Recommender System: Techniques, Comparison & Solutions

Divyesh Gohel
Department of Computer Science and Information Technology
Atmiya University
Rajkot, India
div.gohel@gmail.com

Dr. Pratik Vanjara
Department of Computer Science and Information Technology
Shree Maniben Virani & Smt. Navalben Virani Science College
Rajkot, India
pavanjara@gmail.com

Abstract— **There are several benefits of e-commerce websites that include cost effectiveness, convenience, flexibility, fast delivery, increase in income, etc. With these benefits, there is crucial role of e-commerce websites in business and users. However, e-commerce websites produce an overload of data, hence, Recommender Systems (RSs) provides a solution for the data overload problem. The present study, reviews different types of RSs and its pros and cons. Then, it does comparative study of different types of RSs. After the review, it's concluded that collaborating filtering technique used more than all other ones in e-commerce websites. There are problems with almost all techniques including the collaborative filtering technique too. However there is a novel model proposed that fixes the collaborative filtering technique of 'cold start' at its best.**

Keywords— Recommender system, Data collection, Content-based, collaborative, and Hybrid filtration systems.

I. INTRODUCTION

Deciding over something is a routine task. And, we make our decisions based on the recommendations that we get from our trusted ones. Hence, where our trusted ones fail to recommend us, Recommender System enters. We believe that our close ones guiding us will be correct for us. But the matter is, how will they recommend us while shopping something online?

The RSs takes its place in the online world. For instance, you are at a restaurant that's already been in your town for a long time. But you've been waiting for a recommendation from someone you trust. If some of your trustworthy encouraged you to have food there, you will grasp some time and go there. This is how recommendation changes our thoughts.

In the same way, recommender systems work over the internet. It makes certain decisions about the products based on your choices. Not being less than magic, these systems are software tools that aim to recommend satisfactory products to users having similar kinds of interests. In simple words, a recommender system is a class of filtering systems that predicts the user's interest. It's based on the [1] ratings, like, interaction of any user on various products available across the internet.

The most common implementation of a recommender system is in news, songs, movies, restaurants, online dating applications, social media, etc. It's widely used on E-Commerce sites because users interact more than other sites here. So, it gets easy to know their likes and dislikes. Their particular interaction is stored in tables, and these tables work like input data of the recommender system. But, with these advantages, this system requires necessary improvements to be more applicable in real life.

The software tool suggests which item can be perfect for users like us based on our interaction within the software. The main goal of this system is to provide the right product to the accurate user. It also bears the capacity to recommend whether you will prefer one item or not. It's entirely based on your prior interaction with similar products [4].

The concept of a recommender system emerged when researchers started to study different problems related to the recommendation. Its goal is to reduce the amount of information overload and provide individual services. But along with this, RSs have certain limitations discussed in the following paper, along with some relevant future solutions.

II. TYPES OF RECOMMENDER SYSTEM

There are mainly three types of recommendation techniques: content-based filtering, hybrid filtering, and collaborative filtering. They are very different and have their drawbacks and profits. If you are not aware of the depth and techniques of how the Recommender System is implemented, here are its main techniques. Here, the Fig. 1. Explains different types of RSs techniques.

The names of these techniques themselves depict what kind of method is used in that technique to collect data and recommend accordingly. However, an in-depth explanation of each technique is necessary, so let us get straight to the explanation part.

A. Content-based Recommender Systems

This filtering technique recommends products based on a single customer interacting with the site and their data [5]. User's interaction with the item and its description plays a vital role in this technique.

