A Novel FAHP Based Book Recommendation Method by Fusing Apriori Rule Mining

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***Abstract*—Book recommendation is becoming increasingly significant library service, considering it improve access to relevant books by making personal suggestions based on previous examples of user's preference. Most existing approaches are either collaborative-filtering based, considering the data sparsity and cold-start problems, collaborative-filtering approaches suffer from many challenges. In this paper, we present a Fuzzy Analytical Hierarchy Process (FAHP) based method by fusing Apriori rule mining. Apparently, multiple factors (e.g., similar preference, professional background, education degree and book's publishing house etc.) may influence reader's borrowing decision. Therefore, we first adopt Apriori algorithm to develop association analysis for evaluating the relevance of books in terms of book-loan history. Second, FAHP takes the result of association between books and other subjective/objective factors into account and makes final recommendation according to an overall ranking result. A thorough experimental comparison, based on real-world data, illustrates advantage of our scheme over collaborative filtering approaches.**

Keywords—book recommendation; associated rule; Apriori algorithm; FAHP

I. INTRODUCTION

Library offers users an efficient way to find books they look forward. Almost every library establishes information system infrastructure, but most of them just provide basic function for information retrieval. It is far from satisfying users' different information requirements, especially when they wish to get personalized recommendation. As an important function of digital library, book recommendation system offers user the opportunity to find more specific and personalized books, which are of their own interest.

Around 1990s, digital library's development was initiated, Borgman's two competing visions of digital library stimulated lots of discussions on definition of a digital library [1]. After many years' research and experiment, the development of book recommendation has become a hotspot. Led by Eric Lease Morgan since 1998, MyLibrary [2], an outstanding instance in the area of book recommendation application, was developed to let users design their own library digital resource according to their preferences and needs. Based on this project, many universities have developed their own library system, Lehigh University's MyLibrary@Lehigh [2] and North Carolina State University's MyLibrary@NCState [3]. It is noticeable that the success in industry has promoted the enthusiasm of academic research. A plenty of works have been conducted to study book recommendation mechanisms. Many methods have been studied in this area, among which, cluster analysis and association analysis are studied intensively.

Cluster analysis is used to set objects in such a way that objects in the same group (called a cluster) are more similar (in some sense or another) to each other than to those in other groups (clusters) [4]. There are some outstanding algorithm like K-means algorithm [5] and Genetic algorithm-base clustering technique [6]. However, cluster based methods are not much applicable for fine-grained personalized recommendation.

Association analysis aims to reveal dependence and relevance between items (e.g. books in library or goods in market). It can help people making significant decisions, such as classification design, cross-shopping and so on. As a typical application, "Shopping Basket Analysis" helps customers to find association between stuffs, and may tell users which items are frequently purchased at the same time. For instance, association analysis on supermarket sales data discovers an interesting phenomenon that, around 90% people will buy butter after they get bread. This finding can help market manager to adjust marketing strategies, like put bread and butter together on the shelf. Agrawal [7]-[8] introduced association rules in 1993, and then proposed the famous Apriori algorithm, with the basic objective of finding frequent item set over transaction databases. Based on Apriori algorithm, lots of works have been conducted to study the personalized recommendation mechanisms. Enrique Lazcorreta [9] proposed a method which towards personalized recommendation automatically with Apriori algorithm on information system. This algorithm is also proved useful in personalized IPTV channel-recommendation. HongYi Chang [10] designed an efficient IPTV channel-switching mechanism for recommendation. In university library area, S Shirgaonkar [11] utilized Apriori algorithm to mine association rules for library information service. However, Apriori based approaches only take the coexistence relation between items into account,

but ignore other important factors (such as the item property, user profile, and etc.) which may have important effect on the recommendation result.

