Recommender Systems Challenges and Solutions Survey

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Recommender Systems Challenges and Solutions Survey

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Abstract— **Today's Recommender system is a relatively new area of research in machine learning. The recommender system's main idea is to build relationship between the products, users and make the decision to select the most appropriate product to a specific user. There are four main ways that recommender systems produce a list of recommendations for a user – content-based, Collaborative, Demographic and hybrid filtering. In content-based filtering the model uses specifications of an item in order to recommend additional items with similar properties. Collaborative filtering uses past behavior of the user like items that a user previously viewed or purchased, In summation to any ratings the user gave those items rate and similar conclusions made by other user's items list. To predicts items that the user may find interesting. Demographic filtering is view user profile data like age category, gender, education and living area to find similarities with other profiles to get a new recommender list. Hybrid filtering combines all three filtering techniques. This paper introduces survey about recommendation systems, techniques, challenges the face recommender systems and list some research papers solve these challenges.**

Keywords-; Recommender system , Bigdata , content-based filtering , collaborative filtering ,hybrid filtering,machine learning.

I. INTRODUCTION

Recommender systems are playing an important role to help e-commerce growing in many applications at WWW. Also, a recommender system is one of the most important research areas today's because it helps users to find their interest in the internet [1].

Many products are being purchased online, and there is increasing customer demand for a large number of items available on websites to be filtered so that specific item can be more easily founded according to their actually interest[2].

Recommender systems used to predict the rating that the user will give to an item if this the first time to see on the site by using information filtering systems from the user's rating list history on the site or by finding the item's similarity specification or by finding the common interests using demographic information from their profile [1].

List of sites using a recommender system

1. Movie recommendation [net flix]
2. Book recommendation [Amazon]
3. Music recommendations [pendura]
4. News recommendation [Yahoo]

Data mining is one of the important analysis techniques used in RS. The data mining methods that are most commonly used in RS: classification, clustering and association rule discovery [3].

Recommender systems have different types of filtering such as (Collaborative, content-based, and hybrid) to make an effective recommendation engine. If you buy an item from the site you will be recommended more items based on the content item specifications you bought [4]. For example, the book you bought you will be recommended by the system the same book topics or more books published by the same authors.

Benefits for business while using recommender systems:

Revenue—past years, many researchers have studied and generate many algorithms to learn increasing rate for an online customer like Amazon site. Also, These algorithms study the difference between shopping online sites with others using recommender systems for items to increase revenue by increasing the number of sales.

Client Satisfaction— many times customers tend to expect to see near similar product recommendation from their last browsing search on the site. Mainly because they believe they will get more serious chances for better products. When they leave the situation and get back afterward; it would assist if their browsing data from the previous shopping or viewing product list. This could further facilitate and guide their e-Commerce activities, similar two experienced assistants. This case of client satisfaction contributes to client retention.

Personalization—we often get recommendations from our friends. They recognize what we like better than anyone else. This is the only reason they are adept at recommending things and is what recommendation systems try to model. You can utilize the data collected indirectly to improve your website's overall services and assure that they are suitable according to a user's preference.

Discovery—people need to be recommended items they would like or prefer, and when they find a web page for shopping or movie, songs, etc. meet their hopes they bound to visit this site again.

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Provide Reports—is an integral piece of a personalization scheme. Making the client accurate and up to the minute, reporting allows him to make strong conclusions about his site and the management of a movement. Founded on these reports clients can get offers for slow-moving products in order to make a drive in sales.

Now days, all the world move to build techniques and software used big data to handle rapidly increasing in data size [5]. Big data need to match and join output results between tables in a database with high performance. Some techniques like map reduce[6], hive[7], spark, etc. And how to join results between different queries. All these techniques will affect on recommendation system future.

In this paper, we focus on discussing recommender systems techniques widely used today in this field: Content-based recommendations, Collaborative recommendations, Demographic recommendations and Hybrid Approaches and data mining methods used in recommender systems. List recommender systems issues and challenges and how to overcome these challenges and finally we present my research paper solve many challenges in recommender system in last year's.

The rest of this paper is organized as follows: recommender system techniques in section II. Recommender system research challenges in section III. . A literature review of recommender system techniques described in detail in Section IV. Finally, a conclusion is given in Section V.

