NEWS RECOMMENDER SYSTEM USING HYBRID CONTENT-BASED FILTERING AND COLLABORATIVE FILTERING

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ABSTRACT

The development of online news services has offered users numerous choices, resulting in information overload. This makes it challenging for users to locate desired news within a specific timeframe. To address this, recommender systems have been developed to help users discover and select news articles. These systems analyse user preferences and utilise various algorithms to suggest relevant information. Recommender systems have proven effective in domains like movies and music, enhancing user experiences and decision-making. This study presents a recommender system combining content-based filtering and collaborative filtering to provide accurate and diverse news recommenders. Content-based filtering suggests articles based on their attributes, while collaborative filtering analyses user behaviour and preferences. The system combines recommenders from both approaches using weighted ranking. Evaluation metrics, such as recall, assess the system's efficacy by measuring the proportion of relevant news articles suggested. The hybrid model outperforms individual approaches, with 0.5 in Recall@5 and 0.6 in Recall@10. The hybrid model that combines content-based filtering & collaborative filter models produces better performance than the two original models.

I. INTRODUCTION

The development of news on online services has provided users with many choices. One popular news agency service can provide a much greater volume or amount of communication than a user can digest. Information overflow resulting from the ability of the user to discover news is hindered when there are several news items because more recent news has been uploaded [1],[2]. The relationship between the time users require to search and read news recommended by the system is inversely proportional. Consequently, individuals encounter difficulty locating desired news content within a specific timeframe. Therefore, it is imperative to develop a recommender system that can assist readers in discovering and choosing news articles. A recommender system is a purpose-built system that helps users in achieving their objectives by providing suggestions for information that may prove beneficial. These suggestions may include reading materials or product recommenders [3], which can aid users in making more informed decisions and achieving their desired outcomes. The recommender system employs various algorithms to filter data and suggest the most pertinent information [4].

By analysing user interest preferences, recommender systems have become extremely useful for various domains, including movies [5], restaurants [6], and tourism [7]. The recommender system algorithm aims to provide recommenders based on user preferences and to assist users in locating the items they desire. Consequently, many businesses implement recommender systems to enhance the viewing experience, health-based adjustments, and decision-making efficiency [8].

An example of implementing a recommender system in applications such as the Netflix movie streaming service that analyses user data, preferences, ratings given by other users and user viewing history. Netflix can recommend content according to user interests and preferences [9]. This can help find exciting movies, increasing the fun and satisfaction of watching. Similarly, the news recommender system suggests articles to readers so that readers may locate information using data gathered from reading histories or based on the similarity of reading histories between one reader and another. This allows readers to access information more quickly. Readers may obtain information more quickly and easily thanks to a recommender system, which also helps them save time.

Asghar et al. [10] proposed using collaborative filtering with content-based filtering techniques for personalised news recommender, a customised news recommender framework called Hybrid Customized News Recommender (HYPNER), which includes both collaborative filtering and content-based filtering approaches. The name of this framework comes from its hybrid nature. The framework improves the accuracy of news recommenders by

overcoming the difficulties of scalability caused by massive news corpora, enriching the user's profile, reflecting the precise attributes and characteristics of news items, and proposing a vast collection of news items. Experiments for validation indicated that HYPNER obtained an 81.56% increase in F1-score and a 5.33% improvement in diversity compared to an existing recommender system.

Combining cosine similarity and Autoencoder (DAE) in the proposed by A. Manikantan [11] on Hybrid Recommender System for Video Games offers a powerful approach to enhance the recommender process. The system measures the similarity between game characteristics by utilising cosine similarity, allowing for effective content-based filtering. On the other hand, the Autoencoder (DAE) plays a crucial role in capturing implicit data representations of users' purchasing habits, enabling personalised recommender through collaborative filtering. By integrating these two techniques, the system leverages the strengths of both approaches, resulting in a more accurate and comprehensive game recommender for users.

Recommender system that utilises the bidirectional-encoder-representations-from-transformers (BERT) technique to model user behaviour sequences. This method was proposed by C. Channarong et al. [12]. by considering the target user's historical data, a content-based filtering (CBF) approach. The HybridBERT4Rec model leverages BERT for content-based filtering (CBF) and collaborative filtering (CF) to predict rating scores. In the context of recommender systems, Collaborative Filtering (CF) involves identifying users who share similar preferences with the target user. In contrast, Content-Based Filtering (CBF) entails extracting features from the target user's interactions with purchased items. The system utilises BERT with the ratings of other users who evaluated the target item as a secondary input to extract the attributes of the target item, thereby producing a profile of the target item. The system utilises both profiles to predict a rating score upon acquiring them. The model has undergone experimentation with three distinct datasets, and the findings indicate that it exhibits greater accuracy compared to alternative methodologies.

