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SPR SYNTHESISED: AN EFFECTIVE COLLABORATIVE BASED RECOMMENDATION SYSTEM BASED ON USER SENTIMENTS

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ABSTRACT

In the current era of electronic and mobile commerce, recommendation system acts as a crucial one in suggesting the products / services to the consumers as well as the users based on their interests. There exist two forms of such systems viz. content based and collaborative based. Among that content-based technique is suitable to suggest the products belonging to the same category. In that extent, collaborative based technique may be a right choice that suits all the sectors. In collaborative techniques, the recommendations may be made on the user based or the item-based similarity. For the similarity calculation, typically the ratings given by the user are used. In some situation, the ratings may be the contradictory or it may not convey the user's opinion entirely. To prevent this, the proposed study integrates the sentiment analysis with the collaborative-based recommendation systems. Here, along with the rating, polarity of the opinion which indicates the strength of the sentence and the user sentiment is also exploited to compute the similarity score. In such practice, the recommendations given by the system will be more accurate. The results shown that, the accuracy of the system will be more for the item-based filtering when polarity or the synthesis of polarity and rating is utilized for similarity calculation. For the user-based filtering technique, the mixture of polarity, rating and the user sentiment will be the efficient one.

Keywords: *Recommendation System, Sentiment Analysis, Polarity, Collaborative Filtering, User based, Item Based*

1. INTRODUCTION

Recommendation system is a useful methodology that recommends the people with the interested and the needed content during the online shopping, online education and entertainment. It is important because the social media now a days is upgrading everyday with the massive amount of data. Among that it is necessary for every organization to filter such data and provide the useful one for their users by knowing their wishes without their knowledge so as to endure themselves in this competitive world. Recommendation System assists such organizations. It is used by almost all the social networks like YouTube, Instagram, Online Shopping apps, Facebook, Music apps, Book apps, educational apps, etc. In all such applications, the things will be recommended to a particular user, if his/her interests match with other users interests or other users' purchased products. The matching of interests can be measured using the similarity score of the user profiles. If the users are similar, then the product liked by a user will be recommended to the other similar users and vice versa. In such manner, the massive content can be scrutinized and given to the user in a satisfiable manner.

Recommender systems are vital for online platforms, yet conventional collaborative filtering methods frequently overlook user sentiment, resulting in suggestions that are less personalized and accurate. This research seeks to overcome the shortcomings of current systems by combining sentiment analysis with collaborative filtering to improve the quality of recommendations. A critical requirement exists for a blended method that takes into account both user-item interaction trends and emotional context derived from user-created content

Till now the recommendation system considers the rating given by the user for a product will be utilized for computing similar users. But unfortunately, the rating may sometimes be misleading or partially conveys the user's real thought. To avoid such thing, the proposed study uses the mixture of user sentiment which may be positive or negative, polarity and the rating for similarity calculation. This depicts the integration of sentiment analysis with the recommendation system. Hence the proposed study targets with the research question "Can sentiment analysis improve the accuracy of collaborative filtering in recommender systems?" and "How does the integration of user sentiments affect the quality and personalization of recommendations?". The objective of the study is to propose the hybrid techniques for collaborative filtering based on the synthesis of Rating, Sentiment & Polarity and to identify which type of combination is suitable for which technique. The outcome of the proposed research depicts that the incorporation of sentiment analysis into the recommendation improves accuracy.

The results of this study are significant for researchers and professionals in the fields of recommender systems, sentiment analysis, human-computer interaction, and e-commerce. Given the importance of recommendation systems in digital marketplaces, incorporating user sentiments can improve the relevance, personalization, and satisfaction of the suggested items. This research specifically attracts developers focused on creating smart recommendation systems, scholars investigating hybrid recommendation frameworks, and companies looking to enhance customer interaction and loyalty

2. LITERATURE REVIEW

Product recommendation algorithms are frequently employed in a variety of sectors, such as online content platforms, streaming services, and e-commerce. A product recommendation system is made to make recommendations for consumers based on their behaviour, preferences, and other pertinent information. To analyse user data and provide tailored recommendations, it makes use of algorithms and data analytic tools.

A sentiment-based recommendation system takes into account both user preferences and the sentiment or opinion that users have about goods or services. It takes user reviews, ratings, or feedback and uses natural language processing (NLP) algorithms to extract sentiment-related information. The system can produce recommendations based on sentiment analyses, such as positive, negative, or neutral, that match users' feelings about the products. This method contributes to a more customized and fulfilling user experience by personalizing recommendations according to consumers' emotional reactions.

