

A Literature Review and Classification of Recommender Systems on Academic Journals

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Recommender systems have become an important research field since the emergence of the first paper on collaborative filtering in the mid-1990s. In general, recommender systems are defined as the supporting systems which help users to find information, products, or services (such as books, movies, music, digital products, web sites, and TV programs) by aggregating and analyzing suggestions from other users, which mean reviews from various authorities, and user attributes.

However, as academic researches on recommender systems have increased significantly over the last ten years, more researches are required to be applicable in the real world situation. Because research field on recommender systems is still wide and less mature than other research fields. Accordingly, the existing articles on recommender systems need to be reviewed toward the next generation of recommender systems. However, it would be not easy to confine the recommender system researches to specific disciplines, considering the nature of the recommender system researches. So, we reviewed all articles on recommender systems from 37 journals which were published from 2001 to 2010. The 37 journals are selected from top 125 journals of the MIS Journal Rankings. Also, the literature search was based on the descriptors “Recommender system”, “Recommendation system”, “Personalization system”, “Collaborative filtering” and “Contents filtering”.

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The full text of each article was reviewed to eliminate the article that was not actually related to recommender systems. Many of articles were excluded because the articles such as Conference papers, master's and doctoral dissertations, textbook, unpublished working papers, non-English publication papers and news were unfit for our research. We classified articles by year of publication, journals, recommendation fields, and data mining techniques.

The recommendation fields and data mining techniques of 187 articles are reviewed and classified into eight recommendation fields (book, document, image, movie, music, shopping, TV program, and others) and eight data mining techniques (association rule, clustering, decision tree, k-nearest neighbor, link analysis, neural network, regression, and other heuristic methods).

The results represented in this paper have several significant implications. First, based on previous publication rates, the interest in the recommender system related research will grow significantly in the future. Second, 49 articles are related to movie recommendation whereas image and TV program recommendation are identified in only 6 articles. This result has been caused by the easy use of MovieLens data set. So, it is necessary to prepare data set of other fields. Third, recently social network analysis has been used in the various applications. However studies on recommender systems using social network analysis are deficient. Henceforth, we expect that new recommendation approaches using social network analysis will be developed in the recommender systems. So, it will be an interesting and further research area to evaluate the recommendation system researches using social method analysis.

This result provides trend of recommender system researches by examining the published literature, and provides practitioners and researchers with insight and future direction on recommender systems. We hope that this research helps anyone who is interested in recommender systems research to gain insight for future research.

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1. Introduction

Recommender systems have become an important research field since the emergence of the first paper on collaborative filtering in the mid-

1990s (Resnick et al., 1994; Shardanand and Maes, 1995).

In general, recommender systems are defined as the supporting systems which help users to find content, products, or services (such as books,

digital products, movies, music, TV programs, and web sites) by aggregating and analyzing suggestions from other users, which mean reviews from various authorities, and users (Frias-Martinez et al., 2006; Frias-Martinez et al., 2009; Kim et al., 2010). Recommender systems are broadly classified into collaborative filtering (CF) and content-based filtering (CB). CF is an information filtering technique based on user's evaluation of items or previous purchases records. However, this has been known to expose two major issues : sparsity problem and scalability problem (Claypool et al., 1999; Sarwar et al., 2000a; Sarwar et al., 2000b). CB analyzes a set of items rated by an individual user and uses the content of these items, as well as the provided ratings, to infer profile that can be used to recommend additional item of interest (Basu et al., 1998). However, syntactic nature of CB to detect similarity between items that share the same attributes or features causes overspecialized recommendations that only include very similar items to those the user already knows (Lopez- Nores et al., 2008).

Over the last decade, lots of researchers have studied new approaches of recommender systems to solve these problems of CF and CB, and to apply them into real world problems. Especially, applications of data mining techniques to recommender systems have been effective to offer personalized information to the user through analysis of his/her preference.

However, more researches are required to be

applicable in real world situation because research field on recommender systems is still wide and less mature than other research fields. Accordingly, the existing articles on recommender systems need to be reviewed toward the next generation of recommender systems, which means the development of recommendation methods to offer more useful and suitable information to users.