Based on the previous work, this study developed a recommender system that combines collaborative and content-based filtering techniques to offer precise and varied news recommender. Content-based filtering involves recommending articles by considering their intrinsic characteristics, whereas collaborative filtering involves examining user actions and preferences. The system integrates the suggestions derived from both methodologies by employing a rating system that assigns weights to each. Evaluation metrics, such as recall@5 and recall@10, are utilised to evaluate the efficacy of a plan by quantifying the ratio of recommended pertinent news articles. The paper is organised into distinct sections, each serving a specific purpose. The initial section provides an overview of the research topic, while the subsequent section delves into the relevant literature. The third section outlines the system architecture, and the fourth section presents the findings of the system test evaluation. Finally, the fifth section offers concluding remarks.

II. RESEARCH METHODOLOGY

The flow of news recommender system development can be seen in Figure 1. First, the content-based filtering system makes reading recommender based on category, title, abstract, and subcategory factors. This method extracts the intrinsic content of news articles. Collaborative filtering generates recommenders based on user behaviour and preferences by constructing a user-news matrix and employing Singular Value Decomposition (SVD) to extract latent factors. This paves the way for similarity estimates and recommenders based on user-shared characteristics. Finally, a weighted ranking is applied to the combined scores to integrate recommenders from content-based filtering and collaborative filtering. The resulting hybrid approach provides diverse and accurate news recommenders, improving user experience and engagement with the news platform. The system's efficacy is evaluated using metrics such as recall@5 and recall@10, which measure the proportion of pertinent news articles suggested to users. The recall statistic is computed at various rankings, comparing the suggested news IDs to the user's history. This evaluation assists in determining the efficacy of the recommender algorithms in recommending relevant news articles to consumers. The system also integrates user feedback through an interface, allowing the quality of the recommenders to be continuously enhanced.
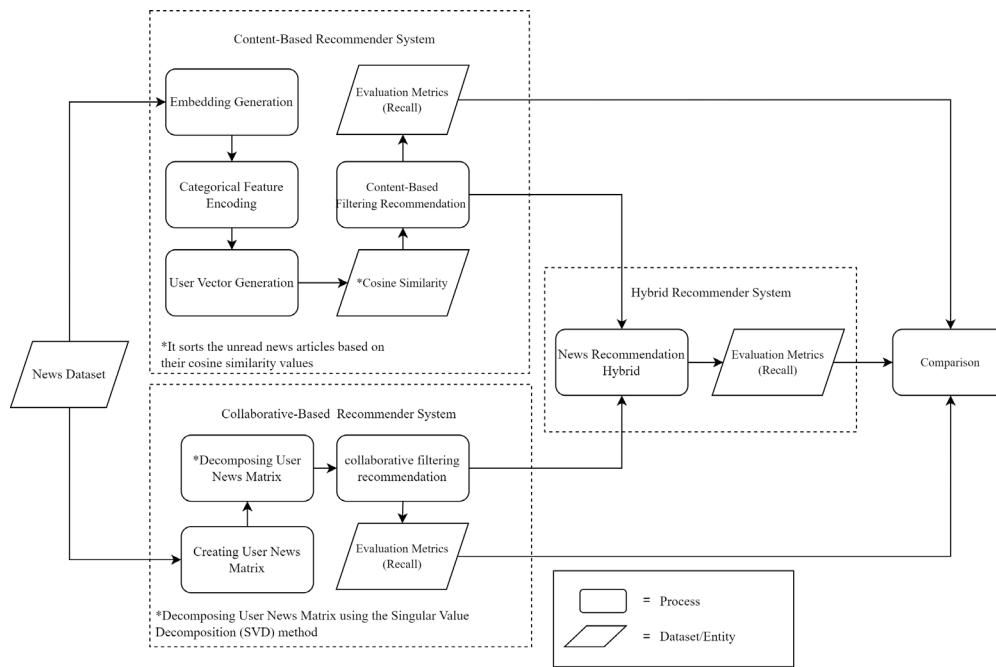
Figure. 1. System design overview

