Journal of Network Communications and Emerging Technologies (JNCET) www.jncet.org
Volume 5, Special Issue 2, December (2015)

Web Recommendation Techniques – Status, Issues and Challenges

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Abstract – Past two decades has seen an extensive research efforts directed towards the development of Recommendation Systems (RS) and Web Personalization (WP). One of the earliest techniques proposed in mid 1990s is of collaborative filtering which aims at suggesting the new items to the user based on ratings by other similar users. This has been later modified and given a name of recommendation systems. Later many techniques have been proposed in literature to recommend items to the users. Many authors have contributed to review the existing literature on these techniques. Some of these are limited in their coverage while others are specific to application areas. This study aims at reviewing the existing literature on Recommendation Techniques (RT) available so far along with the advantages and disadvantages of these techniques. Further, the key issues existing in RT is also discussed and future direction of research efforts to be undertaken is given. This study would be helpful to the researchers, academicians and students working in the area of RS.

Index Terms – Content, Collaborative, Case Based, Hybrid, Intelligent, Recommendation Techniques

This paper is presented at International Conference on Recent Trends in Computer and information Technology Research on 25th & 26th September (2015) conducted by B. S. Anangpuria Institute of Technology & Management, Village-Alampur, Ballabgarh-Sohna Road, Faridabad.

1. INTRODUCTION

RS aims at providing the personalized web experience based on users desires and needs. WP is defined as any set of actions that can tailor the web experience for a particular user or set of users [44]. RS have been applied in many applications like recommendations in tourism, e-learning, e-commerce, news articles, movie, software engineering, food, event etc. [3]. RT is an important part of RS that aims to automatically suggest the web user a set of possible interesting items or web pages. These techniques are based on use of data mining, web mining, text processing and other statistical methods.

Past two decades has seen an extensive research efforts directed towards the development of RS and WP. One of the earliest techniques proposed in mid 1990s is of collaborative filtering which aims at suggesting the new items to user based on ratings by other similar users [36]. This has been later modified and given a name of RS. Later many techniques have been proposed in literature to recommend items to the users. Many authors have contributed to review the existing literature on these techniques. An extensive analysis of distribution of work done in the RS from 2001 to 2010 in various journals covering a number of data mining techniques along with application areas of RS has been given by [12]. A detailed review of ten papers on various recommendation techniques in different domain along with their advantages, disadvantages, relevancy and complexity has been done by [31]. However, their works needs to cover more research contributions at various stages of each recommendation technique. A detailed study on the state of art on the usability of semantic web and intelligent software agents in WP has been given by [3]. But they have not studied RT in detail. So,

it is desirable to have a comprehensive detailed review on various RT along with their strengths and limitations. This motivated us to undertake the task of reviewing RT for RS. The main objectives of this review are:

- To categorize and review research relevant for RT.
- To summarize articles based on machine learning algorithm used in RT.
- To derive suggestions for recommender system re-searchers based on the literature review.

Rest of the paper is organized as follows: section 2 deals with content based filtering approaches, section 3 provides a detailed study of work done in area of collaborative filtering , section 4 covers application of case based reasoning in RS, section 5 and 6 covers the hybrid and intelligent techniques. A detailed comparison of various machine learning approaches used in each RT is discussed in section 7 and conclusions and future research directions are detailed in section 8.

2. CONTENT BASED FILTERING APPROACHES

Content Based Filtering (CBF) approaches aim at generating recommendations based on user profile and item description and contents. This approach uses the items represented as a row in database table. However, the data in web pages is either semi-structured or unstructured. So, this data is converted to structured data by applying text processing techniques like stop word removal and stemming. Each word is considered as a dimension or feature which is used to represent the web page or item. User profile is created by observing his behavior in past with the system both explicitly and implicitly. Various machine learning approaches are then applied on this data to model the user's likes or dislikes. Some of issues related to these approaches are;

- **Limited Content Analysis (LCA):** Since CBF is purely based on the features of the content instead of ratings, an RS cannot know if the recommended service is good or bad. This can be the case if two different items have the same set of features.
- **Overspecialization Problem (OP)** means that an RS only recommends such items that are too similar with the existing item.
- **New User Problem (NUP)** means difficulty to recommend anything for a new user in the absence of any prior information.