In general, this technique is mainly used when recommending restaurants, articles, news, and web pages to someone. Here are the basics of a content-based recommendation system:

To begin with, it starts with the analysis of the information of the product that one user is interacting with the most. Now
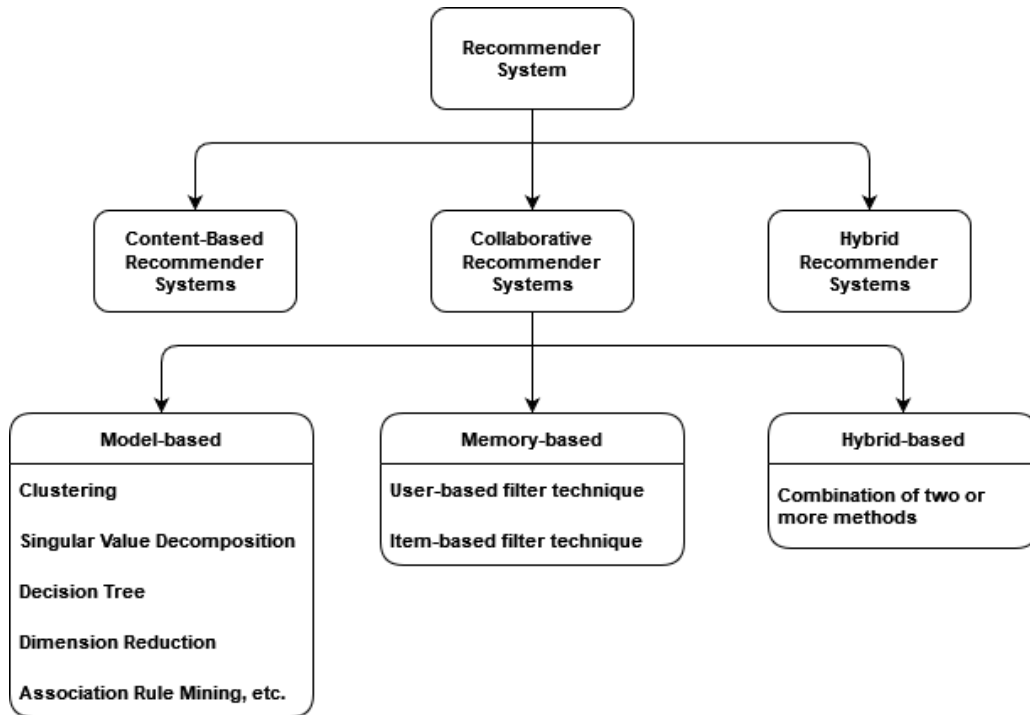
Fig. 1.   Types of Recommender System

select the preferences that can describe that particular item. These preferences are then stored in that user's profile. Secondly, each item is compared to the user's profile, and highly related products are recommended to that user. Below is Table I explaining the advantages and disadvantages of this RSs technique.

TABLE I.   ADVANTAGES AND DISADVANTAGES OF CONTENT-BASED FILTER SYSTEM

Name	Advantages	Disadvantages
Content-Based Filter System	Provides User Independence. Users get transparency. Works based on a single user.	New User problem not solved completely. Analysis of only limited Content is performed.

B. Hybrid Recommender System

As the name suggests, hybrid technique merges different techniques to birth a more extraordinary recommendation approach [8], [10]. This technique avoids some limitations or other techniques. Mainly, hybrid filtering adds up two types that will end up creating a new kind of recommender system [18]. The new design is supposed to be more effective.

Basically, it combines the best specifications of other techniques, and the hybrid is formed. Primarily, one technique is content-based, and another mixing technique varies [22]. This system is followed to avoid sparseness, cold start, and scalability. There are multiple ways you can combine these techniques to form a hybrid technique. Below is Table II

explaining the advantages and disadvantages of this RSs technique [22].

TABLE II.   ADVANTAGES AND DISADVANTAGES OF HYBRID FILTER SYSTEM

Name	Advantages	Disadvantages
Hybrid Filter System	A hybrid system overcomes new user problems, cold start, etc. Combination of collaborative and mainly content-based techniques. Avoids cold start, spareness, etc.	It's expensive and complex to implement.

C. Collaborative Recommender System

There are three more bifurcations of collaborative filtering systems. But first, let us look at what this system is.

The collaborative technique will recommend the user based on someone's behavior or having the same interest [10]. A collaborative system builds the data of user preferences.