In this paper, we classify comprehensive review of literatures on recommender systems that were published in academic journals from 2001 to 2010, to obtain insight on recommender systems. This paper is organized as follows:

- (1) The research methodology used in this study is described
- (2) Criteria for classification of articles on recommender systems are presented
- (3) The articles on recommender systems are analyzed and results of classification are reported
- (4) Conclusions are presented and the limitations and implications of this study are discussed

We hope that result of this study will emphasize the importance of recommender systems and provide both academics and practitioners with insight on recommender system research.

2. Research Methodology

The aim of study is to understand the trend of recommender system researches by examining

the published literatures, and to provide practitioners and researchers with insight and future direction on recommender systems.

Thus, we will identify distribution of articles on recommender systems by year of publication, and classify the articles by data mining technique used for recommendation and by the recommendation field. However, considering the nature of the research on recommender systems, it would be difficult to confine to specific disciplines. Moreover evidence of this can be seen from the fact that articles on recommender systems are scattered across various journals such as marketing, information technology, information science, computer science, management and business. So, it is necessary to compile the increasing literatures on recommender systems systematically. Consequently, following various online journal databases were searched to provide a comprehensive bibliography of the academic literature on recommender systems:

- EBSCO Academic Search Premier;
- EBSCO Business Source Premier;
- Science Direct;
- IEEE/IEE Library;
- ABI/INFORM Database;
- ACM Portal

The literature search on recommender systems was conducted from top 125 journals of the MIS Journal Rankings. The literature search was based on the descriptors “Recommender system”,

“Recommendation system”, “Personalization system”, “Collaborative filtering” and “Contents filtering”. The full text of each article was reviewed to eliminate the article that was not actually related to recommender systems. Many articles were excluded because those were unfit for our research, which is described as follows:

- (1) Conference papers, master’s and doctoral dissertations, textbook, unpublished working papers, non-English publication papers, and news were excluded, because the majority of practitioners and academics often use journals to gain information and disseminate release new finding.
- (2) As researches on recommender systems in this area is relatively current, we have only searched research articles published from 2001 and up to the end of 2010. This 10-year period is considered to be typical of the recommender systems.
- (3) Only those articles that obviously described how the mentioned recommender systems could be applied in the field were selected.

We extracted 187 articles on recommender systems from 37 journals. Each article was prudently reviewed and classified into one of the eight categories in the recommendation fields and data mining techniques. Although the search was not exhaustive, it serves as a comprehensive basis for understanding recommender system research.

3. Classification Method

The framework includes recommendation fields and data mining techniques. In this paper, we classify the reviewed articles into eight categories of recommendation fields and eight categories of data mining techniques. Graphical classification framework for recommender systems articles are shown in <Figure 1>.

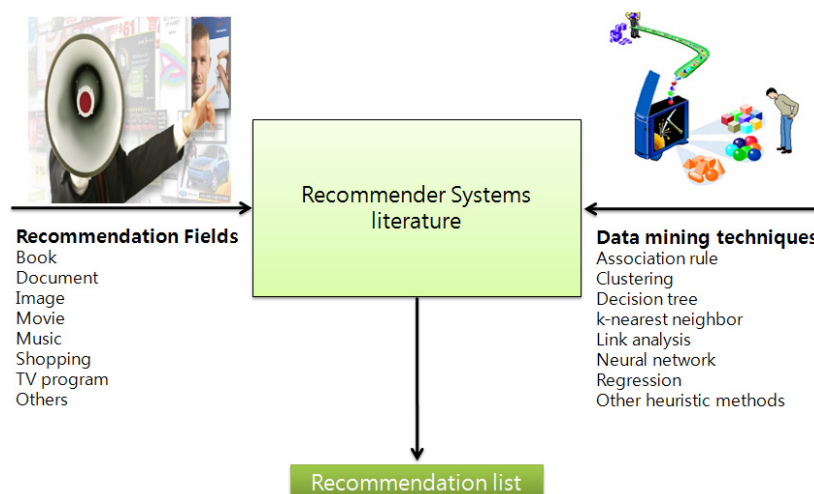
3.1 Classification Framework for Recommendation fields

Many recommender systems have used to suggest users with information to help them determine which products to purchase (Schafer et al., 2001). However, the existing literatures have not classified systematically though recommender systems have been applied to the various business area, thus it is meaningful to investigating recommendation fields. We classify articles

by recommendation fields such as book, document, image, movie, music, shopping, TV program and others. Through in-depth reviews of literature, shopping field includes online, offline and mobile shopping product and document field include paper, web blog and web page. Also others field includes a minority of recommendation field such as tour, food, news and so on.