II. RECOMMENDER SYSTEMS TECHNIQUES

Recommender system gain information about the user using different methods and sources to predict which user needs and recommend items according to this analysis processes results [3]. Fig 1 shows the general concept for the recommender system while matching the user profile with other users profile rate for the common items between them and recommend the difference between them [8].Recommender engine software [4] gives a prediction about what we might like to buy, listen or watch based on three techniques:

- Content-based recommendations
- Collaborative recommendations
- Demographic recommendations
- Hybrid Approaches.

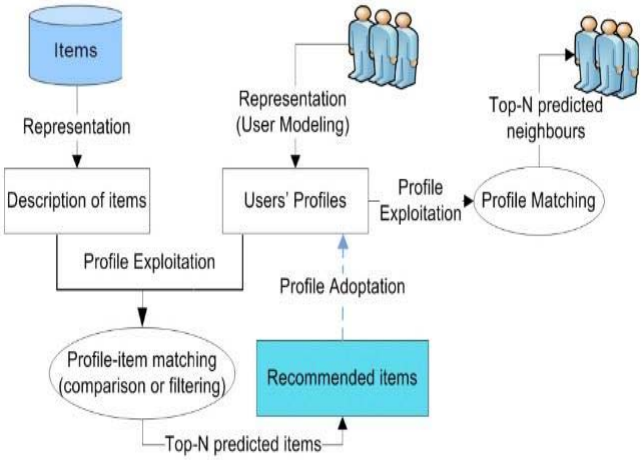

Figure 1. General Concept of Recommender Systems [8].

A. *Content-based recommendations*

Content-based filtering methods are grounded on a description of the item and a profile of the user's tastes[9]. It also recommends items similar to those which a given user has liked in the item rate list. Indeed, the basic operation performed by a content-based system consists in matching the user basic data like age, gender, location and the rated item list on the site stored in his account with the similar items have a common specification, in order to recommend new items meets his/her interests.

The content-based recommendation process steps :

- *Content analyzer*

When Information has no structure like, text some kind of pre-processing step is required to extract structured relevant information. The primary responsibility of the component is to present the content of items like, documents, Web pages, news, product descriptions, etc. Coming from information sources in a form suited for the following processing steps. Data items are analyzed by feature extraction techniques in order to shift item representation of the original information space to the target one. This agency is the input to the profile learner and filtering component.

- *Profile learner*

This model constructs a user profile by collecting user preference data and tries to generalize this data. Normally, the generalization strategy is realized through machine learning techniques, which are able to understand a good example of user interests, starting from items liked or disliked in the past. For illustration, the PROFILE LEARNER of a Web page recommender can implement a relevance feedback method in which the learning technique combines vectors of positive and negative examples into a prototype vector representing the user profile. Training examples are Web pages on which positive or negative feedback has been provided by the user.

- *Filtering component*

This model uses user data profile to find matching items related to the item list, but new products and present this new item to the user. A recommended list of potentially interesting items.The matching is realized by calculating the cosine similarity between the prototype vector and the item vectors. Figure 2 discusses content based steps [9].

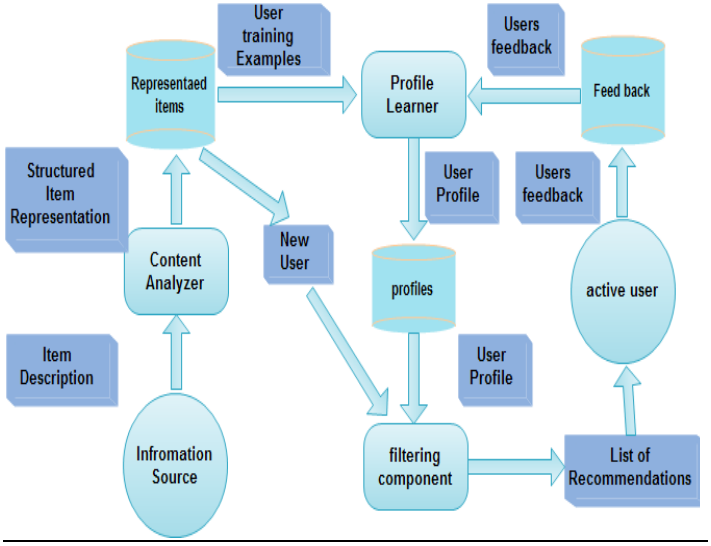

Figure 2. Content based recommendation architecture.