Depending on this data set, users receive recommendations. This technique plays a remarkable role in various apps. It's an extensively used technique in apps where users are most active, and the app needs to send recommendations constantly. Below

is Table III explaining the advantages and disadvantages of this RSs technique.

TABLE III. ADVANTAGES AND DISADVANTAGES OF COLLABORATIVE FILTER SYSTEM

Name	Advantages	Disadvantages
Collaborative Filter System	Uses data of multiple users with the same interests. Improving performance and recommendation.	Doesn't fully overcome Similar word trouble, Data sparsity, Cold start, and Scalability.

This technique compares similar user interactions and recommends the user as per the comparison [13], [15]. This system reviews more everyday items and generates user sets that affect recommendation results.

The application of this technique contains large data sets. This system is mainly classified into three parts:

- Model-based
- Memory-based
- Hybrid-based

Let us see all these methods in detail:

1) Model-based

The model-based technique doesn't use the whole data set. But, it generates a model from that data set. And this model recommends the user about products [17]. It uses previous user ratings to learn about the model and improve its performance by using collaboration. Machine learning, Data mining, etc. techniques are used for the model-based technique. Below is Table IV explaining the advantages and disadvantages of this RSs technique.

TABLE IV. ADVANTAGES AND DISADVANTAGES OF MODEL-BASED COLLABORATIVE FILTER SYSTEM

Name	Advantages	Disadvantages
Model-based Collaborative Filter System	Better handling of scalability and spareness. Improves performance and recommendation. Not gulps much CPU memory.	I might lose important information. Comparatively expensive.

Here are the examples of Model-based techniques:

- Clustering
- Singular Value Decomposition
- Decision Tree
- Dimension Reduction

- Association Rule Mining, etc.

These examples resolve spareness and other problems. Let us see some examples in brief.

a) Clustering: Cluster means the collection of data sets that are mostly the same as one another. These sets then fall under the same cluster. And other groups fall under the different clusters. In general, we can call clusters as criteria. Methods like Minkowski distance, Pearson correlation, etc., are used to calculate similar data sets in one cluster.

b) Association rule: It brings practices based on data sets of items in use by the user. It classifies rules that recommend the item's occurrence based on other items in the transaction.

c) Decision tree: This technique performs based on three graphs. These graphs are generated by a set analysis of training and labels. This method is comparatively more interpretable than other filtering techniques.

d) Matrix filter: This filtering technique suggests unknown values in the user-item matrix. It is one of the majorly used filter techniques in the correlation-system basis on the nearest user. The results of this technique are dependent on the rating history of datasets of users-items.

e) Regression technique: This method comprises two or more variables to connect it with linear relations. Then this regression technique is used to examine associative associations amongst variables and independent variables.

f) Bayesian classifier technique: The Bayesian filter technique works based on the byes theorem and conditional probability definition. Its most common use is Naive Bays Classifier.

2) Memory-based

The memory-based technique applies to the item rated by the customer before. These items are further recommended to the user sharing the same opinion.

Once the user with the same interest is found, different algorithms nest up and find preferences. This technique has excellent effectiveness in real-life applications.

This technique uses a complete data set to form recommendations for users. Below is Table V explaining the advantages and disadvantages of this RSs technique.

TABLE V. ADVANTAGES AND DISADVANTAGES OF MEMORY-BASED COLLABORATIVE FILTER SYSTEM

Name	Advantages	Disadvantages
Memory-based Collaborative Filter System	Easy to implement and use.	Data parsing occurs and acquires much CPU space.

This filtering technique is further classified into two different types:

- User-based filter technique
- Item-based filter technique

a) User-based filter technique: User-based techniques calculate the similarity between users and not products. It compares users based on their ratings on the same products and then recommends items.

b) Item-based filter technique: This filtering calculated similarity between items and not customers. It uses a user-item matrix and composes data where how the users target similar products. Then it gets the most similar product and recommends it to the user.

