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# AN ONTOLOGY-BASED DOCUMENT RECOMMENDATION SYSTEM: DESIGN, IMPLEMENTATION, AND EVALUATION

Deng-Neng Chen
*National Pingtung University of Science and Technology*, dnchen@mail.npust.edu.tw

Cheng-Hsun Wu
*National Pingtung University of Science and Technology*, wjs8916@msn.com

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Chen, Deng-Neng, National Pingtung University of Science and Technology, Shuefu Rd. 1, Neipu, Pingtung 912, Taiwan, dnchen@mail.npust.edu.tw

Wu, Cheng-Hsun, National Pingtung University of Science and Technology, Shuefu Rd. 1, Neipu, Pingtung 912, Taiwan, wjs8916@msn.com

## Abstract

*With the explosion of information, more and more people are embarrassed to manage information effectively. How to search and retrieve accurate information match to people's requirements has been an important issue in information management research. Although search engine can solve this problem partly, the support of manage information is still limited. To use search engine, the users should input precise keywords by themselves first and this stage might cause much confusion to users. For that reason, we need a recommendation system that can catch users' preferences to help users to obtain information more quickly and conveniently without copious process.*

*In our research, a recommendation system is designed based on users' profile. We use ontology technology to be the core of our recommendation system, because ontology can describe the concepts and relations of individual's domain knowledge. Formal Concept Analysis (FCA) algorithm is one of the most popular methods to build ontology, and we apply it to construct our experimental system to recommend master theses to subjects. In order to evaluate our recommendation system, we developed a FCA-based system and another Scoring FCA-based system as treatments, and a Keyword-based system as a control group. We focus on both users' satisfaction on information quality and system quality of our systems. The results show that users have higher information satisfaction on Scoring FCA-based system and FCA-based system than Keyword-based system. This study contributes to research and practice in information recommendation system.*

*Keywords: Recommendation System, Ontology, Formal Concept Analysis (FCA), User Satisfaction.*

# 1. RESEARCH BACKGROUNDS AND MOTIVATIONS

With the explosion of information and information technologies, more and more people are confused to manage information effectively to help their decision making. To help people to deal with the huge amounts of information, semantic web technology is proposed (Berners-Lee & Fischetti 1999). Semantic web is defined as a set of metadata which describes the attributes of original data. It can help to handle the data or information in effect, and help to build more information added value services, such as the recommendation system (Goldberg et al. 1992).

Recommendation system is designed to recommend individual information automatically. It recommends information to user based on personal profile, and can help to retrieve information and make decisions effectively. There are many recommendation technologies have been proposed, such as Resnick & Varian (1997), Pazzani (1999) and Schafer et al. (1999). Burke (2002) claims a recommendation system should have three elements, they are background data, users' preferences information, and an algorithm to calculate the data and preferences to make a good recommendation to user. Therefore, a recommendation system should have a mechanism to present the structure of information and personal preferences profile. Ontology technology is one of the most proper technologies. Gruber (1993) defined an ontology is a specification of a conceptualization. It is a set of descriptions of the concepts and relationships. Ontology can be used in knowledge presentation in knowledge engineering. Nowadays, there are lots of ontology construction methods based on machine learning have been proposed. Formal Concept Analysis (FCA) proposed by Wille (1982) has been proofed as an effective data analysis method to discover conceptual structures of a dataset. It has also been evaluated to develop domain ontology (Stumme & Maedche 2001, Haav 2004, Obitko et al. 2004, Formica 2006, Zhao et al. 2006). In our research, we try to build a document recommendation system based on FCA. We can acquire individual's preferences through his/her documents browsing. Based on FCA analysis, we can get user's personal ontology and then design a documents recommendation system for the users. We also propose a Scoring FCA method to enhance the performance of traditional FCA-based recommendation.

The remainder of this article is organized as follows: Section 2 describes the details of FCA algorithm, and explains how it can be used to construct the ontology. In section 3, we detail our research hypotheses and measurements. The experiment design includes the recommendation system architecture and experiment flow are shown in section 4. Section 5 highlights the key analysis results and their implications. We conclude in Section 6 with a summary and some future research directions.