3.2 Classification Framework for Data Mining Techniques

In general, data mining techniques are defined as extracting or mining knowledge from amount of data. It is used for the exploration and analysis of large quantities of data in order to discover meaningful patterns and rules (Berry and Linoff, 2004). It can be used to lead decision making and predict the effect of decision. Especially, a lot of researchers have used data mining technique for improving the performance of recom-



<Figure 1> Classification Framework

mender systems. Accordingly, it is meaningful to classify the articles by data mining techniques for recommender systems. We broadly classified data mining techniques into the following eight categories: Association rule, Clustering, Decision tree, k-nearest neighbor, Link analysis, Neural network, Regression, and other heuristic methods.

- (1) Association rule : Given a set of transactions where each transaction set of items, an association rule applies the form $X \Rightarrow Y$, where X and Y are two sets of items (Cho et al., 2002).
- (2) Clustering : Clustering method is identifying a finite set of categories or clusters to describe the data. Among the clustering methods, most popular clustering methods are K-means and self-organizing map (SOM). K-means takes the input parameter, K , and partitioning a set of n objects into K clusters (Berry and Linoff, 2004). The SOM is a method for an unsupervised learning, based on artificial neurons clustering technique (Lihua et al., 2005).
- (3) Decision tree : Most popular classification method are decision tree induction. The top node in a tree is called as a root node. A decision tree is a tree that each internal node (non-leaf node) denotes a test on an attribute, each branch represents an outcome of the test, and each terminal node (leaf node) denotes a class prediction (Kim et al., 2002).
- (4) k-nearest neighbor : The k-NN (k-nearest neighbor) model make a user profile using the

user's preference ratings that are gained directly from explicit ratings of items or provided indirectly from the purchase or usage information (Kim et al., 2009). k-NN is a popular method of CF.

- (5) Neural network : Neural network builds a class of very pliable model that can be used for a diversity of different applications, such as prediction, non-linear regression, or classification (Anders and Korn, 1999).
- (6) Link analysis : Link Analysis has presented great potential in improving the accomplishment of web search. Link analysis consists of PageRank and HITS algorithms. Most link analysis algorithms handle a web page as a single node in the web graph (Cai et al., 2004).
- (7) Regression : Regression analysis is a powerful diversity process for analyzing associative relationships between dependent variables and one or more independent variables. The regression has been used for curve fitting, prediction, testing systematic hypotheses about relationships between variables (Malhotra, 2007).
- (8) Other heuristic methods : Heuristic methods developed by many researchers, include mixture model, ontology method and so on.

3.3 Classification process

Each of selected articles was reviewed and classified according to the suggested classification framework by two of the four authors of this pa-