Based on the above mentioned consideration, we proposed a Fuzzy Analytic Hierarchy Process (FAHP) based book recommendation approach by fusing Apriori in this paper. Specifically, we perceive book recommendation as a multi-criteria ranking problem. Factors which may affect the recommendation results reflect on three aspects: association rule of books in circulation, book property (such as the publishing house, and copyright owner), and reader's profile (such as professional background, education degree). First, Apriori algorithm is adopted for measuring the association strength of books in circulation. Based on that, a multi-criteria ranking model is established within FAHP framework. In particular terms, we designed a "goal—criteria—sub-criteria" three-layer structure to make a fine-grained ranking about potential items (books). In criteria layer, we defined three criteria, i.e., implicit factor, explicit factor and outcome factor. The three factors correspond to user profile, book property and association strength (support and confidence) respectively. Based on the structure, books are finally ranked according to the integrated impacts.

The rest of this paper is structured as follow. In Section 2, related work will be introduced. In Section 3, we will elaborate our model. Experiments are conducted in section 4 and in section 5 we present a prototype based on our proposed model. Finally, section 6 concludes this paper and discusses the future work.

II. Related work

In this section we discuss related works from the following aspects:

A. Collaborative Filtering (CF)

Collaborative filtering is widely used in recommendation systems. The underlying assumption of CF is that if someone *A* holds same opinion on issue *x* with person *B*, then *A* is more likely to have same opinion with B on another issue *y* than to have the opinion on *y* of other persons. Pazzani [12] investigated content-based filtering and demographic filtering. Content-based filtering is an instance of memory-based filtering. It accomplishes the task by content representation, profile learning and recommendation generation. User's demographic information, such as gender, age and education were adopted for restaurant recommendation. Kai Yu et al. [13] developed a probabilistic framework for memory-based collaborative filtering (PMCF). However, its efficiency of the active learning scheme still needs to be improved. Moreover, the meta-information filtering computational complexity is higher than that of competing methods. CF is also proved useful in digital library research, Fengrong Gao [14] presented a new method which unified partition-based collaborative filtering, but it needs to involve an updating algorithm when either user data or item data changes.

B. Association Rules

Association rule based methods have received tremendous attention in various communities. Association rules mining approaches are intended to find existing or potential association of data items (attributes, variables). Xiangju Qin et al. [15] utilized U-Apriori algorithm and Classification Based on Associative (CBA) algorithm as an associative classifier to process uncertain data. They also redefined support, confidence, rule pruning and classification strategy. Based on Apriori algorithm, Felix von Reischac [16] developed an application to enable consumers to access and share product recommendations using their mobile phone. Tiantian Xu [17] distinguished different variations of Apriori algorithm and presented the B_Apriori+ algorithm to mine frequent patterns with multiple minimum supports efficiently, however it assumes that users do not care more about run-time and space.

In addition, Lunfeng Gong [18] developed library system through statistical analyzing the literature-lending records, and discovered patterns of circulation records, which helped providing readers personalized information service. Zhu Zhen [19] explored improved association rule mining algorithm, and presented a method that could filtrates basic item set, or ignore the transaction records which are useless for frequent items generation.

C. Other algorithm

Up to now, many algorithms recommend items based on rank or score given by users, however in most libraries' book-loan records, it is unavailable. Yan et al. [20] discussed users' behavior from library book-circulation records. Attributes, like user's school and degree are introduced to study community's book-loan behaviors through descriptive statistics theory. However, the study mainly concentrated on the external knowledge dependency between schools, but ignored the internal knowledge dependency within certain school. Keita Tsuji [21] proposed an approach to recommend books by adopting algorithms of Support Vector Machine (SVM), Random Forest and Adaboost. However, authors did not further study the impact of data size on the algorithms.

Our work differs from previous studies by combining both association rules and fuzzy mathematics to study users' book loan patterns and then do recommendation, in this way, many other factors can be utilized by us besides result from one algorithm. By different kinds of factors we can clearly realize the association rules between books in many aspects. So it is a novel way to study users' book loan patterns and knowledge dependency rules based on the hybrid method in digital library.