Sentiment analysis plays a crucial role across various fields, as it affords valuable perceptions into the attitudes, opinions, and emotions as conveyed through documented information. [1]. This analysis supports businesses in understanding client sentiment, product reputation, market trends, and prevailing sentiments on social media platforms. Machine learning models are widely employed in sentiment analysis tasks due to their ability to autonomously detect patterns and classify sentiments from large datasets. Star ratings in customer reviews serve as a commonly used metric for assessing product satisfaction, and sentiment can be effectively integrated through these ratings. In this work [2], the researchers classified the ratings into five different categories that represent a range of polarity values, from strongly negative to strongly positive. By classifying ratings based on sentiment, the study enables the extraction of meaningful insights regarding product satisfaction and customer opinions.

By harnessing the capabilities of recommendation systems, users are provided with customized suggestions that correspond to their individual tastes and preferences, thereby enhancing the personalization and overall satisfaction of the shopping experience. This underscores the critical role of recommendation systems in augmenting user satisfaction and optimizing the product selection procedure within the apparel sector [3]. An analysis and comparison of the Root Mean Square Error values across various algorithms is conducted. This examination aims to identify the most effective methodology for generating precise recommendations [4 - 13]. Given the extensive body of research in this area, a comprehensive analysis of both memory-based and model-based collaborative filtering was warranted. The authors further emphasized the significance of user satisfaction as reflected in ratings [14, 15].

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Nonetheless, recommendation systems have the potential to enhance their effectiveness by integrating user sentiments, which prompted the decision to incorporate sentiment data into ratings. Although existing literature offers valuable insights into user satisfaction via ratings, recommendation systems, and sentiment analysis, this research aims to merge these elements to develop a shopping experience that elicits a greater emotional response. This study bridges theoretical frameworks and practical applications, with a particular focus on e-commerce personalization by identifying the most efficient algorithms for delivering accurate recommendations, as evidenced by the analysis of Root Mean Square Error (RMSE) values.

Recommended systems are commonly divided in accordance with their methods of providing recommendations into the following categories: Content-based recommendation: where users are suggested items that are akin to what the user has liked in the past. Perform Collaborative Filtering (CF) algorithm where a user is suggested items which were liked by other users with the same tastes. c) Hybrid approaches: mixture of content-based and collaborative methods. In CF recommender systems, rating which shows how a certain user liked a certain item has been the most popular representation as of now [17]. However, ratings do have shortcomings especially when the user-item matrix expands in dimensions and evolves due to sparse data and reduced quantities of available data. Because of this there is not a lot of research done to address the problems stated above [18]. One attempted solution is the eliciting of user preferences captured in textual reviews, also known as sentiment analysis, and translating those preferences into figurative languages compatible with CF algorithms.

Based of the above reviews, it is evident that the recommendation system is the eternal concept in the current technical world. The back bone of it is the sentiment analysis. The objective of the proposed work is to provide recommendation based on the sentiments of the user along with the rating. Particularly the polarity score which supports the sentiment analysis are used in the proposed work. The review regarding sentiment analysis is done more by the researchers in [19,20]

The uniqueness of the proposed research lies in the consideration of the user emotions as well as the ratings in the integration format which does not exists till now in a any research findings.

3. EXISTING STATE OF THE ART METHOD

In the existing methods, only the rating is considered for the computation of values in the similarity matrix, whether it may be user item or item user. Such methodology was practically examined with an online product recommendation dataset available online in the Kaggle website. The results are shown in the table.

Table 1: Evaluative Measures of the existing method

Model	RMSE	MAE
R-Based User Collaborative Filtering	2.09	1.58
R-Based Item Collaborative Filtering	3.55	3.36

The results shown in the table 1 indicates the poor performance of the system as the error rate is beyond the limit in both the RMSE and MAE. Such performance induced the necessity of the proposed study of the synthesization of the polarity, rating and the sentiments as shown in the following figure 1.