B. *Collaborative recommendations*

Collaborative filtering [9] based systems collect and analyze user's behavioral information in the shape of their feedback, ratings, preferences, and activities. Grounded on this information, then exploits similarities amongst several users or items to predict missing ratings and hence make suitable recommendations. Collaborative filtering (CF) methods produce user-specific recommendations of items based on patterns of ratings or usages like purchases without the demand for data about either items or users.

If person P1 likes item1, item2, item3
If person P2 likes item1, item3, item4
If person P3 likes item1?

And so there is a high chance that person P3 may like item3 because, from the first two statements we knew that person P1, P2, P3 likes item1.

Figure 3 shows content-based and collaborative filtering recommendation [9].

C. *Demographic recommendations*

This technique of recommendation system used user profile information like age, gender, demographic area, education, interests, and their opinion about rating items and find the common users have similarity rating items and interests of divide users by age group and living area [10].

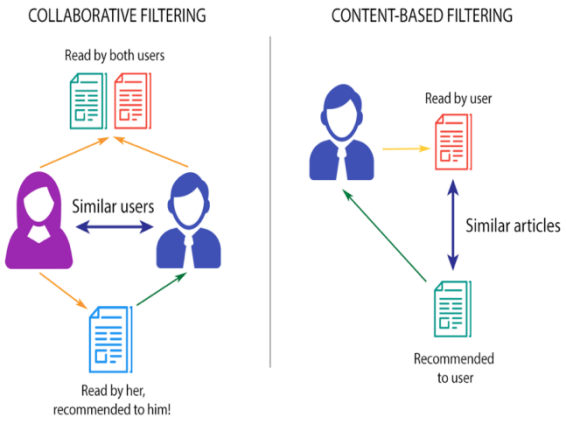

Figure 3. Content-based filtering and Collaborative filtering recommendation.

D. *Hybrid Approaches*

In a hybrid approach, we merge the two recommended techniques content-based and collaborative filtering to get the best advantage and gaining better result and reduce the issues and challenges of these applications [8].

Hybrid approaches have multi-methods [11]:

- Weighted: we combined numerically every recommend component given a different score by the system.
- Switching: the system has multiple choices of different recommendation item to the user and chooses the preferable one according to the user preference.
- Mixed: system recommends multiple different items together at the same time to the user.
- Feature Combination: multiple knowledge sources are merged to build recommendation system features.
- Feature Augmentation: one of the important parts of the next technique is feature augmentation which used to compute a set of features of recommender systems.
- Cascade: Recommender list has a weighted priority item has the high rate appears first, then items with low score descending.
- Meta-level: Is one of the input techniques used to generate and produces some sort of model to the next step of the recommender system algorithm.

Merging these different methods achieve high performance and alleviate problems and challenges rise by using content-based or collaborative filtering only.

E. *Data mining methods used with a recommender system and big data*

A lot of data mining methods used to retrieve valuable business information from huge datasets like big data are very important today, according to rapidly increase in data size. This we gain high performance when the number of users increased and the number of products to in recommender systems[3].

We will discuss some methods used in data mining and recommender systems:

- Outlier detection: we select the values are different than any sample of data is called an outlier.
- Cluster analysis: we make a cluster or group with the sample of data is similar in some way with the others in the same group. This algorithm needs to find the items are similar in specification or users buying similar items in the large data structure. Then matching these results and suggest a new recommended item list to the user.
- Classification: after data are divided into groups by clustering methods. We use classification to make matching from different clusters. This can be done by a decision tree. We define the main node and the following objects in the tree of items or users.
- Association analysis: this method aims to formulate the inference rule by defining the relationship between the data sets. We need to find which product already bought together to identify correlation.
- Regression analysis: is an analysis method used to create models to find the relationship between a dependent variable through multiple independent variables.