3) Hybrid-based

The hybrid filter technique will use a combination of two or more methods for recommending or preferring products to active users.

There are different ways to combine multiple products in one method, like individually implementing techniques and combining outputs or using model techniques and then adding outputs. You can also use memory-based with model-based techniques too. Below is Table VI explaining the advantages and disadvantages of this RSs technique.

TABLE VI.   ADVANTAGES AND DISADVANTAGES OF HYBRID COLLABORATIVE FILTER SYSTEM

Name	Advantages	Disadvantages
Hybrid Collaborative Filter System	Improving sparsity	It's expensive and complex to implement.

III. COMPARATIVE ANALYSIS OF DIFFERENT RECOMMENDER SYSTEMS

Here are some of the disadvantages that are yet to be overcome and require thought to solve them using other research.

A. Cold Start

When anyone is a new user of any e-commerce website, there are hardly any techniques to provide the best-recommended products.

B. Changing preferences of the user

This is a significant challenge that the recommender system faces [19]. The system tries to accommodate users' preferences by considering their interests and profile.

C. Performance deterioration

As the number of users increases, the ease of performance decreases. This tool will require more resources to process and collect the increasing information from the growing audience.

D. Sparsity

Sparsity ultimately back holds the process of recommendation. How? It's because not all users will continue to interact with multiple products. Some of them might just not be available to interact for a longer time. So, gathering their likes and dislikes is troublesome for this system. In layman's words, spareness is a problem that arises because of less information available.

E. Similar Words

Similar words are the main challenge to overcome shortly. Products with a similar name but different functionality will appear in the same list after the user searches for the same [21]. In such cases, most systems are confused in finding the right product for the customer.

F. Privacy

Certain users might feel that their privacy is breached and might not permit the system to access some of their data. So, some information remains inaccessible by the system. Or, it might happen that the system might not have enough space to store all the information of numerous users. So, this challenge also hinders the path of a perfect recommender system.

Using any techniques from the three main techniques of collaborative systems ultimately depends on the type of software [23]. Generally, all three techniques share almost the same percentage of share in preference. But as we know, Collaborative System is easy to implement and overcomes many disadvantages of content-based techniques. Also, it's more cost-effective than the hybrid technique.

The path discussed in this collaborative system and the main disadvantage of the collaborative system is Cold Start [25]. Overcoming a cold start may look easy, but the solution to overcome it is needed now. Let us see the plan that can overcome the limitations of the Collaborative technique.

IV. RESEARCH FINDINGS

We have carried out this research by reading through selected and well-published papers. Here is the comparative analysis of all three RSs techniques. Fig. 2. represents the study of Content-Based, Collaborative, and Hybrid techniques.

As shown in the Fig. 2. The comparison of each technique is made based on the following 5 factors:

- Security
- Response Time
- Scalability
- Accuracy
- Operating Cost

As we see, every technique has its own advantage and disadvantage. Like at first look, the Content-based technique will look perfect to use because it has the highest security scale, but the fact that brings it down is its less accuracy than Collaborative and Hybrid, and operation cost is the highest.

When we look for a hybrid technique, one can go for it, however the major drawback is operation cost and less security. But as mentioned earlier, many research papers conclude that Collaborative Technique is best to use. It has disadvantages too, but as per studies, it is easy to implement.