# 2. FCA-BASED RECOMMENDATION

In our research, the ontology of documents is constructed by FCA technology. FCA is an information retrieval method, it can find out the conceptual structure from a text-based dataset (Wille 1982). FCA can help to structure and crystallize the text data, and this could assist people to catch up the conspectus of the dataset effectively. Therefore, FCA can be used to build the domain ontology (Bain 2003, Formica 2006). The FCA-based ontology construction process is shown in figure 1. First, the keywords of documents are retrieved and used to construct the formal context and concepts lattices. In this stage, the concepts in the documents and relationships between concepts are established. Then, the weights of relationships are calculated. We also propose a scoring method that the user scores his/her preferences on the browsing documents. Finally, the ontology of the user can be built. The ontology construction process is shown in the followings step by step.

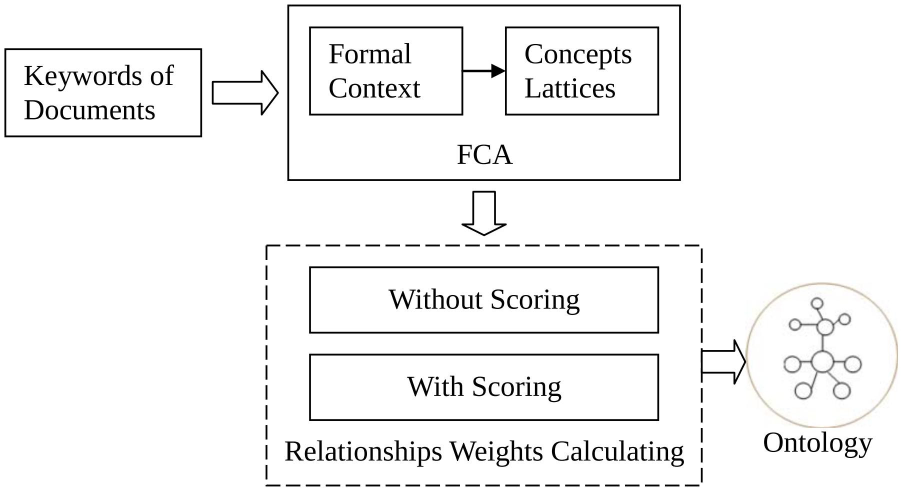


*Figure 1.* *The concepts of Ontology-based recommendation systems.*

**Step 1**: Constructing the formal context

Formal context is a table contained the relationships between documents and keywords. We illustrate a formal context from our experimental dataset in table 1. In this example, we have 9 documents $D_1, D_2, ..., D_9$ and 10 keywords. If the keywords belong to the documents, the intersection grid will be denoted by “1”.

| | EC | B2C | B2B | C2C | Online Retail | E-Marketplace | SCM | Mobile Commerce | Auction | CRM |
|---|---|---|---|---|---|---|---|---|---|---|
| $D_1$ | 1 | 1 | 1 | 1 | | | | 1 | | |
| $D_2$ | 1 | | 1 | | | | 1 | | | |
| $D_3$ | 1 | 1 | 1 | | | 1 | | | | |
| $D_4$ | 1 | 1 | | 1 | | | | | | 1 |
| $D_5$ | 1 | | | 1 | | | | | 1 | |
| $D_6$ | 1 | 1 | 1 | 1 | 1 | | | | 1 | |
| $D_7$ | 1 | 1 | | | 1 | | | | | 1 |
| $D_8$ | 1 | | 1 | | 1 | 1 | | | | |
| $D_9$ | 1 | | 1 | | | 1 | 1 | | | |

*Table 1.* *A formal context example.*

**Step 2**: Constructing all concepts

We define a concept *A* as a subset of concept *E*, and concept *B* is a subset of concept *T*, then, we denote as $A \subseteq E$ and $B \subseteq T$. If $A' = B$ and $B' = A$, there will be a new concept *C* and denote as $c(A, B)$. In the other words, concept *C* contains all the relationships between concept *A* and *B* in the formal context.