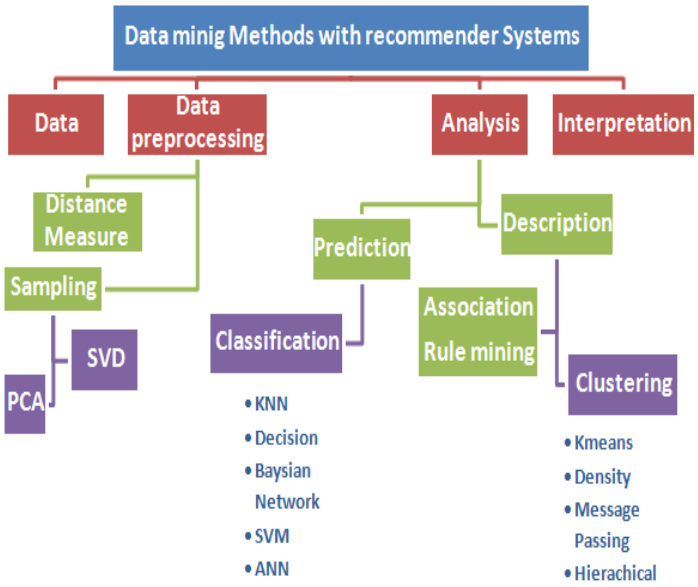

Figure 4. Data mining methods with recommender systems.

F. *Comparison of recommender systems techniques*

In this section we will discuss advantages and disadvantage of recommender systems, techniques shown in table 1.

TABLE 1. List advantages and disadvantages of recommender systems

No	Techniques	Advantage	Disadvantage
1	Content-Based recommendation Filtering	1. The system didn't use the user's data to recommend items. 2. The system has the ability to recommend new items to the users based on similarity between items specifications..	1. We need for analysis and detect all item features to create a recommendation list 2. The system didn't depend on the user's rate to this item so that evaluation of the product quality not included .
2	Collaborative recommendation Filtering	1. The system didn't use demographic information to recommend items 2. The system matches similar items between users. 3. The system able to recommend to the user items outside their preferences and may like this item.	1. The quality of the system depends on the highest rating item list. 2. There's a problem how to recommend items to the new user (cold start problem).
3	Demographic recommendation filtering	1. It is not based on user-item ratings, it gives recommendation before user rated any item.	1. Gathering of demographic data leads to privacy issues. 2. Stability vs. plasticity problem.
4	Hybrid Approaches	1. It's combine all advantage between content based and collaborative filtering. 2. It's based on Content Description and user's evaluation. 3. Solve Over specialization 4. Increase customer satisfaction rate.	1. Suffer from the cold start problem. 2. Early Rater problem for products. 2. Sparsity problem.

III. RECOMMENDER SYSTEM RESEARCH CHALLENGES

The recommender system faces many challenges needed to be investigated and need solutions in this section we will introduce some of them.

Cold Start problem: cold start problem arises mainly when we have a new user to the site or when adding a new item to the system. Firstly, how we would recommend items to the new user we don't know his interests and he didn't rate any item yet. Secondly, to whom we can recommend this new item to others, even no one rate this item neither it's good or bad to be likely by users [4].

Sparsity Problem: Sparsity Problem is an important issue in recommender systems, it's happening when a user has large matrix contain buy items or watch movies or listing for music. Sparsity evolved when the user didn't rate these items. While recommender systems depend on users rating matrix users to recommend to the others [4].

Scalability: Scalability measure the ability of the system to work effectively with high performance while growing in the information. Recommender system needs to recommend items to the users without no change while the number of users increased or the number of items increased too. To achieve this we need more computations and get expensive [1].

Over Specialization Problem: Recommended item to users are based on those already known or defined by user profile only without discovering new items and other available options [4].

Diversity: ensuring that the recommender results span as much as possible your item space, and do not come all from the same cluster [12].

Novelty: recommended items must contain new ones.

Serendipity: beyond novelty, it may also be an objective that some recommended items are not only unheard of, but also surprising user wouldn't have thought before [12].

Privacy: privacy is one of the important challenges in recommender systems. Recommender systems to recommend items matching their interests, we must know some information about the user data. Users need to know which information needed to recommend more preferably items to him, and how it applied[13].