A. Content-Based Filtering Recommender System

A content-based filtering recommender system examines the content of items the user has previously engaged with and proposes comparable items that align with the user's preferences and interests [13]. The systems mentioned above employ item characteristics, such as genre, directorship, and cast members, to discern items resembling those that have already garnered user approval [14]. The system additionally offers elucidations for the generated recommenders and enables users to adjust their profile correspondingly, observing the direct impact of their modifications on the outcomes [13]. An illustration of a content-based filtering recommender can be seen in Figure 2.
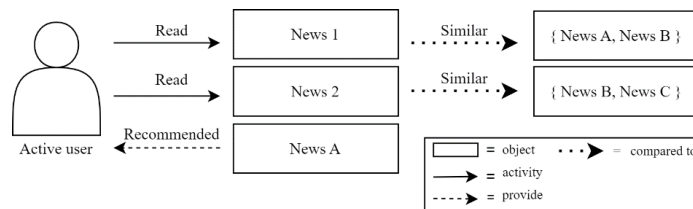

Figure. 2. Overview of content-based filtering recommender system

B. Collaborative Filtering Recommender System

A recommender system that operates collaboratively employs an analytical approach to determine items akin to those a user has previously favoured by scrutinising the inclinations and actions of numerous users [15]. An illustration is in Figure 3. The systems above employ collaborative filtering techniques to suggest things to users by analysing the preferences of other users with similar tastes. Using user ratings and item features to provide comprehensive and lucid explanations has been infrequently employed [16]. Recommender systems based on collaboration can address the cold start issue by leveraging comparable users' actions to provide suggestions. As per a survey conducted on recommender systems based on knowledge graphs, collaborative filtering has emerged as a conventional approach and a recent advancement in filtering techniques for such systems [17].
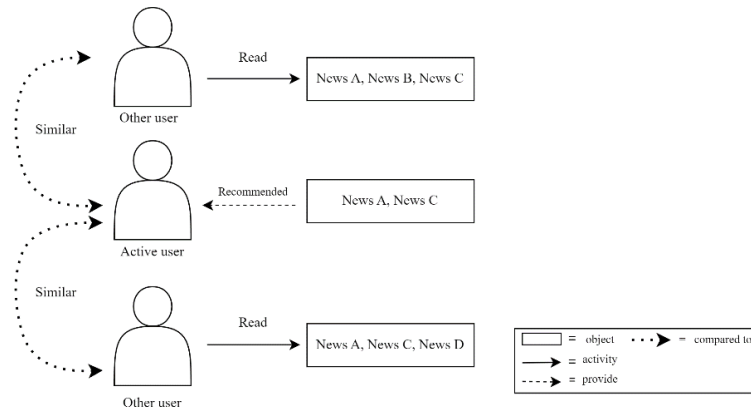
Figure. 3. Overview of collaborative recommender system

C. Hybrid Recommender System

A hybrid recommender system is an amalgamation of multiple recommender systems [18], including but not limited to content-based filtering and collaborative filtering recommender systems. The primary objective of such a system is to offer users a more comprehensive range of more precise and diverse recommenders. The utilisation of a hybrid approach has the potential to surmount the constraints inherent in singular recommender systems and capitalise on their respective advantages, thereby furnishing excellent recommenders [14]. An example of a hybrid system is a movie recommender that considers the user's prior viewing habits and the movie's content when making recommenders. Hybrid systems have a rich and successful history in recommender research, as shown by a study of knowledge graph-based recommender systems [17]. In addition, research into collaborative explanations based on features indicated that a hybrid recommender system using a feature-weighting mechanism performed better than traditional collaborative filtering and purely content-based filtering [14].

D. Cosine Similarity

The Cosine Similarity metric is a mathematical similarity measure applied to a pair of non-zero vectors within an inner product space. It quantifies the cosine of the angle formed between the two vectors. [19]. Information retrieval relies heavily on comparing a query and a document and finding how closely they match up. The cosine similarity score ranges from -1 to 1, with one indicating that the two vectors are identical, 0 meaning that the two vectors are orthogonal, and -1 indicating that the two vectors are opposed [19]. In content-based filtering, cosine similarity measures the similarity between two vectors, A and B, by calculating the cosine of the angle between them. The dot product of the vectors represents the similarity in direction, while the magnitudes of the vectors in the denominator account for their lengths [20]. The formula for cosine similarity can be outlined as seen below,

$$similarity(a,b) = \cos(\theta) = \frac{a.b}{||a||\,||b||} = \frac{\sum_{i=1}^{n} a_i b_i}{\sqrt{\sum_{i=1}^{n} a_i^2}\sqrt{\sum_{i=1}^{n} b_i^2}} \quad (1)$$