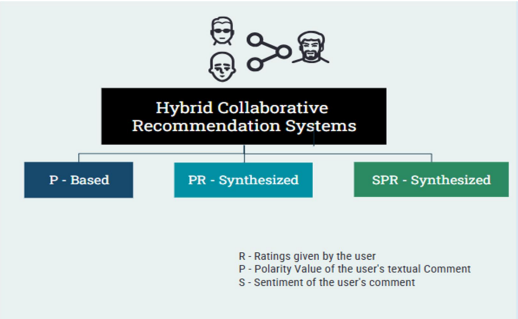

Figure 1. Three proposed techniques

In Fig 1., three features that decides the user interests were utilized in each method. In the method 1, instead of the rating which is common practise, the polarity of the user's view point is used in the construction of similarity matrix. That's why the method is called P-Based. In the second technique, the polarity as well as the rating are blended together to approximate the similarity computation still more. Such methodology is called PR – Synthesized. Then the final methodology combined the polarity and rating with the user's sentiment which may be either positive or negative

in order to compute the similarity. This is called the SPR – Synthesized.

4. PROPOSED HYBRID COLLABORATIVE RECOMMENDATION SYSTEMS

As mentioned earlier, there exists many procedures that improves the efficiency of the recommendation systems. But in the proposed work, three methodologies were discussed, each is suitable to either user based collaborative filtering or the item based collaborative filtering. The proposed techniques are depicted in detail stepwise in the following figure.

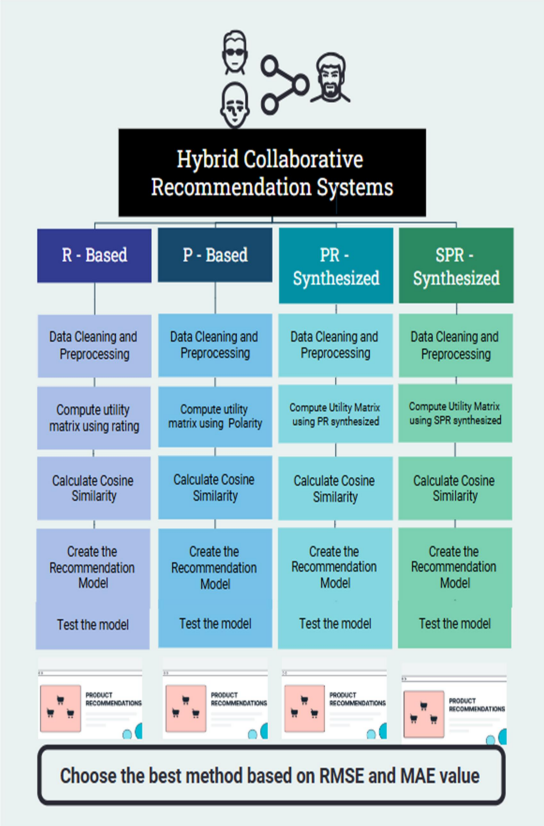

Figure 2. Workflow of the Proposed Methodologies

The works depicted in the figure 2 indicates that each of the proposed methodology involves the basic data cleaning and preprocessing technique, and cosine similarity calculation. But while computing the similarity matrix, different values will be utilized which can be described in detail in the following context. This study adopts a quantitative experimental design, combining collaborative filtering with natural language processing (NLP) for sentiment analysis. Online datasets such as Amazon Product Reviews were used, consisting of user ratings and review texts. User reviews were cleaned and tokenized; sentiment scores were computed using a pretrained transformer-based sentiment analyzer. The algorithmic design comprises of two phases: Standard user-item collaborative filtering was applied and Sentiment scores were integrated into the similarity computation. The metrics like RMSE, and MAE were used to evaluate performance.

4.1 Algorithmic steps for the proposed techniques

Input : Review Dataset
Output : Product Recommendation
Notation : PD – Preprocessed data, P – Polarity of the user sentiments, SM –Similarity Matrix, SC – Similarity Score, R – Ratings, S – User Sentiment, PR – Polarity and Rating synthesized, SPR – Sentiment, Polarity and rating synthesized, ch-choice of the proposed methodology, M – To choose any Proposed method

Steps

Begin:

PD←Tokenize, Lemmatize and Stemming.
For each review I in PD
Calculate the value of Polarity (P)
PR = P * R
SPR = S + PR
End
Choose the type of the proposed methodology using M
Switch(ch):
Case 1:
//User Collaborative Filtering
Iterate through all users
If(M==1)
Return the Cosine similarity score (SC)based on P-value
Else if(M==2)
Return the Cosine similarity score (SC)based on PR-value
Else
Return the Cosine similarity score (SC)based on SPR-value
Create a similarity matrix SM [user1] [user2] = SC
predict_rating(user_id, item_id)
generate_recommendations(user_id, 20)
End
Case 2:
// Item Collaborative Filtering
Iterate through all items
If(M==1)