Shilling Attacks: it happens, if a malicious user or competitor enters into a system and starts giving false ratings on some items either to increase the item popularity or to diminish its popularity [8].

Gray Sheep: gray sheep occurs in collaborative filtering systems where the opinions of a user do not equate with any group and consequently, is unable to obtain the benefit of recommendations [8].

IV. LITERATURE REVIEW

In this section we will discuss research papers studying recommender system techniques

Table 2 discusses others papers author names and solutions they used to overcome recommender system challenges and the advantage of every paper.

TABLE 2. Comparison between papers solutions and advantages

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No	Author name	Solutions	Advantages
1	Ghazanfar and Prugel-Bennett [14]	They Combine all recommender system techniques.	It's applied to eliminate redundant records problems with the recommendation system.
2	Qian Wang, Xianhu Yuan, et al. [15]	They combine the item demographic information with searching for a set of neighboring users have the same interests and using a genetic algorithm.	It's improved system scalability.
3	Kumar, Vikas, et al. [16]	They are constructing the two-class structure of binary matrix factorization.	Generate accurate rating matrix completion than the ordinal matrix.
4	Xuelin Zeng et al. [17]	They use spark to implement ALS matrix factorization to be compared by using MLib to generate SGD matrix factorization	Improve efficiency and accuracy.
5	Dianping. Lakshmi et al. [18]	They discover the relationship between different items compared to a user-item rating matrix to see the similarities.	Generate a new recommender item list to this user and solve novelty and diversity problems
6	Sajal Halder et al. [19]	They Propose a movie swarm mining concept This algorithm used two pruning rules and frequent item mining.	Solve the cold start problem.
7	Arpan V Dev et al. [20]	They used map-reduce technique to delete repeated computation overhead.	Gain high performance compared to others ordinal algorithms.
8	Rahul Katarya, Om Prakash Verma [23]	They use fuzzy, a c-means technique for finding a neighborhood for users.	Solve scalability and accuracy of the movie recommender system.
9	Panigrahi, et al. [24]	They proposed a new hybrid algorithm using K-means and Dimensionality reduction techniques such as ALS.	Solve scalability and sparsity problem.

10	M.R. Lee et al. [25]	They propose a hybrid-filtering recommender system using machine learning and Facebook Fan Page data.	Solve cold start and accuracy problems. Increase customer satisfaction.

Ghazanfar and Prugel-Bennett [14] the paper main idea is to use and combine all recommender system techniques and propose a new one named cascading hybrid recommender system. This technique has all advantage of the three techniques: content-based filtering, collaborative filtering and demographic filtering. It's applied to eliminate redundant records problems with the recommendation system.

By Qian Wang, Xianhu Yuan, et al. [15] used a demographic filtering technique to improve system scalability and genetic algorithms to enhance the accuracy of recommender system. They suggest a hybrid user model by combining the item demographic information with searching for a set of neighboring users have the same interests and using a genetic algorithm to determine the weight features in the user model.

Kumar, Vikas, et al. [16] propose a new method to generate an accurate rating matrix completion than the ordinal matrix by constructing the two-class structure of binary matrix factorization.

Xuelin Zeng et al. [17] the paper need to solve the efficiency and accuracy of their model. They propose a technique named by Parallel Latent Group Model (PLGM). They use spark to implement ALS matrix factorization to be compared by using MLib to generate SGD matrix factorization.

Dianping. Lakshmi et al. [18] in this paper they ask to discover the relationship between different items compared to a user-item rating matrix to see the similarities and generate a new recommender item list to this user. Named by item-based collaborative filtering techniques.

Sajal Halder et al. [19] propose a movie swarm mining concept. This utilized to solve the cold start problem to recommend items to the new user an how to manage and increase viewing times for the newest and Famous movies. This algorithm used two pruning rules and frequent item mining.

Arpan V Dev et al. [20] propose an algorithm based on similarity joins between the items and users' interests called extended prefix filtering. This algorithm used the map-reduce technique to delete repeated computation overhead. Big data applications used this technique to gain high performance compared to others ordinal algorithms [21,22].

Rahul Katarya, Om Prakash Verma [23] proposes a hybrid movie recommender system based on collaborative filtering technique. In this paper, to address the scalability and accuracy of the movie recommender system they used fuzzy, a c-means technique for finding a neighborhood for users.