III. Proposed Approach

In order to develop association books recommendation model, we propose a combination of two algorithm. First, Apriori algorithm will be utilized to develop association analysis, it will take library's circulation records into account and evaluate strength of association between books. Second, FAHP will take the result of Apriori algorithm and other subjective and objective elements into account. FAHP can structure the decision-making problems, and provide guidelines, goal weight, and alternatives, to give determination of consistency for different criteria, which makes the final result more reliable.

A. Description of Apriori algorithm

As a representative algorithm of association analysis, Apriori algorithm is designed for frequent item set mining and

association rule learning over transaction database. It identifies frequent individual items in the database and extends the item sets to larger and larger sets if the item sets are still sufficiently often in database. Actually, the frequent item sets determined by Apriori algorithm could be reveal the hidden association rules that imply the general trends in the database. The basic algorithm of Apriori is stated as follows.

For convenience, notations appear in this paper are listed in Table I. Let $I=\{i_1, i_2, \cdots, i_m\}$ be the set of item. D is the transaction set, T denotes one subset of items and $T \subseteq I$, TID is assigned to identify each transaction record. For example, Let A and B be another two subsets of items of I. If $A \subseteq T$, we call item set T contains (or supports) A. B is a set of items in I that is not present in A.

TABLE I. NOTATIONS

Symbols	Descriptions
$I=\{i_1,i_2,\cdots,i_m\}$	Item set
D	Transaction set
T	One set of items
TID	Transaction number
$A \rightarrow B$	Association rule AB
$C(A \rightarrow B)$	Confidence of Association rule AB
$S(A \rightarrow B)$	Support of Association rule AB
L_k	The set of large k-item sets
C_k	The set of candidate k-item sets

Definition 1. The association rule will be presented as $A \rightarrow B$, where $A \subset I$, $B \subset I$ and $A \cap B = \Phi$.

Definition 2. Support. For rule $A \rightarrow B$, its *Support S* is defined as $P(AB)$, which means the possibility that subsets A and B are contained in transaction D at the same time. It is given by:

$$S(A \rightarrow B) = P(AB) = \frac{|AB|}{|D|} \qquad (1)$$

Definition 3. Confidence. For rule $A \rightarrow B$, its *Confidence C* is defined as $P(A|B)$, which describes the conditional possibility that subset A is contained in D given the fact that B is contained. It is given by:

$$C(A \rightarrow B) = P(A|B) = \frac{|AB|}{|A|} \qquad (2)$$

Definition 4. Threshold. The minimum acceptable Support value and *Confidence* value, denoted as *min_sup*. If the support is not large enough, it means that the rule is not reliable or not worth consideration.

Definition 5. Item set. An item set with k items is called k-item set. If the number of times it appears is greater than threshold, it is defined as frequent item set.

Definition 6. Strong association rule. $A \rightarrow B$ is called strong association rule, if $S(A \rightarrow B) > min\_sup$.

The detail procedure of Apriori algorithm is elaborated in Algorithm 1. The principle is that frequent item set L can be generated through recursive function, generate k+1 item set from k-item set, find frequent item set L_k from candidate item set C_k. Suppose for the k-th iteration in the outer loop, candidate set for k large itemset is generated by apriori_gen(), C_k = apriori-gen(L_k-1). For this C_k, we search whole database of transactions TD in the inner loop, each item set is used to refine or prune C_k to a truncated subset C_t The algorithm will scan the database and calculate every item's value of support, and find items which satisfy *min_sup* to get frequent item set 1, labeled as L_1; and then L1 can be used to get frequent item set 2, labeled as L_2; L_2 can be used to get frequent item set 3, labeled as L_3, and so on until no new frequent k item can be found.