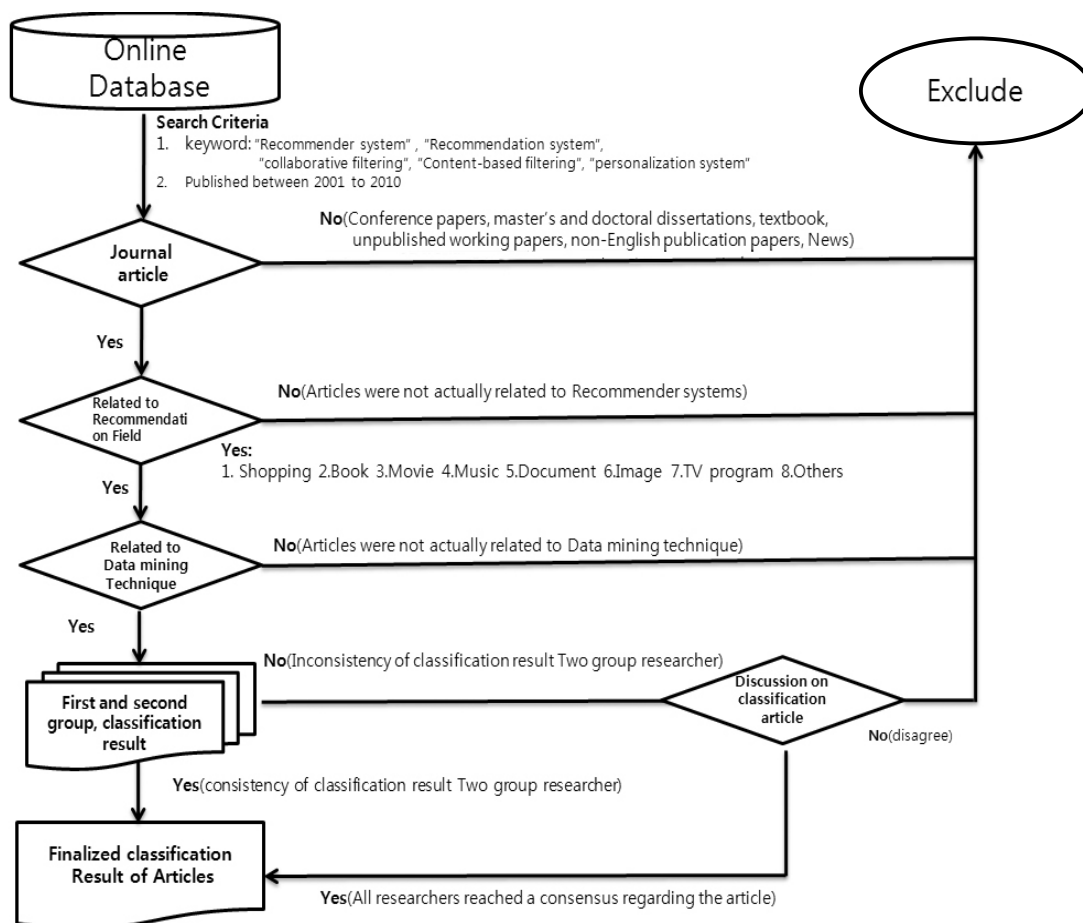
per (first team). And the rest two authors (second team) finally verified the classification results.

The classification process is composed of the following four steps:

- (1) Online data base search.
- (2) Initial classification by one of the two researchers in the first team.
- (3) Independent verification of classification results by the other one of the first team.

(4) Final verification of classification results discussed by the second team.

In case of disagreement in the classification of the article, we exclude the article. The selected criteria and evaluation framework is shown in <Figure 2>. The set of articles was analyzed by year of publication, by journals in which the articles were published, and by recommendation fields and data mining techniques.



<Figure 2> Selection Criteria and Evaluation Framework

4. Classification of the Articles

We selected a total of 187 articles from 37 journals. According to classification framework, the selected articles were classified. The result of analysis will offer guideline for future research on recommender systems. The details are expressed below.

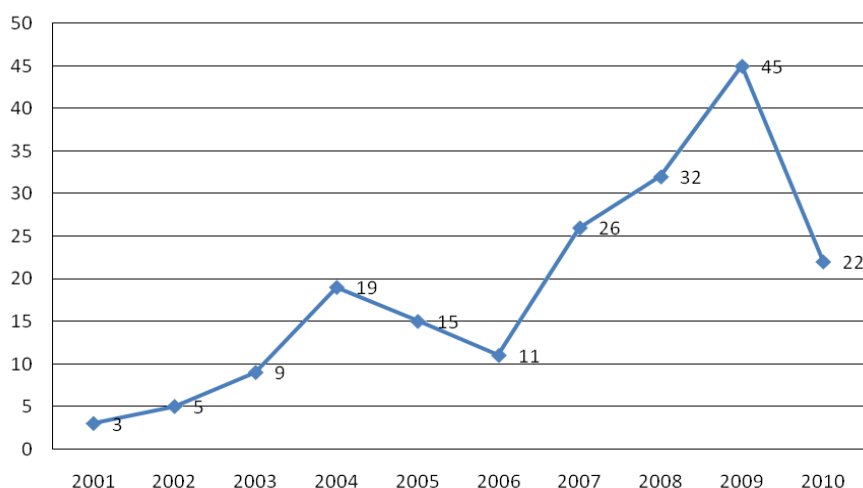
4.1 Distribution of Article by Year of Publication

The distribution of articles by year of publication from 2001 to 2010 is presented in <Figure 3>. It is apparent that publications which are related to recommender systems have steadily increased from 2000 to 2004, while these researches have rapidly increased from 2007 to 2009. Such a rapid increase is guessed as an issue happened in conjunction with recommender systems. Also the decrease of literatures related to recommender

systems appearing in 2010 is judged to be under research since we searched articles on recommender systems on April in 2010, and it is anticipated that literatures in 2010 will be increased more than those in 2009 since 26 articles were completed in the first quarter of 2010.