Depending on fewer drop-outs of the collaborative system than other techniques, here is the research that is done along with the model that we can implement in the future to overcome
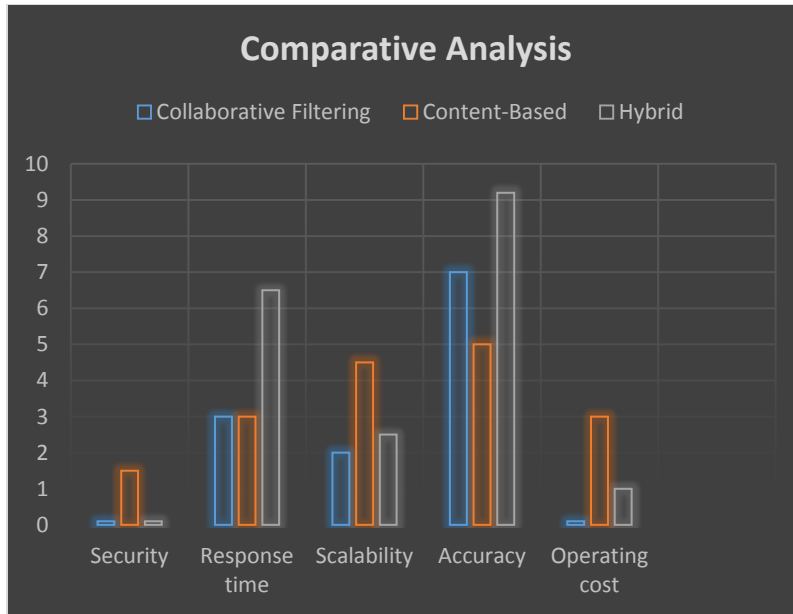
Fig. 2.   Comparative Analysis of all Three RSs Techniques

significant future challenges that we will encounter in Collaborative RSs [23].

For instance, as Fig. 3. Shows you, users, 1,2, and 3 and the ratings they give to Products P 1,2,3,4. There are higher chances of User1 buying a product that User2 purchases than other random users buying other products. Finally, the matrix looks like below Fig. 3.

Collaborative System	P1	P2	P3	P4
User 1	4			1
User 2	5	4		
User 3		3	4	2

Fig. 3.   Matrix form of the Collaborative Systems

Now, let us look at the formula on which a memory-based and model-based collaborative system work.

A. Memory-based System

The utility matrix is memorized in this type of technique and recommendations are formed by questioning the given client's whole utility matrix. Le us take a look at an example: We want to know how much a user naming I like a product naming k. Eq. (1) shows our equatorial representation of the memory-based collaborative system.

$$\overline{Y}i = \frac{1}{|Ii|} \sum_{j \in Ii} Yij \tag{1}$$

This is the average rating given by a user i to all of the products they have rated. Using this information, we can calculate his product k rating as shown here in Eq. (2):

The similarity between users a

$$\hat{Y}ik = \overline{Y}i + \frac{1}{\sum_{a \in U_k} |Wia|} \sum_{a \in U_k} Wia(Yak - \overline{Y}a) \tag{2}$$

All users that have rated k

A's rating k- a's average ratings

Users 'a' and 'i's' similarity can be calculated using various methods, including Jacquard's similarity, Cosine's similarity, Pearson's correlation coefficient, and so on. These outcomes are easy to produce and explain, but performance suffers when the data is sparse.

B. Model-based System

Matrix Factorization is one of the most common model-based technique solutions [8]. We use the utility matrix Eq. (3) to generate representations of the clients or items. This is how it looks:

$$\begin{bmatrix} 5 & 1 & 4 & 5 & 1 \\ & 5 & 2 & 1 & 4 \\ 1 & 4 & 1 & 1 & 2 \\ 4 & 1 & 5 & 5 & 4 \\ 5 & 3 & 3 & & 4 \\ 1 & 5 & 1 & 1 & 1 \\ 5 & 1 & 5 & 5 & 4 \end{bmatrix} \approx \begin{bmatrix} u_{11} & u_{12} & \cdots & u_{1k} \\ u_{21} & u_{22} & \cdots & u_{2k} \\ u_{31} & u_{32} & \cdots & u_{3k} \\ u_{41} & u_{42} & \cdots & u_{4k} \\ u_{51} & u_{52} & \cdots & u_{5k} \\ u_{61} & u_{62} & \cdots & u_{6k} \\ u_{71} & u_{72} & \cdots & u_{7k} \end{bmatrix} \times \begin{bmatrix} v_{11} & v_{21} & v_{31} & v_{41} & v_{61} \\ v_{12} & v_{22} & v_{32} & v_{42} & v_{62} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ v_{1k} & v_{2k} & v_{3k} & v_{4k} & v_{6k} \end{bmatrix}$$