ALGORITHM I APRIORI ALGORITHM

Input: *TD*: Database of transactions; *min_sup*: minimum support threshold
Output: *L*: frequent itemsets in *TD*
Method:
L_1=Find_frequent_1_itemset (*TD*);
//Find frequent 1 item set
for (k=2; $L_{k-1} \neq \varphi$; k++){
C_k=Apriori_gen(L_{k-1});
//Generate new candidate item set
for each transaction $t \in TD$ {
C_t=subset (C_k, t);
/*Get candidate item set which is contained in transaction t*/
for each candidate $c \in C_t$ C.count++;
}
$L_k=\{c \in C_t \,|\, c.count \geq \min\_sup\}$;
}
Return $L=U_k L_k$;
//Return the union of $\underline{L_k}$
procedure Apriori_gen ($\underline{L_{k-1}}$: frequent (k-1)-itemsets; *min_sup* support threshold)
for each itemset $l_1 \in l_{k-1}$ {
for each itemset $l_2 \in l_{k-1}$ {
if $(l_1[1] = l_2[1]) \wedge (l_1[2] = l_2[2]) \wedge \cdots \wedge (l_1[k-1] = l_2[k-1]) \wedge (l_1[k-2] = l_2[k-2])$ then{
c=*A* join *B*;
for each itemset $l_1 \in l_{k-1}$ {
for each candidate $c \in C_k$ {
if l1 is the subset of c then
c.num++; }}}}}}
$C'_k = \{ c \in C_k | \text{ c.num} = k\}$;
return C'_k;

B. FAHP

The Fuzzy Analytic Hierarchy Process (FAHP) method involved in Multiple-criteria decision-making or multiple-criteria decision analysis. FAHP uses a systematic and logical approach in ranking and decision making process. It considers multi-criteria to develop decision analysis and uses "pair-wise comparisons" and matrix algebra to weight different criteria.

First, FAHP will define unstructured problem and its hierarchy, and then a triangular fuzzy comparison matrix will be given for calculation, at last result will be ranked and we can know which one is the best choice for our special needs. On the other hand, library book recommendation is a problem of multiple-criteria ranking, there are many factors influence this problem like co-existence when we lend books, book's press (it is possible that the same press can publish similar books) and reader's background (e.g. major or grade). It is reasonable that we need a method calculate and rank result of multiple-criteria and FAHP is a natural approach to handling it.

By FAHP, they can firstly break down their decision problem into more comprehensive sub-problems, and each sub-problem can be analyzed independently. So we can combine Apriori algorithm's result with other elements through FAHP. We assume every book has its own attributes and that can be categorized into three major factors: implicit factor, explicit factor and outcome factor. Outcome factor is given by Apriori algorithm's result. Explicit factor characterizes information of press of books. Implicit factor is characterized by different reader's preference (i.e. students in the same school or department should have the similar needs). In this way, the actual situation will be reflected more truly, and the recommendation will be reliable. The steps of FAHP approach are stated as follows.

1) Establish Factors Set

Book recommendation is a complicated problem which is influenced by many factors, so the first step is to decompose the decision problem into a hierarchical structure. After we decompose this problem we can recognize how to make decision through this structure and its factors clearly.

We select three criteria and four sub-criteria to develop the quantization for goal associated books. As we mentioned before, sub-criteria Confidence% and Support%, come from Apriori algorithm, belong to criteria outcome factor, reader's school belongs to implicit factor and book's press belongs to explicit factor. The relationship between them is shown in Fig. 1.

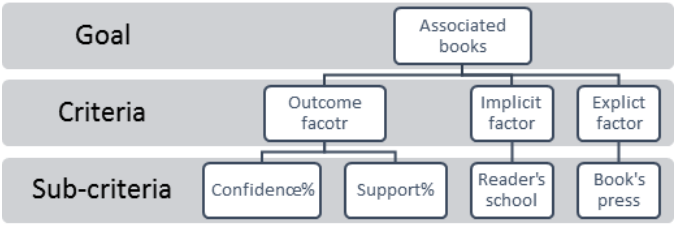

Fig. 1. Establishing judgment matrix.