4.2 Distribution of Articles by Journals in which the Articles were Published

Our results contain a total of 37 different journals. Distribution of articles by journal is shown in <Table 1>. The majority of articles are published in the Expert Systems with Applications, which focuses on the knowledge of the application of expert and intelligent system industry, government and university worldwide. The journal contains more than 35% (68 out of 187 articles, 36.36%) of the total number of articles. The IEEE Intelligent system (20 out of 187 articles, 10.70%), and the Decision Support System



<Figure 3> Distribution of Articles by Year of Publication

(12 out of 187 articles, 6.42%) had the second and third biggest percentage of recommender systems-related articles among the journals.

<Table 1> Distribution of Articles by Journals in which the Articles were Published

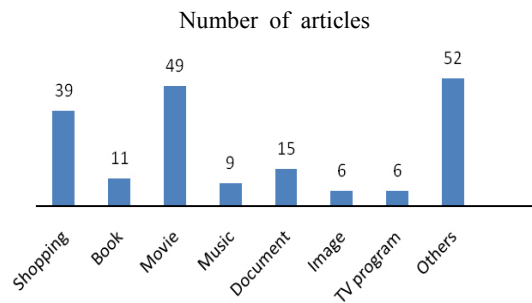
Journal	No. of articles
Expert Systems with Applications	68
IEEE, Intelligent Systems	20
Decision Support Systems	12
ACM Transactions on Information Systems	11
Knowledge-Based Systems	10
IEEE Transactions on Consumer Electronics,	7
International Journal of Electronic Commerce	7
IEEE, Internet Computing,	7
IEEE Transactions on Knowledge and Data Engineering,	5
Electronic Commerce Research and Applications	4

4.3 Distribution of Articles by Recommendation Fields and Data Mining Techniques

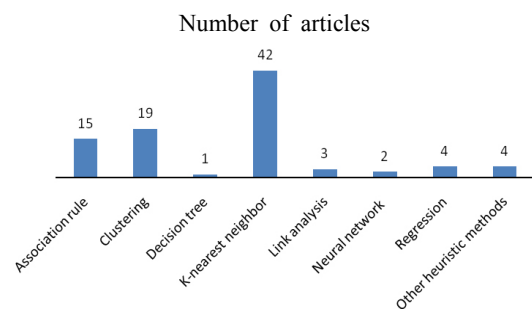
Distribution of articles by recommendation field is shown in <Figure 4>. The most of the articles are related to movie (49 out of 187 articles, 26.2%) and shopping (39 out of 187 articles, 20.9%). Because recommender systems in movie and shopping areas have more abundance of practical applications than others, it is interpreted that many articles were published while the fewest of the articles are related to image and TV program field (6 out of 187 articles, 3.2%). In particular, as the data of MovieLens are freely accessed, many recommendation methodologies

are suggested and evaluated with the MovieLens data. That might explain why the recommender system researches in movie field are more than those in other fields.

Distribution of articles by recommendation fields and journals is shown in <Table 2>. Among the recommendation fields and journals, the Expert Systems with Applications contained most of recommendation field.



<Figure 4> Distribution of Articles by Recommendation Fields



<Figure 5> Distribution of Articles by Data Mining Techniques

Distribution of articles by recommendation fields and data mining techniques are shown in <Table 3> and <Figure 5>. Among data mining techniques, k-NN (k-nearest neighbor) is used in

the most of recommendation fields. Because CF system is one of the most successful methodologies in recommender systems, k-NN is a popular type of CF, and has been applied in the most of the recommendation fields.