Some of existing work in CBF is discussed in this section. A CBF based approach for recommending articles for home improvement has been proposed by [33]. They have used relevance feedback mechanism for learning user model. An application of decision trees for personalizing advertisements on web pages has been described by [23]. [19] have evaluated a number of content-based recommendation models that make use of user and item profiles described in terms of weighted lists of social tags. This work may be extended for other techniques also. A web recommender have been proposed by [2] that models user habits and behaviors by constructing a knowledge base using temporal web access patterns as input. Fuzzy logic based knowledge representation is used to provide timely personalized recommendations to the user. The approach may be further extended for mobile devices and by incorporating the information from social media. A system, Farseer, has been proposed by [15] for personalized real-time content recommendation and delivery in online social communities. Both online and offline models are used to recommend newly generated content items to individual users in real time using interest based clustering and cluster based con-tent recommendation. The work may be extended to large and diverse social communities. Next section describes the research undertaken in the area of collaborative filtering approaches.

3. COLLABORATIVE FILTERING APPROACHES

Collaborative Filtering (CF) is one of oldest and effective approach used in e-commerce which is based on considering other people's interest while generating recommendation. With passage of time this technique has been applied successfully for recommending web pages and news articles also. CF offers various personalization tasks like finding new items, finding similar users, opinion on new item, assisting in finding domain specific tasks etc. CF approach does not require any information regarding the contents of the item for generating recommendations. There are two approaches used for CF namely memory based and model based. Memory based algorithms requires all ratings, items, and users be stored in memory and model-based algorithms that periodically create a summary of ratings patterns offline [8]. Memory based approach is more accurate while model based approach is more scalable. Some of issues related to these approaches are;

Scalability Problem (SP): Since the number of users and item is very large it is computationally very expensive to store them in memory in real situations.

Cold Start Problem (CSP): Another important issue in CF based techniques is to generate recommendation in case of new user with no ratings or a new item which is not yet rated by anyone.

Sparsity Problem (SPP): User ratings are often stored as user-item matrix and item-user matrix. This data is often sparse in real situations. So, we have two users with only a

few co-rated items this may then give high similarity score and may dominate the actual neighbor of the user.

Shilling Effect (SE): This refers to biased or false rating given to some particular items e.g. giving excellent rating to personal items and low ratings to competitors [34].

Serendipity: This refers to the problem related to not recommending new and interesting items to the user.

Memory based approaches are very expensive in terms of time and space complexity. So many researchers have put their efforts in reducing the processing speed and memory requirements by applying sub-sampling and clustering. A technique has been proposed by [5] based on association rule mining and clustering to identify the user interest automatically and then applying it to find similar users for collaborative filtering. This approach can be further extended by using agents at client side. An approach to consider only top n neighbor and thus reducing the time and memory requirements has been proposed by [8]. But this technique was found difficult in predicting for target item not in nearest neighbor. A framework based on association rule mining for generating effective and accurate recommendations has been proposed by [6]. They have proposed a data structure for storing frequent item set and used this data structure to generate recommendations from item sets without the need to first generate association rules. [33] have proposed a fuzzy approximate reasoning approach for identifying the degree of similarity between current session and nearest neighbor and the sessions which similar to more than one profile and none. But, the approach still needs to be tested in real environment. An approach which is more accurate as well as scalable has been proposed by [9]. The fuzzy nearest prototype of the active user is used to find a group of like-minded users within which a memory based search is carried out. The group is small compared to the entire set, thus making the technique scalable.

An approach had been proposed by [28] to smooth the sparse rating matrix in case of CF technique by using fuzzy kernel method. The proposed system uses fuzzy based similarity, to find the interlinked similar users. A model based approach has been proposed by [46] using predictive bilinear regression models to provide accurate personalized recommendations of new items for both existing and new users. This approach is more scalable with less computational overhead. The proposed approach may be further extended for personalized search as well. [17] had addressed the scalability problem in model based approach by using entropy based similarity measure at two levels in user session for considering only trustworthy neighbors in CF. A particle swarm intelligence based clustering approach has been proposed by [39] for identifying similar users. This approach is more efficient and accurate but still needs to be evaluated with benchmark dataset on web usage mining.