E. Singular Value Decomposition

Collaborative Filtering uses SVD to uncover hidden variables that affect user preferences by decreasing the dimensionality of the user-item matrix [21]. Recommenders are made to users based on the skeletal matrix. It has been shown that SVD-based Collaborative Filtering may provide reliable suggestions for users. SVD decomposes the user-item matrix into three matrices, U, Σ, and V, where U and V are orthogonal matrices, and "Σ" is a diagonal matrix containing the singular values of the original matrix [22]. The formula for SVD can be outlined as seen below,

$$M = U \sum V^T \quad (2)$$

F. Evaluation Metric

We use Recall@5 and Recall@10 to see how well the recommender system can remember important news people and tell them about it. Recall@5 and Recall@10 are evaluation metrics used in information retrieval to measure the effectiveness of a search algorithm. For example, suppose the system recommends ten stories to users based on their interests and history. In that case, Recall@5 will calculate how many of the top five stories are relevant and memorable to the user. This metric helps measure the system's effectiveness in providing recommenders matching

user preferences and how well the system captures the user preferences that are important in the first five recommenders.

III. RESULT AND DISCUSSION

A. Dataset

In this research, we use Microsoft News Dataset. The dataset was obtained from the website Kaggle.com which is https://www.kaggle.com/datasets/arashnic/mind-news-dataset in tsv format with embeddings of entities in the news extracted from knowledge graph and embeddings of relations between entities extracted from the knowledge graph, obtained by selecting 50000 User Id and their corresponding behaviour logs with 156965 Impression Id.

B. Content-Based Filtering Recommendation

In a content-based filtering recommender system that utilises user vectors, news embedding vectors, unread news articles, and cosine similarity, users can receive a recommender for the most relevant news based on their interests and preferences. The system analyses the user's reading history and calculates the average embedding vector of the previously read articles to form the user vector. Then, the system matches the user vector with the embedding vectors of the unread news articles and calculates the cosine similarity between them. The news articles with the highest similarity are recommended to the user, providing a personalised experience in discovering relevant news. Details of the news input are shown in Table 1.

TABLE I
THE EXAMPLE INPUT NEWS

News ID	Category	Title
N25567	Movies	The Fast and the Furious Director Rob Cohen Ac...
N12440	Movies	Trailer - One Last Night
N64498	Sports	PGA Tour winners
N2073	Sports	Should NFL be able to fine players for critici...

News with a high cosine similarity value will be recommended to users. Table 2 shows the results of news content-based filtering recommenders by entering the news ID used as input.

TABLE II
THE EXAMPLE OF CONTENT-BASED FILTERING RECOMMENDATION

News ID	Category	Title	Cosine Similarity
N36456	Sports	NFL sending message with multiple fines for cr...	0.005
N36282	Sports	NFL sending message with multiple fines for cr...	0.021
N36377	Sports	NFL cracks down on internal dissent over offic..	0.019
N41309	Movies	Trailer - The Report	0.059
N28811	Movies	Trailer - Scandalous	0.028
N46502	Sports	2019-20 PGA Tour tournament winners	0.007
N3051	Sports	Another week, another rules controversy as Eur...	0.008
N21157	Movies	Trailer - Full Count	0.085
N53870	Sports	Controversy erupts at Pinehurst following rule...	0.022
N64508	Sports	NFL Reviewing Myles Garrett's Helmet Swing In ...	0.028

C. Collaborative Filtering Recommendation

User with ID U10022 has 30 reading histories with categories of sports, tv, movies, lifestyle, autos, and news. Based on the user's reading history and similarities with other news, the system will generate a list of 10 recommended news articles designed to provide suggestions that align with users' interests and preferences, as inferred from their past reading behavior. The system analyses users' reading history and compares it with other news articles to discover similarities and provide relevant recommender. The system leverages the resulting user and news representations to determine recommender once the user-news matrix is created and decomposed using the SVD method. In this case, the system prioritises news articles that exhibit high similarity to users' preferences. Table 3 shows the results of the collaborative filtering news recommender.

