710	1.038
2	Discounted item (description)	3.609	1.060
3	The ratio of purchase (graph)	3.536	1.069
4	The 64% of recommended customers purchased this item (description)	3.371	1.014
5	This item is similar to purchased items in the past (description)	3.277	1.031
6	The ratio of click (graph)	3.261	0.993
7	This item is similar to purchased items in the past (description)	3.253	1.229
8	The ratio of basket (graph)	3.248	1.036
9	The ratio of basket (description)	3.235	0.947
10	Detailed process (description)	3.185	1.108
11	The preference on Product Taxonomy (graph)	3.181	1.251
12	The ratio of basket (table)	3.180	0.989
13	The ratio of click (description)	3.162	0.972
14	The ration of click (table)	3.161	0.926
15	The preference on Product Taxonomy (description)	3.149	1.218
16	The preference on Product Taxonomy (table)	3.138	1.058
17	The ratio of purchase (description)	3.090	1.111
18	Recommender system confidence in prediction (description)	3.058	1.120
19	The ratio of purchase (table)	3.049	1.206
20	Recommended by a famous magazine(description)	2.825	1.250

6. CONCLUSION

Collaborative filtering (CF) is the most successful recommendation method, but its widespread use has exposed some limitations, such as sparsity, scalability, and black box. Many researchers have focused on sparsity and scalability problem but a little has tried to solve the black box problem. Most CF recommender systems are black boxes, providing no transparency into the working of the recommendation. This research suggests an improved CF recommender system with explanation facilities to overcome the black box problem. Explanation facilities make it possible to expose the reasoning and data behind a recommendation. Therefore, explanations provide us with a mechanism for handling errors that come with a recommendation. Furthermore, it is proposed to use web usage mining and product taxonomy to enhance the recommendation quality for e-commerce environment. For such purposes, it is developed a recommender system named WebCF-Exp(Web usage mining driven Collaborative Filtering with Explanation facilities). To test the performance of WebCF-Exp, EBIB (e-Business & Intelligence Business) research internet shopping mall and explanation interfaces are developed. Experiments are conducted with the data provided by EBIB Research Internet shopping mall. Our experiment result shows that WebCF-Exp recommendation system shows better performance than existing CF recommendation systems. And explanation with simple graph and description, showing the evaluation of similar customers, is better than other explanation types. Furthermore, the higher customer understands explanation interface, the more helpful customer purchase a product. Based on these results, an explanation facility added recommendation system is expected to be a useful tool in internet shopping malls.

REFERENCES

[1] Ahn, D.H., J.K. Kim, Y.H. Cho, "A comparative evaluation of hybrid product recommendation procedures for Web retailers", *APDSI (9th Asia-Pacific Decision Sciences Institute) Conference 2004, Seoul, July 1-4*, 2004.

[2] Billsus, D., M.J. Pazzani, “Learning collaborative information filters”, *In Proc. 15th International Conference on Machine Learning*, pp 46-45, 1998.

[3] Cho, Y.H., J.K. Kim, “Application of Web usage mining and product taxonomy to collaborative recommendations in e-commerce”, *Expert Systems with Applications*, Vol.26, pp 233-246, 2004.

[4] Dahlen, B.J., J.A. Konstan, J.L. Herlocker, N. Good, A. Borchers, J. Riedl, “Jump-starting movielens: User benefits of starting a collaborative filtering system with dead data”, *University of Minnesota TR* 98-017, 1998.

[5] Han, J., Y. Fu, “Mining Multiple-Level Association Rules in Large Databases”, *IEEE Transaction on Knowledge and Data Engineering*, Vol.11, No.5, pp 798-804, 1999.

[6] Herlocker, J.L., J.A. Konstan, J. Riedl, "Explaining Collaborative Filtering Recommendations", *In Proc. 2000 ACM Conference on Computer Supported Cooperative Work*, pp 241-250, 2000.

[7] Lawrence, R.D., G.S. Almasi, V. Kotlyar, M.S. Viveros, S.S. Duri, "Personalization of supermarket product recommendations", *Data Mining and Knowledge Discovery*, Vol.5, No.1, pp 11-32, 2001.

[8] Lee, J., M. Podlaseck, E. Schonberg, R. Hoch, "Visualization and analysis of clickstream data of online stores for understanding web merchandising", *Data Mining and Knowledge Discovery*, Vol.5, No.1-2, pp 59-84, 2001.

[9] Mobasher, B., R. Cooley, J. Srivastava, "Automatic Personalization based on Web usage mining", *Communications of the ACM*, Vol.43, No.8, pp 142-151, 2000.

[10] Resnick, P., N. Iacovou, M. Suchak, P. Bergstrom, J. Riedl, "GroupLens: An Open Architecture for Collaborative Filtering of Netnews", *In Proc. Computer Supported Cooperative Work, Chapel Hill, NC,* pp 175-186, 1994.

[11] Sarwar, B., G. Karypis, J. Konstan, J. Riedl, "Analysis of recommendation algorithms for e-commerce", *In Proc. ACM E-Commerce*, pp 158-167, 2000.