<Table 2> Distribution of Articles by Recommendation Fields and Journals

Field	Journal	No. of articles
Book	ACM Transactions on Information Systems	2
	Decision Support Systems	2
	IEEE, Internet Computing,	2
Document	Expert Systems with Applications	4
	IEEE, Intelligent Systems	3
	Decision Support Systems	2
Image	Expert Systems with Applications	4
Movie	Expert Systems with Applications	21
	ACM Transactions on Information Systems	6
	International Journal of Electronic Commerce	4
Music	IEEE Transactions on Audio, Speech, and Language Processing,	3
	Expert Systems with Applications	2
Others	Expert Systems with Applications	22
	IEEE, Intelligent Systems,	7
Shopping	Expert Systems with Applications	13
	IEEE, Intelligent Systems	5
	Decision Support Systems	3
TV program	IEEE Transactions on Consumer Electronics	3

Note) The selected journals contain at least two articles by each recommendation field.

<Table 3> Distribution of articles by Recommendation Fields and Data Mining Techniques

Field	Data mining technique	No. of techniques
Book	k-NN	1
	Regression	1
	Link analysis	1
Document	k-NN	3
	Clustering	4
	Neural network	2
Image	k-NN	3
	Other heuristic methods	1
	Link analysis	1
Movie	k-NN	20
	Clustering	7
	Association rule	4
Music	k-NN	2
	Association rule	1
	Clustering	1
Others	Clustering	4
	k-NN	3
	Regression	3
Shopping	k-NN	10
	Association rule	10
	Clustering	3
TV program	Other heuristic methods	3
	Decision tree	1
	Link analysis	1

5. Conclusion and Future Work

Recommender systems have attracted the attention of academics and practitioners. In this paper, we have identified 187 articles on recommender systems, which are published from 2001 to 2010 to understand the trend of recommender systems-related research and to provide practitioners and researchers with insight and future direction on

recommender systems. The results represented in this paper have several significant implications:

- (1) Based on previous publication rates, the interest in the recommender system related research will grow significantly in the future.
- (2) 49 articles are related to movie recommendation whereas image and TV program recommendation are identified in only 6 articles. Therefore, more researches are required to be studied for image and TV program recommendation. This result has been caused by the easy use of MovieLens data set. So, it looks to be necessary to prepare data set of other fields.
- (3) Recently, social network analysis has been used in the various applications. However studies on recommender systems using social network analysis are deficient still now. Henceforth, we expect that new recommendation approaches using social network analysis will be developed. So, it will be an interesting further research area to evaluate the recommendation system researches using social method analysis.
- (4) Our classification model will provide the practitioner and academic with guideline for future researches on recommender systems.

However our research have the following limitations: First, as the limitation of time and human beings, we only surveyed articles published from 2001 to 2010, in which searching is based on 125 journals of the MIS Journal Rankings. Therefore, if the research is extended to

cover other journals such as computer science, marketing, and so on, the results might be different. Second, our finding is based on articles which were selected from only academic journals. But if the articles in conference would be included, the result will give more diverse meanings. Third, our study was conducted based on a keyword search of “Recommender system”, “Recommendation system”, “Personalization system”, “Collaborative filtering” and “Contents filtering”. Besides these 5 keywords, we didn’t search all the keywords including “Hybrid Filtering” and so on. Finally, we didn’t include non-English paper in study.

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Abstract

추천시스템관련 학술논문 분석 및 분류*

박득희** · 김혜경** · 최일영** · 김재경**

1990년대 중반에 협업 필터링의 출현으로 인하여 추천시스템에 관련된 연구가 늘어나게 되었다. 협업 필터링의 출현 이후 내용 기반 필터링, 협업 필터링과 내용 기반 필터링이 혼합된 하이브리드 필터링 등 새로운 기법들이 출현함으로써 2000년대에는 추천시스템의 연구가 눈에 띄게 증가하였다. 하지만 현재까지 추천시스템에 관련된 문헌들에 대한 리뷰와 분류가 체계적으로 되어있지 않다. 이와 같은 문제에 대한 해결방안으로써, 본 연구에서는 2001년부터 2010년도까지의 추천시스템에 관련된 문헌들 중 MIS Journal Ranking의 125개의 저널에서 추천시스템(Recommender system, Recommendation system), 협업 필터링(Collaborative Filtering), 내용 기반 필터링(Content based Filtering), 개인화 시스템(Personalized system) 등의 5가지 키워드로 제한하여 조사하였다. 총 37개의 저널에서 논문을 검색하였으며, 검색되어진 논문을 분석한 결과 추천시스템과 관련이 없는 논문을 제외한 총 187개의 논문을 선정하여 분석하였다. 이 연구에서는 그러나 컨퍼런스 논문, 석사, 박사 학위 논문, 영어로 작성되지 않은 논문, 완성되지 않은 논문 등은 제외하였다.