An SVD based CF which aims to solve the cold-start problem by generating a lower rank approximation of user-item matrix and removing noise from data is given by [42]. But, this approach needs to be validated in real environment. Shilling problem is addressed by [10]. They have proposed a framework based on boosted item based collaborative filtering followed by association rule mining to solve the problem of sparse data collected from user profiles. It also helps in generating more reliable recommendations. This approach is currently being applied to item-user matrix and may be extended to user-item based matrix. [22] has designed a new similarity metrics which provide greater precision in the results offered to users who have cast few votes based on neural learning. This algorithm may be extended by incorporating the automatic selection of features. Cluster ensembles have applied by [11] to CF in RS. Self-organizing maps (SOM) and k-means were used for clustering and three ensemble methods namely the cluster-based similarity partitioning algorithm (CSPA), hyper graph partitioning algorithm (HGPA), and majority voting are used. The work may be extended by incorporating more clustering methods with their evaluation on more data sets.

A special cluster skipping inverted index structure has been proposed by [18] to search each user in the cluster rather than using cluster representative for generating recommendations. This improves the accuracy of RS while maintaining the accuracy. [47] has proposed a CF based framework for recommending contents on mobile to ad-dress CS problem using classification and association rule mining. An approach has proposed by [4] to solve the CS problem. They have proposed a solution which classifies the users according to demography and preferences. A new user is classified in any of the existing classes and then similar users are found from that class only and then recommendations are generated. Social network information in RS has been used by [49]. Missing values in user-item matrix is calculated using rating records by user and his friends. Suitable friend group is identified using bi-clustering algorithm. An unsupervised learning approach for handle the scalability problem is taken up by [40]. User profile is matched with one of the partitions generated using k-nearest neighbor algorithm. Particles warm optimization (PSO) is used to assign weights to various alpha estimates and global neighbors of the user are also found for making recommendations.

Accuracy of CF systems can be improved considerably by adding multi-criterion ratings. Multi-criterion based modified CF algorithm has been proposed by [29]. Clustering is used to identify the customer segments and preferences for each of these clusters are identified. Regression models are used to assign weights to the different quality factors. The approach may be tested with additional datasets in future. The work may be extended by incorporating spatial and temporal aspects for generating recommendations. Next section discusses the case based filtering approaches.

4. CASE BASED FILTERING APPROACHES

Case Based Filtering approaches use case based reasoning for generating recommendations. A database of past cases has been maintained. Similar past cases has been retrieved and matched with the user's current preferences and behaviour. Case Based Recommender Systems (CBRS) generally follows the classical cycle of retrieve, reuse, revise, review and retain. A case based approach for recommending restaurants have been proposed by [37]. . This approach has been used by [13] for travel recommendations. [24] had proposed a case intelligence base approach for personalized recommendations in the field of e-commerce. The proposed solution uses existing past similar cases for generating recommendations and thereby solving the problem of personalized knowledge acquisition.

5. HYBRID RECOMMENDER SYSTEMS

A hybrid strategy had been proposed by [7] to solve CS and SP in CF systems by incorporating the CBF approach. FilterBots were used which automatically scans the con-tents of the UseNet group documents for assigning rating to the new items and users of the system. This approach helped in improving the coverage and accuracy of a CF system. This approach may be improved by providing the appropriate mechanism for selection among a number of software agents and trust between agents and users.

A hybrid framework by considering the site structure with web usage mining has been given by [36]. They have found that frequent item set is more suitable in case of highly interconnected site and sequence mining in case of less connected website. The proposed model selects the model on fly automatically to generate recommendation. This approach is found better than any sequential or non-sequential approach. In another study [21] have proposed a hybrid approach combining past user-tem ratings and attributes of users and items for learning prediction function. This approach was useful in solving the CS problem.

A hybridization of CB and CF based RS has been proposed by [41]. The weights of different attributes of an item are computed from the collaborative social network using regression analysis. In future, the work may be eval-uated by humans with other regression techniques.

Another hybrid RS proposed by [25] was based on web page clustering and web usage mining. Relevant concepts from web pages have been identified by selecting only a few features from identified important sentences. These pages are clustered into different themes. This approach may be further extended by incorporating semantic knowledge with web usage mining and clustering for generating intelligent recommendations.