**Step 3**: Constructing concept lattices

If the set of documents contain the same term $B_1$ can be included totally in the other set of documents contain the term $B_2$, we denote $B_1$ is the sub-concept of $B_2$. For all concept $C$, if $B_1 \subseteq B_2$ then $c_1(A_1, B_1)$ is the sub-concept of $c_2(A_2, B_2)$, and is denoted by $(A_1, B_1) \leq (A_2, B_2)$. This relationship can be called as inheritance. Moreover, if a set of documents contain the term $B_1$ can be included partially in the other set of documents contain the term $B_2$, we denote the relationship between $B_1$ and $B_2$ is intersection. For all concept $C$, if $B_1 \subseteq B_2$ and $B_2 \subset B_1$ then $c_1(A_1, B_1)$ and $c_2(A_2, B_2)$ is intersection. Based on constructing the relationships of inheritance and intersection, we can build a concept lattices. This concept lattices can be deemed as ontology. Figure 2 is an ontology example that is built from the formal context in table 1.

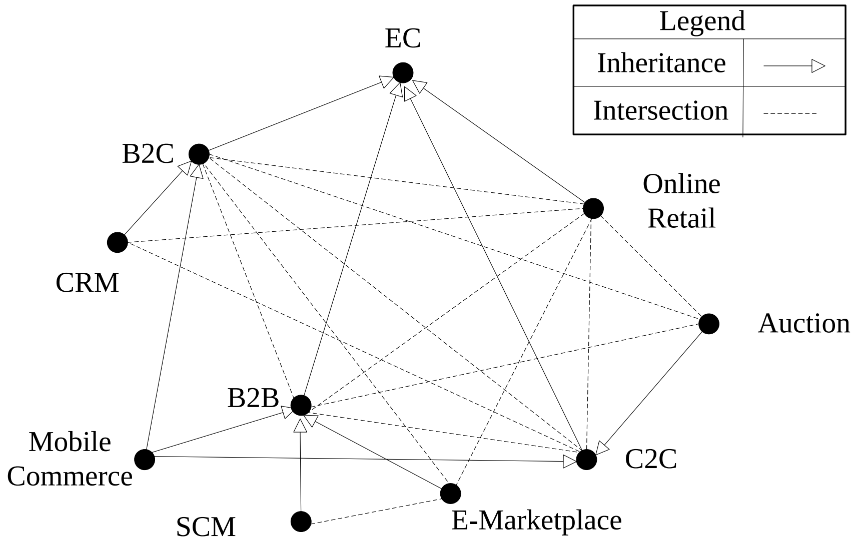


*Figure 2. An ontology example.*

**Step 4**: Calculating the weights of relationships between concepts

From step 1 to 3, we can get the relationships between concepts of documents. However, in order to recommend documents to users, we need to know the information of relationships' weights. Hou & Chan (2003) proposed the weight calculating method. First, the frequency of terms in each document should be counted such as shown in table 2.

| | $Term_1$ | $Term_2$ | $\cdots$ | $Term_n$ |
|---|---|---|---|---|
| $D_1$ | $N(D_1, Term_1)$ | $N(D_1, Term_2)$ | $\cdots$ | $N(D_1, Term_n)$ |
| $D_2$ | $N(D_2, Term_1)$ | $N(D_2, Term_2)$ | $\cdots$ | $N(D_2, Term_n)$ |
| $\vdots$ | $\vdots$ | $\vdots$ | | $\vdots$ |
| $D_k$ | $N(D_k, Term_1)$ | $N(D_k, Term_2)$ | $\cdots$ | $N(D_k, Term_n)$ |

*Table 2. The frequency of terms in each document.*

Based on the information in table 2, we can calculate the weight of each couple of terms by the following function.

$$R_{ij} = \frac{\sum_{l=1}^{N_D} X_{i,l} X_{j,l} - N_D \overline{X_i}\,\overline{X_j}}{\sqrt{\left(\sum_{l=1}^{N_D} X_{i.l}{}^2 - N_D \overline{X_i}^2\right)\left(\sum_{l=1}^{N_D} X_{j,l}{}^2 - N_D \overline{X_j}^2\right)}}$$

$X_{i,l}$ is the freqnency of $Term_i$ in $D_l$, in the other word, $X_{i,l} = N(D_l, Term_i)$.