본 연구에서는 187개의 논문을 분석하여 2001년부터 2010년까지의 각각의 년도 별 추천시스템의 연구에 대한 동향 분석, Journal별 추천시스템의 게재 분류, 추천시스템 어플리케이션의 사용 분야(책, 문서, 이미지, 영화, 음악, 쇼핑, TV 프로그램, 기타)별 분류 및 분석, 추천시스템에 사용된 데이터마이닝 기술(연관 규칙, 군집화, 의사 결정나무, 최근접 이웃 기법, 링크 분석 기법, 신경망, 회귀분석, 휴리스틱 기법)별 분류 및 분석을 수행하였다.

따라서 본 연구에서 제안한 각각의 분류 및 분석 결과들을 통하여 현재까지 추천시스템의 연구에 대한 연구 동향을 파악 할 수 있었으며, 분석결과를 통해 추천시스템에 관심이 있는 연구자와 전문가에게 미래의 추천시스템의 연구에 대한 가이드라인을 제시 할 수 있을 것이라고 기대한다.

Keywords : 추천시스템, 문헌 연구, 데이터마이닝 기법, 분류

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저 자 소개



박득희

안양대학교에서 통계학 학사를 취득하였으며, 경희대학교 일반대학원 경영학과에서 MIS 전공 석사과정에 BK21사업 장학생으로 재학 중이다. 주요 관심분야로는 데이터 마이닝, 추천시스템, 사회 네트워크 분석, CRM 등이다. 한국IT서비스학회지에 논문을 게재하였으며, 2011년 2월에는 싱가포르에서 열린 2011 International Conference on Social Science and Humanity (ICSSH 2011) 국제학술대회에서 논문을 발표하였다.



김혜경

현재 경희대학교 경영대학에서 연구교수로 재직하고 있다. 경희대학교 물리학과에서 학사, 일반대학원 경영학과에서 MIS 전공으로 석사학위와 박사학위를 취득하였으며, University of Texas at Dallas에서 Post Doc.과정을 역임하였다. 주요 관심분야는 고객관계관리, 상품추천시스템, 사회 네트워크 분석, 복잡계 시스템 등이며, IEEE Transactions on Systems, Man, and Cybernetics (Part A), IEEE Transactions on Services Computing, International Journal of Information Management, Electronic Commerce Research and Applications, Expert Systems, Expert Systems With Applications, 등 다수의 국제학술지에 관련논문을 게재하였으며, Workshop on Information Technologies and Systems, Workshop on eBusiness 등 다수의 국제학술대회에서 논문을 발표하였다.



최일영

경희대학교에서 경제학 학사, 동 대학원에서 MIS전공으로 경영학과에서 MIS 전공으로 석사학위를 취득하였다. (주)케논코리아에서 비즈니스 솔루션 대리료 3년간 근무 후 경희대학교 박사과정에 BK21사업 전일제 장학생으로 진학하여 2011년 박사학위를 취득하였다. 주요 관심분야로는 CRM, 데이터마이닝, 그린 비즈니스/IT, 사회 네트워크 분석 등이다. 경영과학회지, 경영과학, 정보관리학회지, 지능정보연구, Information Systems Review 등에 논문을 게재하였다.



김재경

서울대학교에서 산업공학 학사, 한국과학기술원에서 경영정보시스템 전공으로 석사 및 박사학위를 취득하였으며 현재 경희대학교 경영대학 교수 및 BK21 사업단장으로 재직하고 있다. 미국 미네소타 주립대학교, 그리고 텍사스 주립대학교(달라스)에서 교환교수를 역임하였다. 주요 관심분야로는 비즈니스 인텔리전스, 추천시스템, 유비쿼터스 서비스, 사회 네트워크 분석 등이다.