Return the Cosine similarity score (SC)based on P-value
Else if(M==2)
Return the Cosine similarity score (SC)based on PR-value
Else
Return the Cosine similarity score (SC)based on SPR-value
Create a similarity matrix SM [item1] [item2] = SC
predict_rating(item_id, user_id)
generate_recommendations(item_id, 20)
End
End

As specified in the pseudo code, the given review data set will first undergone the steps like tokenization, lemmatization and stemming. The outcome will be the cleaned and pre-processed review data (PD). After that the feature that the proposed technique used to compute similarity will be calculated. For the methodology1, it will be the polarity score of the sentiments, and for the method2 and 3, it will be the polarity – rating synthesized and the sentiment score – polarity – rating synthesized respectively. The reason behind the fact of such features is as these indicates the users' opinions of the products which contributes the most in recommending products.

Next to that, the similarity score will be computed and placed in the similarity matrix. For the user based collaborative filtering, the similarity matrix will be calculated as user vs item and for the item based it will be item vs user. The similarity score will be measured by comparing the feature score given by more users for a particular item or the score given by a user for more items. Here cosine similarity is used to find the similar items, which is the dot product of vector A and vector B divided by the multiplied value of magnitude of vector A and the magnitude of vector B. Here A and B may be the user and item or item and user.

Based on the similarity score, the predicted rating will be found. With that, the recommendations will be given by filling the unrated items with the predicted value. Any percent of recommendations can be given. In the proposed work, 20 items were recommended.

4.2 Proposed Method I - P-Based Collaborative Recommendation System

In the polarity-based recommendation system which is a first proposed approach, polarity value is calculated for each of the user comments. For such calculation, the built-in corpus dictionary in Python was used. The procedure is suitable for both the user based and the item based collaborative technique.

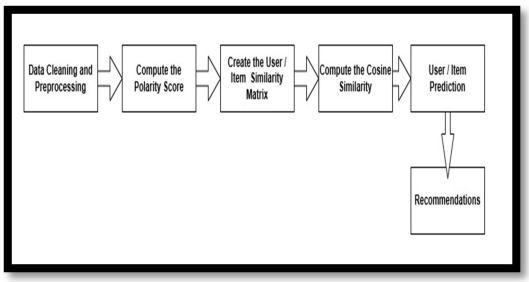

Figure 3: P-Based Collaborative Filtering

As specified in the fig 3. the first step is this method is data cleaning and preprocessing. After that the user similarity matrix will be created with the polarity score as the value in the matrix. For the item-based filtering, item similarity matrix will be built. The format of the similarity matrix is as follows,

User Similarity Matrix

	Item 1	Item 2	……	Item N
User 1	P11	0	…..	0
User 2	0	0		P2N
. .				
User M	0	0	……	PMN

Item Similarity Matrix

	User 1	User 2	……	User N
Item 1	P11	0	…..	P1N
Item 2	P21	0		P2N
. .				
Item M	0	0	……	PMN

In both the matrices, the polarity value of the user sentiment is placed instead of ratings. After

the matrix construction, the similar users or similar items will be calculated by using the cosine similarity. Based on the similarity, the unrated values will be predicted. Then the recommendations will be made based on the highest value of the predicted ratings. If such method is used for recommendations, the efficiency can be measured based on the RMSE and MAE.

The obtained results for the proposed methodology are as follows,

Table 2: Evaluative Measures of the P-Based Filtering

S.No	Model	RMSE	MAE
1.	P – Based User Collaborative Filtering	2.29	1.55
2.	P – Based Item Collaborative Filtering	0.43	0.05

The readings in the table 2 indicates that when the polarity is used instead of the ratings in the utility matrix for collaborative filtering, then the RMSE and MAE value for the user based one are 2.29 and 1.55 respectively which indicates the average performance of the system. But for the item based, the values are 0.43 and 0.05 which denotes the highest performance.