$$\approx \begin{bmatrix} 0.2 & 3.4 \\ 3.6 & 1.0 \\ 2.6 & 0.6 \\ 0.9 & 3.7 \\ 2.0 & 3.4 \\ 2.9 & 0.5 \\ 0.8 & 3.9 \end{bmatrix} \times \begin{bmatrix} 0.0 & 1.5 & 0.1 & 0.0 & 0.7 \\ 1.3 & 0.0 & 1.2 & 1.4 & 0.7 \end{bmatrix} \tag{3}$$

Our utility matrix decomposes into V and U in a low-dimensional space, where V represents movies, and U means users. This can be accomplished via matrix decomposition techniques such as PCA or SVD or by employing neural networks to train the two encapsulating matrices using an optimizer such as SGD or Adam. Eq. (4) is used for the same.

$$\hat{Y}_{ij} = U_i \cdot V_j \qquad (4)$$

We only need to calculate rating Y for each user 'i' and each movie 'j' to suggest the films with the highest expected rating [25]. This method is particularly beneficial when we have a large amount of data with a high degree of sparsity. Matrix factorization aids in the reduction of dimensionality, allowing for faster computing. A disadvantage of this technique is we tend to miss interpretability because we don't know the exact elements of the item/user vector.

There are certain disadvantages of Collaborative RSs like Cold start that can be solved using the following model mentioned in the future direction.

V. FUTURE DIRECTIONS

Through deep research on the collaborative RSs, the main limitation that should be terminated shortly is a 'cold start'. For that, the modular representation Fig. 4. shows how we can overcome the 'cold start' repulsion while implementing the collaborative system.
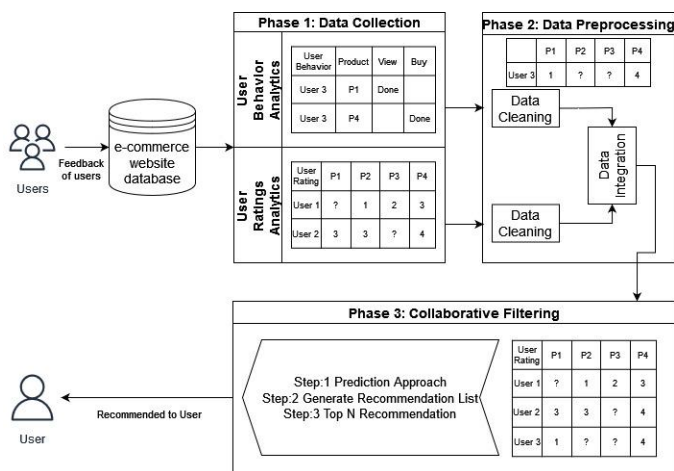

Fig. 4. Future Directions to Overcome Collaborative RSs limitations

The model shows when a user is ultimately a newbie to any e-commerce site, how will he/she/others get recommendations? The solution to this 'cold start' trouble is that products should be recommended based on their popularity. The product's popularity can be seen in the user's behavior with that product and ratings.

Using this model of Collaborative Filtration technique, we can overcome the 'cold start' drawback. When any new user joins the e-commerce website, s/he is recommended on the basis of the previous user's behavior and ratings.

When many users send their feedback after purchasing or viewing the products, it is stored in the e-commerce website database. From this data collection, while studying User Behavior Analytics, User 3 only views Product naming P1 and

buys Product naming P4. While learning User Ratings Analytics, User 1 and User 2 gives different ratings to products P1, P2, P3, P4.

These data then fall under the Data Preprocessing step, showing that User 3 has no interaction with Products P2 and P3. Hence, using data cleaning and data integration process, phase 3 has resulted in Collaborative Filtering.

Based on these ratings and behavior, top N products are recommended to the new user that has just entered the e-commerce world.