Panigrahi, et al. [24] this paper used to eliminate user-oriented collaborative filtering technique challenges like scalability and sparsity by proposing a new hybrid algorithm using K-means and Dimensionality reduction techniques such as ALS.

M.R. Lee et al. [25] propose a hybrid-filtering recommender system using machine learning and Facebook Fan Page data to achieve the high satisfaction of recommending the item to users and accuracy also, solve cold start problem. In this algorithm to extract from yahoo, movies and Facebook fan pages were used content-based filtering. Also then compare the output results of this algorithm with others recommender system like, Netflix, YouTube, and Amazon.

Li Xie, et al. [26] this paper solves the overcome problems from using ALS algorithms in recommendation systems merged by using the force of big data distributed computing platform of spark. This issue solved by determining the similarity joins between users and items by designing a new loss function. Algorithm Output results computed by comparing the root mean square in different iterations with others existing collaborative filtering techniques.

V. CONCLUSION AND FUTURE WORK

A recommender systems are an important research field today. Rabidly, increasing in data size like a number of items and users over sites raises the big data analysis techniques like Spark, Map-Reduce, Apache Hadoop, etc [27]. Recommender system used to recommend items to the user according to their interests and previous items rate list.In this paper, we discuss four techniques in recommender systems and list advantages and disadvantages for everyone [11]. Discuses recommender system challenges: like, cold start, scalability, privacy, gray sheep, Shilling attack, and novelty, Sparsity, Diversity, over specialization problem. Also, discusses some research topics solutions used to overcome challenges and their advantages. In future work, what about using Big data algorithm like map reduce to increase performance in recommender systems [28].

REFERENCES

[1] Soanpet .Sree Lakshmi and Dr.T.Adi Lakshmi. "Recommendation Systems:Issues and challenges".(IJCSIT) International Journal of Computer Science and Information Technologies, Vol. 5(4) ,2014, pp.5771-5772.

[2] Mohammed FadhelAljunid and Manjaiah D.H."A SURVEY ON RECOMMENDATION SYSTEMS FOR SOCIAL MEDIA USING BIG DATA ANALYTICS". International Journal of Latest Trends in Engineering and Technology, Special Issue (SACAIM 2017), pp.48-58.

[3] P.Priyanga , Dr.A.R.Nadira Banu Kamal. "Methods of Mining the Data from Big Data and Social Networks Based on Recommender System". International Journal of Advanced Networking & Applications (IJANA), vol 8(5) 2017, pp.55-60.

[4] Lalita Sharma and Anju Gera. "A Survey of Recommendation System: Research Challenges". International Journal of Engineering Trends and Technology (IJETT), vol 4(5) 2013, pp.1989-1992.

[5] Radhya Sahal, Mohamed helmy Khafagy, Fatma A. Omara,"Comparative Study of Multi-query Optimization Techniques

using Shared Predicate-based for Big Data", International Journal of Grid and Distributed Computing Vol. 9, No. 5 (2016), pp.229-240

[6] Mina samir shnoda,mohamed helmy khafagy,samah ahmed senbel,"JOMR: Multi-join Optimizer Technique to Enhance Map-Reduce Job",The 9th International Conference on INFOrmatics and Systems (INFOS2014),pp:80-86

[7] Hussien SH. Abdel Azez, Mohamed H. Khafagy & Fatma A. Omara ,"Optimizing Join in HIVE Star Schema Using Key/Facts Indexing", IETE Technical Review, 2017.DOI:10.1080/02564602.2016.1260498

[8] Shah Khusro, Zafar Ali and Irfan Ullah. "Recommender Systems: Issues, Challenges, and Research Opportunities". Information Science and Applications (ICISA) 2016, pp.1179-1189.

[9] Debashis Das, Laxman Sahoo,Sujoy Datta." A Survey on Recommendation System". International Journal of Computer Applications ,vol 160(7), February 2017 , pp.6-10.

[10] Dr. Sarika Jain, Anjali Grover, Praveen Singh Thakur, Sourabh Kumar Choudhary." Trends, Problems And Solutions of Recommender System". International Conference on Computing, Communication and Automation (ICCCA2015) , (2015). pp.955-958.