4.3 Proposed Method II - PR – Synthesized Collaborative Filtering

The second proposed methodology utilizes the combination of the polarity as well as the rating value which is a hybrid of the existing R-based and the proposed P-based. The process flow is as follows,

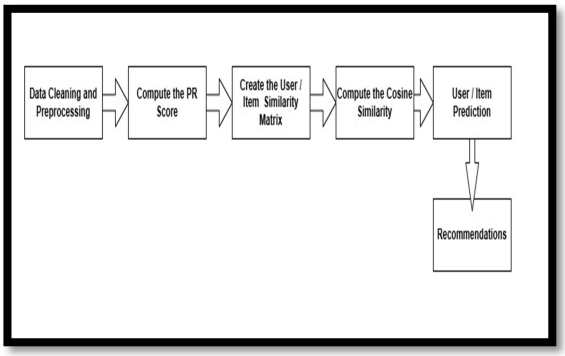

Figure 4: PR – Synthesized Collaborative Filtering

In fig 4. The procedures are same as that of the first one. But instead of Polarity Score, PR – Score will be calculated using the formula,

$$PR_{i,j} = R_{i,j} * P_{i,j} \quad (1)$$

In (1), R means the ratings provided by the user which may ranges from 1 to 5 and P means the polarity value. The reason for the product of both is that the resultant value indicates the number of times the polarity value contributes. That is, if the rating is 1 and the polarity value is 0.5 then the result will be 0.5. But if the rating is 3 then the result will be 0.15 which means the three times of the polarity value. This equation removes the contradictory between the user rating and the strength of the user sentiment. After that, the similarity calculation, prediction and recommendations will be made as usual. The RMSE and MAE values for the PR-synthesized method are as follows,

Table 3: Evaluative Measures of the PR-Synthesized technique

S.No	Model	RMSE	MAE
1.	P R – Synthesized User Collaborative Filtering	2.02	1.69
2.	P R – Synthesized Item Collaborative Filtering	0.58	0.32

Like P – based method, the PR – Synthesized method provides the less RMSE and MAE for the item-based filtering and more for the user based one. This result in table 3 indicates that the PR – Synthesize collaborative filtering is an efficient one for the item-based filtering because the rating and polarity both denotes the items weightage.

4.4 Proposed Method III - SPR – Synthesized Collaborative Filtering

The third methodology considers an extra parameter called the user sentiment which may be positive or negative along with the polarity and the rating. The reason for this parameter is that it denotes purely whether the user likes or dislikes the item. The process flow depicts the methodology as follows,

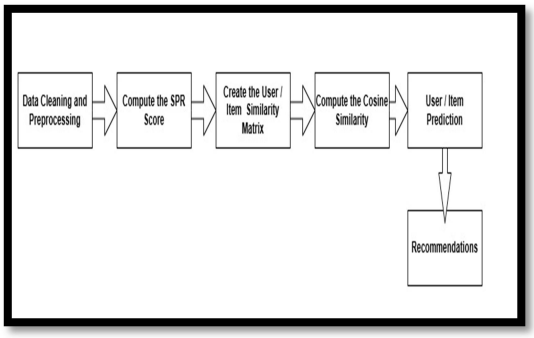

Figure 5: SPR – Synthesized Collaborative Filtering

In fig 5. Like the previous methods, the steps will be followed. But for the matrix value, SPR score is calculated using the below formula,

$$SPR_{i,j} = S_{i,j} + R_{i,j} * P_{i,j} \qquad (2)$$

In (2), the variable S indicates the user sentiment. The value will be indicated as 1 if the sentiment is positive and 0 if it is negative. The advantage of adding this extra parameter is that it will boost up the weightage of the matrix score if the review is positive that may contribute to the more accurate recommendations. It may be evident from the following table.

Table 4 : Evaluative Measures of the SPR-Synthesized technique

S.No	Model	RMSE	MAE
1.	SP R – Synthesized User Collaborative Filtering	0.06	0.03
2.	SP R – Synthesized Item Collaborative Filtering	0.08	0.06

The results in table 4 shown that the RMSE and MAE values both are in the acceptable range for the accurate recommendation system. It means that the proposed method is more efficient for both the user based and the item based collaborative filtering.

5. RESULTS AND DISCUSSIONS

In this paper, three different novel methodologies are proposed based on the combination of the user feedbacks like the user ratings, user sentiment and the polarity score. Each one is efficient for either user based or item-based filtering. But the third methodology is suitable to both. The combined results are clearly depicted in the table.

Table 5: Evaluative Measures of the Proposed techniques

S.No	Methods	Model	RMSE	MAE
1.	Existing Method	R - Based UCF	2.09	1.58
		R - Based ICF	3.55	3.36
2.	Proposed Method I	P - Based UCF	2.29	1.55
		P - Based ICF	**0.43**	**0.05**
3.	Proposed Method II	PR– Synthesized UCF	2.02	1.69
		PR– Synthesized ICF	**0.58**	**0.32**
4.	Proposed Method III	SPR– Synthesized UCF	**0.06**	**0.03**
		SPR– Synthesized ICF	**0.08**	**0.06**

The term UCF means User collaborative Filtering and ICF indicates the item collaborative filtering. The results show the RMSE and MAE value for each of the proposed methodology. The acceptable value of RMSE and MAE generally is up to 0.5. In our methodology, P – Based ICF has the RMSE of 0.4. and MAE of 0.05. Then for the PR – Synthesized ICF, the error rate is 0.58 and 0.32. Finally, for the SPR – Synthesized, The RMSE values are 0.06, 0.08 and the MAE are 0.03, 0.06 which indicates the more efficient and the accurate system.