After constructing the hierarchical structure of evaluation, an AHP pair-wise comparison scale table is generated for establishing the judgment matrix [22]. If the weight or importance of two factors are equal, scales for pairwise comparison should be 1; if one factor has moderate importance when compared with another, scale should be 3, and so on. Definitions of the relative importance for fuzzy numbers is shown in Table II.

TABLE II. DEFINITIONS OF THE RELATIVE IMPORTANCE FOR FUZZY NUMBERS

Symbols	Descriptions
1	Equal importance
3	Moderate importance
5	Strong importance
7	Demonstrated importance
9	Extreme importance
2,4,6,8	Intermediate Values

The result of the fuzzy pair-wise comparisons can be used to construct a fuzzy judgment matrix. The matrix $R=(r_{ij})_{m\times n}$ is shown as follow, where r_{ij} is the preference degree of preference degree of factor xi to factor x_j.

$$R_i = \begin{bmatrix} r_{i11} & r_{i12} & \dots & r_{i1n} \\ r_{i21} & r_{i22} & \dots & r_{i2n} \\ \vdots & \vdots & \vdots & \vdots \\ r_{im1} & r_{im2} & \dots & r_{imn} \end{bmatrix}, (i = 1, 2, 3) \quad (3)$$

2) Calculating weight

Weight can help us determine importance of different factors. After normalizing the result of fuzzy pair-wise comparisons matrix *R*, we utilized the fuzzy analytic hierarchy process to assign the weight in order to reasonable distribution of the weight of each factor.

3) Testing consistency

To ensure judgments of decision makers are consistent, in this step the consistency property of matrices is checked.

Calculate the maximum eigenvalue (λ_{max}): via the numerical analysis of the eigenvalue solution, to identify the eigenvector and the largest eigenvalue λ_{max}.

Consistency test: after λ_{max} is obtained, we need to calculate the Consistency Index (*C.I.*) and Consistency Ratio (*C.R.*) in order to test the consistency of the weights. If *C.I.* and *C.R.*≤0.1, then to pass the consistency test [22]. The formulas are shown as follow.

$$C.I. = \frac{\lambda_{\max} - n}{n-1} \quad (4)$$

$$C.R. = \frac{C.I.}{R.I.} \quad (5)$$

Among formulas, the Random Index (*R.I.*) is proposed by Saaty, which in order to adjust the different orders. The R.I. value table is shown in Table III.

At last we can get weight of different factors through ranking.

TABLE III. DEFINITIONS OF THE RELATIVE IMPORTANCE FOR FUZZY NUMBERS

Number of level elements(n)	1	2	3	4	5	6
R.I. value	0	0	0.52	0.89	1.11	1.25

IV. EXPERIMENTS

A. Dataset and Setup

In this paper, we use a whole year book-loan logs from Beijing University of Posts and Telecommunications as our original dataset. A whole year is a complete cycle for university life which can ensure the influence of occurrence of particular events to be minimized, and the analysis results are reasonable to be extended to future. From November 1, 2011 to October 31, 2012, which contains 95,920 book-loan records. Fig. 2 shows the distribution of book lending frequency, the frequency of book been loaned between one and three times is only 25% of total loaned books' frequency. According to association analysis, this kind of loaned record has low frequency and will give negative effect to the quality of result. So that, in this Experiment, we will rule out low frequency loaned books' records.

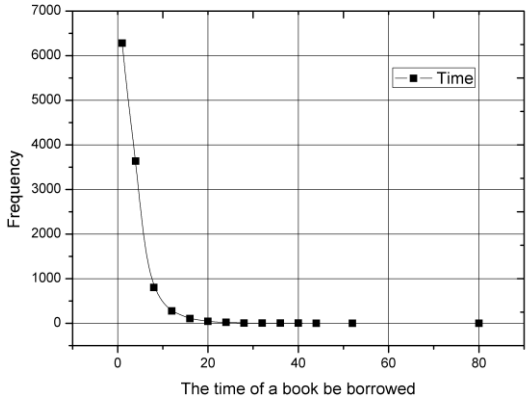

Fig. 2. The distribution of book lending frequency.