$X_{j,l}$ is the freqnency of $Term_j$ in $D_l$, in the other word, $X_{j,l} = N(D_l, Term_j)$.

$N_D$ is the total number of all documents.

By the process from step 1 to 4 of FCA and weights calculating, we can get a weighting ontology of individual. However, this mechanism is recommended documents to user based on only the concepts and relations of the documents (without scoring). We have no information about the user's preferences scale about the different documents. Therefore, in our recommendation system, we add a scoring mechanism on the FCA-based system. The user is required to evaluate his/her preferences on each document from score one to ten. This mechanism can enhance the weight calculation of relationships and is called as Scoring FCA-based system.

## 3. RESEARCH HYPOTHESES AND MEASUREMENTS

Our comparative evaluation of the proposed FCA-based, Scoring FCA-based recommendation systems and benchmark Keyword-based system focuses on user information and user system satisfaction (DeLone & McLean 1992). User information satisfaction pertains to which a user is satisfied with recommendation results by the system. In addition, user system satisfaction concentrates on the use of the system itself and refers to the interactions with the user interface of the actual system. We obtain the user's satisfaction measurement items from DeLone & McLean (1992) and we made some modification to match our target context. Therefore, we propose two research hypotheses as followings and the measurement items are shown in table 3.

*H1: The different recommendation systems will result in different system quality satisfaction.*

*H2: The different recommendation systems will result in different information quality satisfaction.*

| User's Satisfaction | Items | Measurement Scale |
|---|---|---|
| System Quality Satisfaction | 1. The system is easy to use. | Likert's five scale measurements |
| | 2. The system's functions are understandable. | |
| | 3. The system is reliable. | |
| | 4. The system is easy to learn. | |
| | 5. I am satisfied with the response time. | |
| Information Quality Satisfaction | 1. The system's recommendation meets my requirements. | Likert's five scale measurements |
| | 2. The system's recommendation is reliable. | |
| | 3. The system's recommendation is unambiguous. | |
| | 4. The system's recommendation information is precise | |
| | 5. The system's recommendation information is understandable. | |

*Table 3. The measurements of user's satisfactions.*

# 4. EXPERIMENT DESIGN

## 4.1 System Architecture

In order to evaluate the performance of Ontology-based recommendation system, we designed three experimental systems; they are FCA-based recommendation system, scoring FCA-based recommendation system, and a Keyword-based recommendation system. Both of FCA-based and Scoring FCA-based systems are constructed for manipulated groups, and the Keyword-based system is considered as a control group. The overall architecture of our experiment system is shown in figure 3.