There exists the reduction of RMSE and MAE as 1.83 and 1.5 respectively in the proposed method I. In the second methodology, the reduction is 1.44 and 1.39. The above things are based on the comparison of UCF and ICF in the relevant methodologies. While considering the method III, the reduction of RMSE and MAE was nearly 2% comparing to all the proposed and the traditional methodology. This proves the efficiency of the proposed model.

The difference in the error rate can be clearly indicated in the following chart.

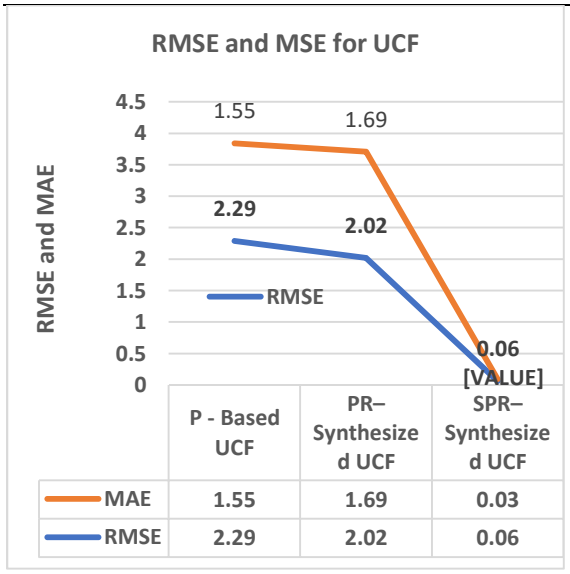

Figure 6: Performance of the Proposed Techniques for UCF

The figure 6 indicates that for the user based collaborative filtering, The SPR – synthesized collaborative filtering is more suitable as it indicates the minimum error rate of 0.06 and 0.03.

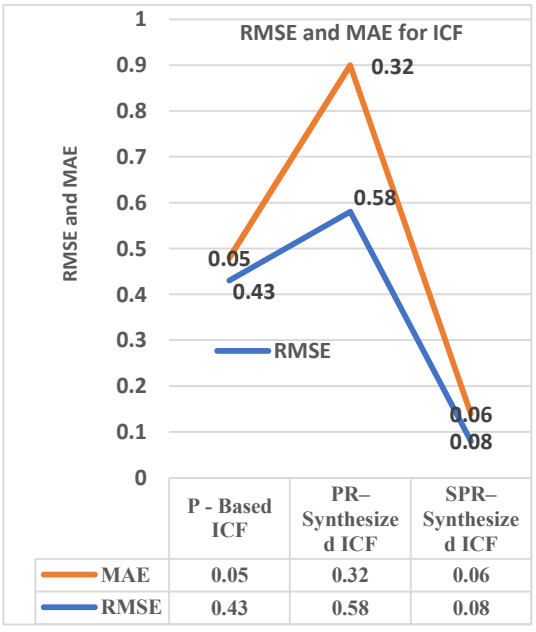

Figure 7: Performance of the Proposed Techniques for ICF

The chart in figure 7 means that all the three proposed methodologies are suitable for the item based collaborative filtering. The chart contains the labels of RMSE and MAE. In all the cases, the values are within the acceptable range.

6. CONCLUSION

The contribution of the recommendation system is unconditional in the modern society of digitalization. The major issue of this is the consideration of rating alone for recommending things using the collaborative filtering technique. This issue is addressed using the three methodologies proposed in this paper namely P – Based, PR – Synthesized and SPR – Synthesized. Here R indicates the rating given by the user, P means the polarity of the user comments and the S denotes the user sentiment that may be good or bad. These three parameters are taken into account for the similarity matrix construction. The methodologies are practically examined using the dataset available online. The result indicates that SPR – synthesized is an efficient technique for both the user as well as item based collaborative filtering. And particularly P – Based and PR – Synthesized is more suitable for the item based rather than the user based.

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