B. Association Analysi

Consider users borrowing a set of books in Beijing University of Posts and Telecommunications. The association rules are mined by Apriori algorithm firstly. The top five related books are shown in Table IV.

TABLE IV. CONFIDENCE AND SUPPROT THROUGH APRIORI ALGORITHM

	Book1-Name	***Book2-Name***	***Confidence (%)***	***Support (%)***
1st	*Developing Graphics, Music, Video and Rich Media Apps for Smartphones and Tablets*	*The Android application development*	33.3	3.01
2nd	*Aim Graduate: The foundation of Electronic technology (digital part)*	*Digital circuit*	25.2	2.89
3rd	*Java programming design*	*Head First C#*	23.2	2.29
4th	*The introduction of database*	*Beginning Android application development*	23.8	2.87
5th	*Higher Mathematics (Volume One)*	*Mathematics (Volume One)*	20.4	2.29

As can be seen, when readers borrow books in the university library, take the top1 associated books as example, there are 33% of readers who has borrowed the *Developing Graphics, Music, Video and Rich Media Apps for Smartphones and Tablets*, may also borrow *The Android application development*; The number of times of these two been borrowed is 3.01% of that of all borrowed books' item sets.

C. Experiment of FAHP

According to the investigation of students, who are actually the user of library, the difference of importance between factors can be given to FAHP. Base on that, and make sure the value of C.I. and C.R. are both less than 0.1. The weight of each factor can be calculated, which is shown in Table V

TABLE V. WEIGHTS OF FACTORS

Factor	***Confidence%***	***Support%***	***Book's press***	***Reader's school***
Weight	0.3671	0. 1957	0. 2771	0. 1600

By the algorithm we can have the top5 associated books according to Apriori algorithm and FAHP as follows in Table VI.

TABLE VI. ASSOCIATED BOOKS THROUGH FAHP

	Book1-Name	***Book2-Name***
1st	*Guide of experiments on Java programming*	*Java programming tutorial*
2nd	*Developing Graphics, Music, Video and Rich Media Apps for Smartphones and Tablets*	*The Android application development*
3rd	*Developing Graphics, Music, Video and Rich Media Apps for Smartphones and Tablets*	*Introduction to android programming*
4th	*Aim Graduate: The foundation of Electronic technology (digital part)*	*Aim Graduate: Digital electronic technology foundation study*
5th	*Image coding technology standard h. 264*	*The new generation of video compression coding standard, h. 264 / AVC*

In this result, we can see that similar books are associated with each other, and there are 89% associated books in top1000 have the same key word, such as Java or telecommunications, in the title. That is to say, this algorithm is reliable enough, and there is no need to take name of book into account

D. Comparison with Collaborative Filtering

1) Evaluation metrics

We use an improved *Precision* metrics to measure the recommendation quality of our proposed approach with collaborative filtering method. We assume that the users are professional readers, if they have at least 100 book loan records.

It is reasonable that they have insight view of books, and most of books they have loaned are associated. In *N* combined associated books we have recommended, there are the number of *Hits* books are loaned by professional readers, Precision is defined as:

$$Precision = \frac{Hits}{N} \tag{6}$$

In addition, if combined associated books set i we have recommended have been loaned by professional readers ti times, we can have the Frequency defined as:

$$Frequency = \sum_{i=1}^{Hits} t_i \tag{7}$$

Higher the Precision and Frequency, higher the quality of our recommendation.

2) Comparison results

The performance of Collaborative filtering (CF) and our method, Apriori algorithm and FAHP (A-FAHP), are presented in Fig. 3 and Fig. 4.