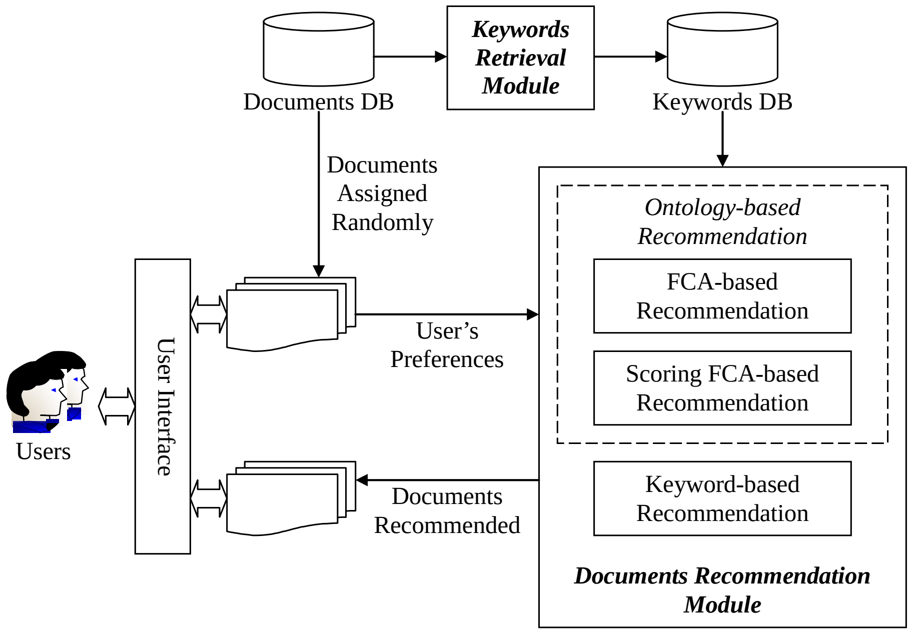


*Figure 3. Experimental system architecture.*

First, we collected 420 master dissertations about electronic commerce (EC) from Electronic Theses and Dissertations System in Taiwan[1]. The documents are collected in a database, and the schema is shown in table 4.

| Doc_no | Author | Title | Department | School | Year | Keywor1 | Keywor2 | Keywor3 | Keywor4 | Keywor5 | Abstract |
|---|---|---|---|---|---|---|---|---|---|---|---|

*Table 4. The schema of documents database.*

The documents recommendation mechanism is designed based on the content of dissertation's abstract, and keywords are applied as the recommendation indexes. Due to the keywords are defined by the authors and different author might use different term to mean the same concept, this will affect the accuracy of recommendation results. Therefore, we need a translation table to define the synonymies of the keywords. This translation mechanism is designed in the keywords retrieval module. The keywords and synonymies are collected in a database, and its schema is shown in table 5.

[1] Electronic Theses and Dissertations System (ETDS) is a database that collects all masters' and doctors' dissertations in Taiwan. The url is http://etds.ncl.edu.tw/theabs/index.jsp.

| Keyword_no | Keyword | Synonymy1 | Synonymy2 | Synonymy3 | Synonymy4 |
|---|---|---|---|---|---|
| 1 | EC | Electronic Commerce | e-Commerce | NULL | NULL |
| 2 | B2B | Business to Business | B2B commerce | Business to Business commerce | NULL |

*Table 5. The schema of keywords database.*

The documents recommendation module is constituted of Ontology-based and Keyword-based modules, and we develop FCA-based and Scoring FCA-based methods for ontology construction. The Keyword-based recommendation is constructed as a baseline system. It recommends documents to users by the keywords of the papers. In FCA and Scoring FCA-based recommendation systems, the systems recommend papers to users based on the FCA-based ontology analysis results.

### 4.2 Experiment Flow

All the qualified subjects are asked to finish all the three experiments, include FCA-based, Scoring FCA-based and Keyword-based recommendation systems. With the purpose of eliminating the learning effects among the three experiments, the order of three systems are assigned to subjects randomly. Figure 4 depicts the overall experiment flow. In Keyword-based recommendation system, system allocates 10 documents from 420 randomly to the subject. The subject selects 5 documents from the 10 based on his/her preferences. The system analyses the keywords of the 5 documents preferred by subject, and recommend the other new 5 documents to subjects by the keywords related documents in the dataset. Finally, each subject indicates his/her information quality and system quality satisfaction about the recommendation system.

When entering the FCA-based system, the subject reads 5 preferred documents from 10 that are assigned randomly by system. The FCA module constructs the ontology from the concepts of the 5 documents, and recommends the other new 5 documents to the subject. Each subject fills his/her information quality and system quality satisfaction about the recommendation system finally. In the Scoring FCA-based recommendation system, the only one difference with the traditional FCA-based system is in the initial stage. The subject reads 5 documents from 10 that are assigned randomly by system and is asked to input his/her preferences by scoring 1 to 10. The larger number means the higher interesting. The remainder stages are all the same with the traditional FCA-based system.