A hybrid approach has been proposed by [43] based on weighted association rule mined from the usage data. The web pages are clustered offline by applying k-means clustering to the pre-processed documents and web structure has been used to rank the documents in the candidate set from recommendation engine. Top n documents are then recommended to the user. This approach may be evaluated with other clustering techniques.

A survey of various approaches for recommenders system along with their limitation has been done by [43]. They have proposed a hybrid recommendation approach combining utility-based filtering and knowledge-based filtering for calculating utility function automatically. This approach overcomes the problem of calculating utility function manually. CF and CBF approaches have been combined by calculating the user similarity based on implicit information collected from discussion group [1]. Association rules mining technique is applied to discover the similar users, and then the related posts are recommended to them using WordNet. This work may be extended by ranking the discovered association rules and assigning them weights. Next section describes the intelligent recommendation techniques.

6. INTELLIGENT RECOMMENDATION TECHNIQUES

Normal web usage logs have been extended to semantics based C-logs by [27]. These semantically enhanced C-logs are then used as input for usage mining and thus generating better recommendations. [26] have proposed a semantic based hybrid technique considering navigational pattern by similar users along with the semantic annotation of web pages and creation of c-logs. They augmented the users' behavior with content-based semantics expressed using domain ontology terms. This approach needs to be tested in real environment.
Fuzzy cognitive personalized agents have been proposed by [10] to assist the customers in selecting the items of their

interest. The proposed agent is capable of learning the user's preferences and making inferences automatically. The agent also learns from past user behavior and generates recommendations by combining, user's & group preferences with expert opinion. But this approach still needs to be evaluated and implemented.

A multi-agent approach for ontology based recommendation system has been given by [35]. This approach aims at solving many problems prevailing in RS such as SP, NUP, OP and LCA by using agents for handling each of these. This approach may be further extended by developing more refined algorithms for filtering agents. An intelligent technique for recommendation by using information from social networking web sites like Facebook and Twitter with ontological user profiles has been proposed by [16]. Friend of a Friend (FOAF) profile is automatically generated from Facebook and Twitter and used in combination with CB and CF techniques to generate recommendations. This approach aims to solve the CS problem as well as generates more accurate recommendations. But the implementation of the proposed work is still not done in real environment. [20] have proposed a generic semantic network based cross domain recommendation system. This framework uses places of interests and music together by linking the concepts between these two domains by using weighted acyclic graphs. An intelligent recommendation technique using semantics for more accurate and diverse suggestions and by using spreading activation and semantic associations has been proposed by [48]. This approach may be extended by employing software agents for automating the various tasks. Most of the CF based RS do not incorporate domain ontology during recommendations. One important reason for not including domain ontology is the automatic construction of ontology. A new approach for creating the domain knowledge automatically and the utilizing this ontology to cluster the similar users from web usage data for recommending web pages to the users have been proposed by [32]. Next section concludes the study by providing a detailed comparison of various machine learning approaches used in each RT along future direction of research in RT.

7. ANALYSIS OF EXISTING RT

This section gives a detailed comparison of discussed RT is provided in the light of their ability to solve inherent problems and machine learning approach. This comparison is given in Table 1.

S.No.	Reference	Capabilities	Machine Learning Approach Used
Content Based Filtering			
1.	[38]	Dynamic user modelling	None of the approach is used. Only various similarity measures are used.
2.	[23]	Recommending advertisements	Decision Trees
3.	[19]	Implicit user interests identification using folksonomy	None of the approach is used. Only various similarity measures are used.
4.	[2]	Timely Recommendations	Fuzzy Logic
5.	[15]	Real-time content recommendation	Interest Based User Clustering
Collaborative Filtering Techniques			
6	[5]	Automatic Identification of Users interests	Association Rule Mining and Clustering
7.	[8]	Scalability and efficiency (Selecting top n items)	K-nearest neighbour
8.	[6]	Scalability and efficiency	Association Rule Mining
9.	[33]	More Coverage	Fuzzy Approximate Reasoning
10.	[9]	More accurate and scalable	Fuzzy Logic
11.	[28]	Handling SP	Fuzzy Clustering
12.	[46]	Handling CS and SP	Predictive Bilinear Models