[11] Yagnesh G. Patel, Vishal P.Patel. "A Survey on Various Techniques of Recommendation System in Web Mining", International Journal of Engineering Development and Research, 2015 IJEDR,Vol 3(4),2015,pp.696-700.

[12] Tanya Maan, Shikha Gupta, Dr. Atul Mishra." A Survey On Recommendation System",international conference on recent innovations in management,engineering,science and technology (RIMEST 2018), (2018).pp:543-549.

[13] Hadeer Mahmoud , Abdelfatah Hegazy , Mohamed H. Khafagy," An approach for big data security based on Hadoop distributed file system", 2018 International Conference on Innovative Trends in Computer Engineering (ITCE), Aswan, 2018, pp. 109-114.

[14] Mustansar Ali Ghazanfar and Adam Prugel-Bennett," A Scalable, Accurate Hybrid Recommender System", 2010 Third International Conference on Knowledge Discovery and Data Mining.

[15] Qian Wang, Xianhu Yuan, Min Sun "Collaborative Filtering Recommendation Algorithm based on Hybrid User Model", FSKD, 2010.

[16] Kumar, Vikas, et al. "Collaborative filtering using multiple binary maximum margin matrix factorizations." Information Sciences 380 (2017): 1-11.

[17] Zeng, Xuelin, et al. "Parallelization of Latent Group Model for Group Recommendation Algorithm." Data Science in Cyberspace (DSC), IEEE International Conference on. IEEE, 2016.

[18] Ponnam, Lakshmi Tharun, et al. "Movie recommender system using item-based collaborative filtering technique." Emerging Trends in Engineering, Technology and Science (ICETETS), International Conference on. IEEE, 2016.

[19] Halder, Sajal, AM Jehad Sarkar, and Young-Koo Lee. "Movie recommendation system based on movie swarm." Cloud and Green Computing (CGC), 2012 Second International Conference on. IEEE, 2012.

[20] Dev, Arpan V., and Anuraj Mohan. "Recommendation system for big data applications based on set similarity of user preferences." Next Generation Intelligent Systems (ICNGIS), International Conference on. IEEE, 2016.

[21] Marwa Hussien Mohamed and Mohamed Helmy Khafagy. "Hash semi cascade join for joining multi-way map reduce." 2015 SAI Intelligent Systems Conference (IntelliSys)(2015): pp.355-361.

[22] Marwa Hussien Mohamed, Mohamed Helmy Khafagy, Mohamed Hasan Ibrahim . "Hash Semi Join Map Reduce to Join Billion Records in a Reasonable Time." Indian Journal of Science and Technology, vol. 11, no. 18, Jan. 2018, pp. 1–9., doi:10.17485/ijst/2018/v11i18/119112.

[23] Katarya, Rahul, and Om Prakash Verma. "A collaborative recommender system enhanced with particle swarm optimization technique." Multimedia Tools and Applications 75.15 (2016): 9225-9239.

[24] Panigrahi, Sasmita, Rakesh Ku Lenka, and Ananya Stitipragyan. "A Hybrid Distributed Collaborative Filtering Recommender Engine Using Apache Spark." Procedia Computer Science 83 (2016): 1000-1006.

[25] Lee, Maria R., Tsung Teng Chen, and Ying Shun Cai. "Amalgamating Social Media Data and Movie Recommendation." Pacific Rim Knowledge Acquisition Workshop. Springer International Publishing, 2016.

[26] Xie, Li, Wenbo Zhou, and Yaosen Li. "Application of Improved Recommendation System Based on Spark Platform in Big Data Analysis." Cybernetics and Information Technologies 16.6 (2016): 245-255.

[27] Radhya Sahal, Mohamed helmy Khafagy, Fatma A. Omara: Exploiting coarse-grained reused-based opportunities in Big Data multi-query optimization.J. Comput. Science ,volume 26,2018,pp: 432-452

[28] Marwa Hussien Mohamed, Mohamed Helmy Khafagy, Mohamed Hasan Ibrahim . "From Two-Way to Multi-Way: A Comparative Study for Map-Reduce Join Algorithms". WSEAS Transactions on Communications, Volume 17, 2018, pp. 129-141.