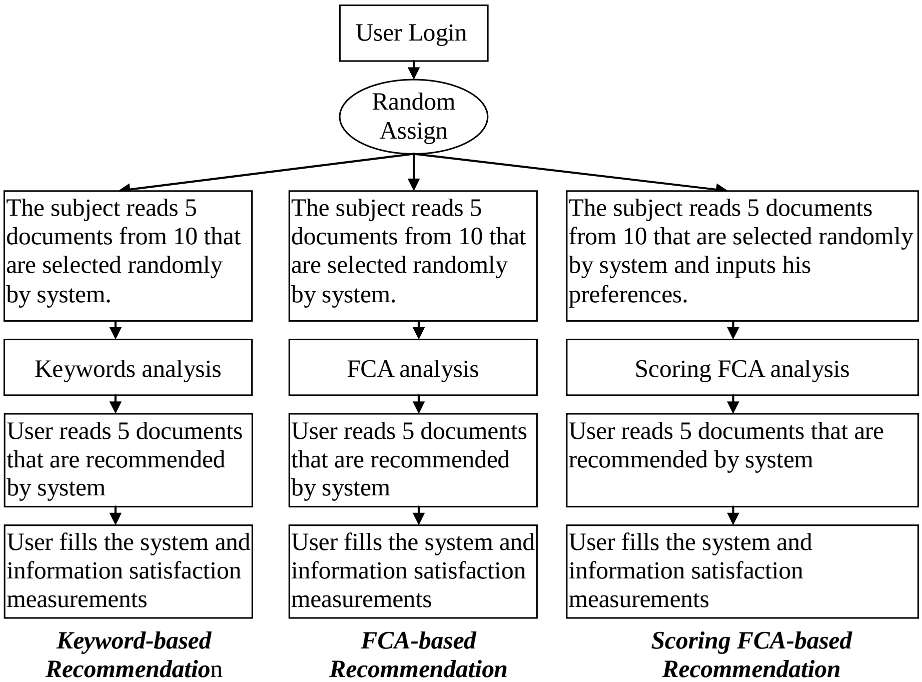


*Figure 4. Experimental flow.*

## 5. DATA ANALYSIS

In order to insure all the subjects have the similar knowledge background on EC, all the subjects in our experiment have ever taken the electronic commerce course in university. The sample size of our experiment is ninety-five. However, not all the subjects have the patience to finish all the three experiments. The final effective sample size is not equal in the three experiments and the number is shown in table 6.

| Recommendation Methods | Effective Sample Size |
|---|---|
| FCA-based System | 95 |
| Scoring FCA-based System | 90 |
| Keyword-based System | 84 |

*Table 6. The effective sample size of each recommendation experiment.*

The goal of the three experiments is to collect the user's satisfaction on system quality and informaiton quality, in addtiton, to analyze the difference among the three experiments. The descriptive statistics data of our measurements is shown in table 7. To test the hypothesis one, we applied one-way ANOVA and the analysis results are shown in table 8.

| System Quality Satisfaction | Recommendation Methods | Mean | SD |
|---|---|---|---|
| 1. The system is easy to use. | FCA-based System | 3.5789 | .97390 |
| | Scoring FCA-based System | 3.6444 | .87809 |
| | Keyword-based System | 3.6429 | .85929 |
| | Total | 3.6208 | .90464 |
| 2. The system’s functions are understandable. | FCA-based System | 3.6000 | .76353 |
| | Scoring FCA-based System | 3.5714 | .78057 |
| | Keyword-based System | 3.5714 | .78057 |
| | Total | 3.6543 | .76502 |
| 3. The system is reliable. | FCA-based System | 3.5263 | .72702 |
| | Scoring FCA-based System | 3.6444 | .76893 |
| | Keyword-based System | 3.4881 | .96310 |
| | Total | 3.5539 | .82060 |
| 4. The system is easy to learn. | FCA-based System | 3.7263 | .83082 |
| | Scoring FCA-based System | 3.6667 | .73439 |
| | Keyword-based System | 3.6548 | .82862 |
| | Total | 3.6840 | .79678 |
| 5. I am satisfied with the response time. | FCA-based System | 4.3158 | .84126 |
| | Scoring FCA-based System | 4.2000 | .81005 |
| | Keyword-based System | 4.1548 | .88487 |
| | Total | 4.2268 | .84458 |