13.	[17]	Scalability Problem	Entropy Based Similarity Measure
14.	[39]	Efficiency and Accuracy	Particle Swarm Based Clustering
15	[42]	Cold Start Problem	Singular Value Decomposition
16	[10]	Sparsity of user and item matrix Shilling Effect	Association Rule Mining
17	[22]	Handling CS	Optimized Neural Learning
18	[12]	Better Accuracy	Self-organizing Map and k-means and ensemble methods
19	[18]	Handling low accuracy in cluster based CF	None of the approach is used.
20	[47]	Handling CS and SP	Classification and Association Rule Mining
21	[4]	Handling CS Problem	C 4.5 (Decision Tree Algorithm)
22	[40]	Enhancing scalability and accuracy	Unsupervised Learning and Particle Swarm Optimization
23	[49]	Improved Accuracy of Predictions	Bi-Clustering
24	[29]	Better Predictive Accuracy	Clustering
Case Based Filtering (CBF) Approaches			
25	[37]	Restaurants Recommendation	Case Based Reasoning
26	[14]	Travel Recommendations	Case Based Reasoning
27	[24]	Quality of Recommendation	Case Based Reasoning
Hybrid Recommender Systems			
28	[7]	Improved Coverage and Accuracy	k-nearest neighbour and text analysis techniques
29	[30]	Better Precision and Coverage	Association Rule mining, Sequential Pattern, Contiguous Sequential Pattern
30	[21]	Better Accuracy	NA
31	[41]	Better Accuracy	Linear Regression Equations
32	[25]	Better Accuracy	Clustering
33	[43]	Accurate Recommendations	Association Rule Mining and Clustering
34	[45]	More accurate and intelligent	-
35	[1]	More Accuracy	Association Rule Mining
Intelligent Recommendation Techniques			
36	[27]	More Accuracy	-
37	[26]	Better Quality of Recommendations	-
38	[11]	Better Quality of Recommendations	Fuzzy Logic
40	[35]	Handling CS, NUP, OP, SP	Apriori Algorithm for

			association rule mining
41	[16]	Handling CS problem and more accurate recommendations	-
42	[20]	Cross domain recommendations	-
43	[48]	Handling OP	Spreading Activation Techniques and Semantic Associations
44	[32]	Better Quality of Recommendations	Clustering

TABLE 1 Machine Learning Approaches Used and Issues Handled by RT

8. CONCLUSION AND FUTURE DIRECTIONS

A detailed review of various recommendation techniques have been presented in the above sections. Analysis of above literature reveals us that CF is the oldest and most widely used RT. Earlier work was limited to the application of k-nearest neighbor technique and was further extended with the application of data mining techniques like clustering, association rule mining, sequence rule mining , classification and hybrid of these techniques. CBF is frequently used in the situations where contents are important in generating recommendation like web pages and news articles etc. Case based, utility based and intelligent semantic based are other RT. Each technique has its own advantages and disadvantages. To overcome the disadvantages of these techniques many hybrid techniques have been proposed.

Although a lot of work has been done, but still there is some work which can be undertaken in the future. Some of future areas of research are:

Agent Based Recommendation Approach: There has been tremendous growth in the applications of semantic and ontology in RT but a little amount of work seems to be available for development of multi-agent systems for RT. These would be of immense use in automating the various tasks involved in RT.

Using Social Media Information in RT: With availability of web 2.0, a number of social network web sites are available like Facebook, Twitter and Linkedin. These websites contains a lot of data about user interests which may be linked with existing techniques for generating more accurate and novel recommendations.

Synergizing with Internet of Things: Internet of Things is an emerging paradigm in ubiquitous computing which aims at generating a lot of data from sensors attached to the things. Again, this data may combine with existing RT for better accuracy. Since the amount of available information is huge, the existing techniques must be modified to handle massive data.

Adding Context Aware Information: The existing techniques should be modified to consider external contextual information like temperature, location, pressure, distance and internal state of the user e.g. emotional state and sentiments.

Big Data Analytics: With the exponential increase in the generated data, RT should be integrated with big data analytics

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