CONCLUSION

After studying several research papers on RSs, a collaborative filtering system can be preferred among all articles. Despite Collaborative System not being the total solution to every single drawback, however, it is more used compare to the other two techniques. Now, it is not difficult to overcome the flaws of the Collaborative Systems, especially the major 'cold start' weakness, if the above mentioned model by us implemented in different e-commerce websites.

REFERENCES

[1] S. Inoue and M. Tokumaru, "Serendipity Recommender System for Academic Disciplines," 2020 Joint 11th International Conference on Soft Computing and Intelligent Systems and 21st International Symposium on Advanced Intelligent Systems (SCIS-ISIS), 2020, pp. 1-4, doi: 10.1109/SCISISIS50064.2020.9322747.

[2] M. Sadeghi, S. A. Asghari and M. M. Pedram, "An Improved Method Multi-View Group Recommender System (IMVGRS)," 2020 8th Iranian Joint Congress on Fuzzy and intelligent Systems (CFIS), 2020, pp. 127-132, doi: 10.1109/CFIS49607.2020.9238688.

[3] Saraswat, Mala, Shampa Chakraverty, and Atreya Kala. "Analyzing emotion based movie recommender system using fuzzy emotion features." International Journal of Information Technology 12, no. 2 (2020): 467-472.

[4] B. Ujkani, D. Minkovska and L. Stoyanova, "A recommender system for WordPress themes using item-based collaborative filtering technique," 2020 XXIX International Scientific Conference Electronics (ET), 2020, pp. 1-3, doi: 10.1109/ET50336.2020.9238305.

[5] S. Amara and R. R. Subramanian, "Collaborating personalized recommender system and content-based recommender system using TextCorpus," 2020 6th International Conference on Advanced Computing and Communication Systems (ICACCS), 2020, pp. 105-109, doi: 10.1109/ICACCS48705.2020.9074360.

[6] Tareq, Shihab Uddin, Md Habibullah Noor, and Chinmay Bepery. "Framework of dynamic recommendation system for e-shopping." International Journal of Information Technology 12, no. 1 (2020): 135-140.

[7] Sohail, Shahab Saquib, Jamshed Siddiqui, and Rashid Ali. "A comprehensive approach for the evaluation of recommender systems using implicit feedback." International Journal of Information Technology 11, no. 3 (2019): 549-567.

[8] K. A. Fararni, F. Nafis, B. Aghoutane, A. Yahyaouy, J. Riffi and A. Sabri, "Hybrid recommender system for tourism based on big data and AI: A conceptual framework," in Big Data Mining and Analytics, vol. 4, no. 1, pp. 47-55, March 2021, doi: 10.26599/BDMA.2020.9020015.

[9] Qomariyah, Nunung Nurul, and Ahmad Nurul Fajar. "Recommender system for e-learning based on personal learning style." In 2019

International Seminar on Research of Information Technology and Intelligent Systems (ISRITI), pp. 563-567. IEEE, 2019.

[10] Sujithra Alias Kanmani, R., B. Surendiran, and S. P. Ibrahim. "Recency augmented hybrid collaborative movie recommendation system." International Journal of Information Technology 13, no. 5 (2021): 1829-1836.

[11] Kumar, Pushpendra, and Ramjeevan Singh Thakur. "Recommendation system techniques and related issues: a survey." International Journal of Information Technology 10, no. 4 (2018): 495-501.

[12] Zhao, Xuesong. "A study on e-commerce recommender system based on big data." In 2019 IEEE 4th International Conference on Cloud Computing and Big Data Analysis (ICCCBDA), pp. 222-226. IEEE, 2019.

[13] Ng, Yiu-Kai. "MovRec: a personalized movie recommendation system for children based on online movie features." International Journal of Web Information Systems (2017).

[14] Kai-lun, C. E. N., Y. U. Hong-yan, and Y. A. N. G. Teng-xiao. "Design and Implement of E-Commerce Real-Time Recommender System with Spark Based on Big Data." Modern Computer 8 (2016): 61-69.