*Table 7. The descriptive statistics of system quality satisfaction measurements.*

| System Quality Satisfaction Measurement | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Easy to use | Between Groups | .258 | 2 | .129 | .156 | .855 |
| | Within Groups | 219.066 | 266 | .824 | | |
| | Total | 219.323 | 268 | | | |
| Understandable functions | Between Groups | 2.487 | 2 | 1.244 | 2.143 | .119 |
| | Within Groups | 154.360 | 266 | .580 | | |
| | Total | 156.848 | 268 | | | |
| Reliable system | Between Groups | 1.174 | 2 | .587 | .871 | .420 |
| | Within Groups | 179.295 | 266 | .674 | | |
| | Total | 180.468 | 268 | | | |
| Easy to learn | Between Groups | .269 | 2 | .134 | .211 | .810 |
| | Within Groups | 169.872 | 266 | .639 | | |
| | Total | 170.141 | 268 | | | |
| Response time | Between Groups | 1.253 | 2 | .626 | .877 | .417 |
| | Within Groups | 189.914 | 266 | .714 | | |
| | Total | 191.167 | 268 | | | |

*Table 8. The ANOVA analysis of system quality satisfaction.*

In table 8, no p value is significant, in the other words, the hypothesis one (H1) is rejected. Due to our experimental systems are built on the same platform and have the same user interface. It is reasonable that subjects have the same satisfaction on system quality among the three recommendation systems. We might also claim that due to the system qualities have no significant difference, and the information quality satisfaction measurement might not be affected by system quality.

The descriptive statistics of information quality measurements and ANOVA analysis results are shown in table 9 and table 10. The test of ANOVA on the measurement item one and two are supported by the data analysis. The hypothesis two (H2) is supported partially. In the other words, different recommendation methods would cause different information satisfaction. This is compatible to the purposes of recommendation systems.

| Information Quality Satisfaction | Recommendation Methods | Mean | SD |
|---|---|---|---|
| 1. The system's recommendation meets my requirements. | FCA-based System | 3.6316 | .66927 |
| | Scoring FCA-based System | 3.6000 | .74653 |
| | Keyword-based System | 3.3571 | .84515 |
| | Total | 3.5353 | .76029 |
| 2. The system's recommendation is reliable. | FCA-based System | 3.6000 | .65882 |
| | Scoring FCA-based System | 3.7000 | .69428 |
| | Keyword-based System | 3.3810 | .83457 |
| | Total | 3.5651 | .73837 |
| 3. The system's recommendation is unambiguous. | FCA-based System | 3.8316 | .76704 |
| | Scoring FCA-based System | 3.7444 | .81504 |
| | Keyword-based System | 3.6905 | .93107 |
| | Total | 3.7584 | .83598 |
| 4. The system's recommendation information is precise | FCA-based System | 3.7684 | .83095 |
| | Scoring FCA-based System | 3.7778 | .83165 |
| | Keyword-based System | 3.6548 | .88487 |
| | Total | 3.7361 | .84699 |
| 5. The system's recommendation information is understandable. | FCA-based System | 3.6842 | .76162 |
| | Scoring FCA-based System | 3.8000 | .81005 |
| | Keyword-based System | 3.7381 | .86594 |
| | Total | 3.7398 | .80988 |