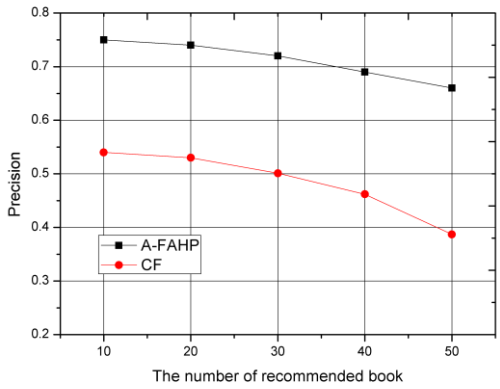

Fig. 3. Precision.

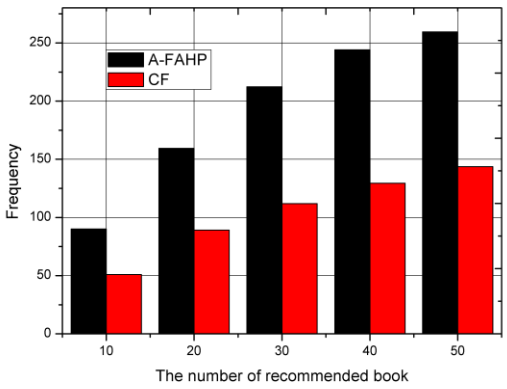

Fig. 4. Frequency of recommended books been loaned.

From the figures, we observe that our new approach significantly improves the quality of associated book recommendation in university library dataset.

V. BOOK RECOMMENDATION SYSTEM

We have also developed a book recommendation system based on the proposed algorithm. Actually, the system is made up of the following modules: circulation database, associate rules mining, rule database, rule matching, user interface and book database (See in Fig. 5).

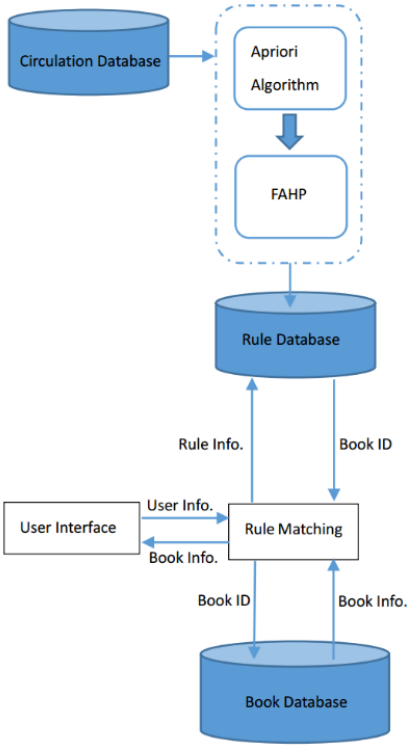

Fig. 5. Flow chart of system

The associate rules are mined by Apriori algorithm and FAHP from circulation database, which are stored in rule database. Rule matching module finds appropriate rules in rule database according to user's information, and then gives Book ID to Book database, after that information of recommendation book will be given back to user. So that, users can input their information at user interface, and then the information of the book and recommendation will be shown.

The interface of associated book for user is shown in Fig. 6, which illustrates the book user search and its associate books. List of searched book and associate books are put at left part, their covers and relationship are illustrated at right part

Fig. 6. Interface of associated book.

VI. CONCLUSION

We proposed a novel approach to the problem of identifying associated rules between books of university library. We first utilized the Apriori algorithm to mining the hidden valuable associate rules from circulation records, and then we improved the method with FAHP and got the final result. In contrast to conventional work, which only depends on few factors or could not work on sparse data reliably, the proposed approach can make efficient recommendation depend on different kinds of factors. The experimental results demonstrated the usefulness by precision and frequency analysis, our approach also achieved a good performance on the comparison with CF.

Further direction emerged from our work will be focused on extensive experiments by considering different types of datasets and more different kind of factors. And we will improve the merging and reduction methods based on the results.

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