[15] Beel, Joeran, Bela Gipp, Stefan Langer, and Corinna Breitinger. "paper recommender systems: A literature survey." International Journal on Digital Libraries 17, no. 4 (2016): 305-338.

[16] Francesco, Ricci, Lior Rokach, and Bracha Shapira. "Introduction to recommender systems handbook." Recommender Systems Handbook, Springer 2011 (2011): 1-35.

[17] O. Artemenko, V. Pasichnyk, N. Kunanec and D. Tabachyshyn, "Using context analysys for providing real time recommendations in e-tourism mobile location-based recommender systems," 2019 IEEE 14th International Conference on Computer Sciences and Information Technologies (CSIT), 2019, pp. 166-169, doi: 10.1109/STC-CSIT.2019.8929822.

[18] Papneja, Sachin, Kapil Sharma, and Nitesh Khilwani. "Context aware personalized content recommendation using ontology based spreading activation." International Journal of Information Technology 10, no. 2 (2018): 133-138.

[19] Lakshmi, Soanpet Sree, and T. Adi Lakshmi. "Recommendation systems: Issues and challenges." International Journal of Computer Science and Information Technologies 5, no. 4 (2014): 5771-5772.

[20] Soni, Karan, Rinky Goyal, Bhagyashree Vadera, and Siddhi More. "A Three Way Hybrid Movie Recommendation Syste." International Journal of Computer Applications 160, no. 9 (2017).

[21] Isinkaye, Folasade Olubusola, Yetunde O. Folajimi, and Bolande Adefowoke Ojokoh. "Recommendation systems: Principles, methods and evaluation." Egyptian informatics journal 16, no. 3 (2015): 261-273.

[22] Thorat, Poonam B., R. M. Goudar, and Sunita Barve. "Survey on collaborative filtering, content-based filtering and hybrid recommendation system." International Journal of Computer Applications 110, no. 4 (2015): 31-36.

[23] M. V. Murali, T. G. Vishnu and N. Victor, "A Collaborative Filtering based Recommender System for Suggesting New Trends in Any Domain of Research," 2019 5th International Conference on Advanced Computing & Communication Systems (ICACCS), 2019, pp. 550-553, doi: 10.1109/ICACCS.2019.8728409.

[24] Riedl, John, Joseph A. KONSTAN, and J. Ben SCHAFER. "Electronic commerce recommender applications." Journal of Data Mining and Knowledge Discovery 5, no. 1/2 (2000): 115-152.

[25] Senbagaraman, M., R. Senthilkumar, S. Subasankar, and R. Indira. "A movie recommendation system using collaborative approach and cuttlefish optimization." In Proceedings of international conference on emerging trends in engineering, science and sustainable technology, pp. 95-99. 2017.

[26] D. Liu, "A Study on Collaborative Filtering Recommendation Algorithms," 2018 IEEE 4th International Conference on Computer and Communications (ICCC), 2018, pp. 2256-2261, doi: 10.1109/CompComm.2018.8780979.

[27] Zhao, Xuesong. "A Study on the Application of Big Data Mining in E-commerce." In 2018 IEEE 4th International Conference on Computer and Communications (ICCC), pp. 1867-1871. IEEE, 2018.

[28] Davidson, James, Benjamin Liebald, Junning Liu, Palash Nandy, Taylor Van Vleet, Ullas Gargi, Sujoy Gupta et al. "The YouTube video recommendation system." In Proceedings of the fourth ACM conference on Recommender systems, pp. 293-296. 2010.

[29] Lu, Jie, Dianshuang Wu, Mingsong Mao, Wei Wang, and Guangquan Zhang. "Recommender system application developments: a survey." Decision Support Systems 74 (2015): 12-32.

[30] Ricci, Francesco, Lior Rokach, and Bracha Shapira. "Introduction to recommender systems handbook." In Recommender systems handbook, pp. 1-35. Springer, Boston, MA, 2011.