*Table 9. The descriptive statistics of information quality satisfaction measurements.*

| Information Quality Satisfaction Measurement | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Meet requirements | Between Groups | 3.924 | 2 | 1.962 | 3.456 | .033** |
| | Within Groups | 150.991 | 266 | .568 | | |
| | Total | 154.914 | 268 | | | |
| Reliable recommendation | Between Groups | 4.602 | 2 | 2.301 | 4.325 | .014** |
| | Within Groups | 141.510 | 266 | .532 | | |
| | Total | 146.112 | 268 | | | |
| Unambiguous | Between Groups | .914 | 2 | .457 | .652 | .522 |
| | Within Groups | 186.380 | 266 | .701 | | |
| | Total | 187.294 | 268 | | | |
| Precise | Between Groups | .811 | 2 | .406 | .564 | .570 |
| | Within Groups | 191.449 | 266 | .720 | | |
| | Total | 192.260 | 268 | | | |
| Understandable information | Between Groups | .620 | 2 | .310 | .471 | .625 |
| | Within Groups | 175.164 | 266 | .659 | | |
| | Total | 175.784 | 268 | | | |

(**: p value < 0.05)

*Table 10. The ANOVA analysis of information quality satisfaction.*

We applied Scheffe's method for post hoc comparison and the results are shown in table 11. The FCA-based and Scoring FCA-based recommendation have no difference, however the FCA-based system gains higher satisfaction than Keyword-based system on meeting the subjects' requirements. It is said that Ontology-based recommendation is better than keywords-based on recommendation quality. This result can clarify the value of ontology and FCA on recommendation research.

Compared to the Keyword-based system, the scoring mechanism upraises the reliability of recommendation results, but has no significant effect with the traditional FCA-based system. This is because the subjects have indicated their preferences on the documents, and they would believe the system might be more reliable.

| Information Quality Satisfaction Measurement | Recommendation Method (I) | Recommendation Method (J) | Mean Difference | Sig. |
|---|---|---|---|---|
| Meet requirements | FCA-based System | Scoring FCA-based System | .03158 | .960 |
| | | Keyword-based | .27444 | .054* |
| | Scoring FCA-based System | FCA-based System | -.03158 | .960 |
| | | Keyword-based | .24286 | .107 |
| | Keyword-based | FCA-based System | -.27444 | .054* |
| | | Scoring FCA-based System | -.24286 | .107 |
| Reliable recommendation | FCA-based System | Scoring FCA-based System | -.10000 | .648 |
| | | Keyword-based | .21905 | .136 |
| | Scoring FCA-based System | FCA-based System | .10000 | .648 |
| | | Keyword-based | .31905 | .017** |
| | Keyword-based | FCA-based System | -.21905 | .136 |
| | | Scoring FCA-based System | -.31905 | .017** |

(*: p value < 0.1; **: p value < 0.05)

*Table 11. The Scheffe's analysis results of information quality satisfaction measurements.*

# 6. CONCLUSIONS

In our research, we have proposed and built a feasible ontology-based recommendation system by FCA technology. We also construct an experiment to validate the performance of our FCA-based and Scoring FCA-based recommendation systems by measuring the subjects' satisfaction. The results show FCA-based recommendation is better than the benchmark, Keyword-based recommendation system. Based on FCA technology, the recommendation system can obtain the user's preferences on the concepts of the documents. It can improve the performance of keywords related only recommendation. In addition, we add a document scoring mechanism on the traditional FCA-based recommendation. This scoring mechanism would help to acquire people's preferences more accurately, and advance the users' satisfaction on information reliability.

The strength of ontology (or FCA analysis) is it can estimate the concepts of documents and the relationships among the concepts can be found out. It will be helpful to someone who is confused by huge amounts of documents and information. This recommendation mechanism can be implemented on documents repository system, and will help people to manage information/documents more effectively. This recommendation mechanism might also be applied in electronic commerce for products suggestion in the e-store.

However, in our experiment, we just allow the subject selects only five preferred documents. This might be not enough on catching the subject's preferences accurately. In the other, based on the same FCA-based recommendation, we might improve on the individual's preferences retrieval mechanism in the future.

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