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TABLE III
THE EXAMPLE OF COLLABORATIVE FILTERING RECOMMENDATION

News ID	Category	Title
N62058	Sports	What Tom Brady, Lamar Jackson Told Each Other ..
N27448	Sports	NFL world reacts to officials handing Packers ...
N40716	Tv	Lori Loughlin Is 'Absolutely Terrified' After ...
N4607	Autos	Cause determined in Jessi Combs' fatal speed r...
N16233	News	Felicity Huffman Is Scheduled to Be Released f...
N54827	News	Deer fatally attacks hunter who shot him
N51706	Sports	Former NFL lineman Justin Bannan arrested for ...
N55189	Tv	'Wheel Of Fortune' Guest Delivers Hilarious, O...
N58090	Sports	Frustrated Antonio Brown has active morning on...
N30353	Lifestyle	Photographer Crosses Paths With A Black Cat Un..

D. Result

In this research, we combine content-based filtering and collaborative filtering to provide targeted suggestions for each user. We give a weight of 0.5 to collaborative filtering and content-based filtering, which is used to make recommendations that will combine the contribution of the two methods with that proportion. The input for the system used is the user ID and news id. Recommendation results are sorted based on a combined rating between content-based filtering and collaborative filtering. Table 4 shows the results of hybrid news from content-based filtering and collaborative filtering recommenders.

TABLE IV
THE EXAMPLE OF HYBRID RECOMMENDATION

News ID	Category	News Recommendation
N30353	Lifestyle	Photographer Crosses Paths With A Black Cat Un …
N58090	Sports	Frustrated Antonio Brown has active morning on ...
N55189	Tv	'Wheel Of Fortune' Guest Delivers Hilarious, O...
N51706	Sports	Former NFL lineman Justin Bannan arrested for ...
N41309	Movies	Trailer - The Report
N16233	News	Felicity Huffman Is Scheduled to Be Released f...
N21157	Movie	Trailer - Full Count
N40716	Tv	Lori Loughlin Is 'Absolutely Terrified' After ...
N27448	Sports	What Tom Brady, Lamar Jackson Told Each Other ..
N62058	Sports	NFL world reacts to officials handing Packers ...

Based on the results displayed in Figure 4, the hybrid model that combines content-based filtering & collaborative filtering models produces better performance than the original models, content-based filtering and collaborative-based filtering. The system performs better than content-based filtering and collaborative filtering strategies, as evidenced by its Recall@5 score of 0.5 and Recall@10 score of 0.6. This suggests that it has the potential to offer more substantial opportunities for the provision of personalised and relevant news recommender. The content-based filtering recommender system achieved 0.4 recall@5 and recall@10, indicating a decent performance, whereas the collaborative filtering system lagged with 0.135 Recall@5 position and 0.27 Recall@10. Therefore, a hybrid approach proved the most effective in improving the news recommender process.
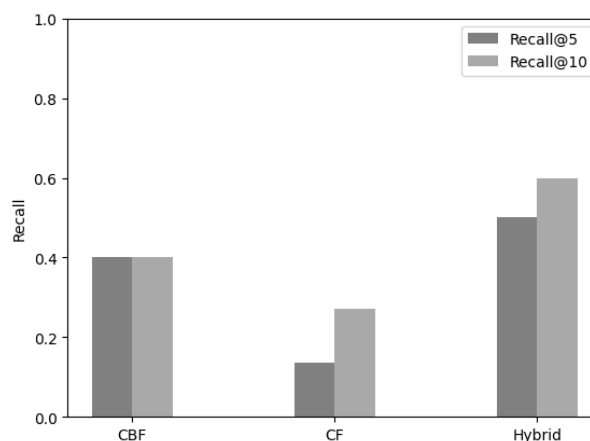

Figure. 4. Comparison of recall@5 and recall@10 content-based filtering, collaborative filtering and hybrid

We utilise a hit-rate metric to compare if any news suggestion results in the reader's click history are purposefully

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left out to assess the effectiveness of the recommender system and ascertain whether the reader clicked the recommender results. The number of reader-recommended top-N news items that get the most clicks is used to calculate accuracy using hit rate. The number of hits is 1. If the reader selects one of the top-N news suggestions, we divide the total number of readers by the number of hits received from all readers. The algorithm's ability to propose news to readers depends on how close it is to 1, while its inability depends on how close it is to 0. The hit-rate calculation formula is as follows,

$$Hit\ Rate = \frac{total\ hit}{total\ recommendation} = \frac{71356}{142691} = 0,50 = 50,0\% \qquad (3)$$

Hybrid content-based filtering and collaborative filtering show that half of the recommendations follow user preferences and perform better than the original models. Content-based filtering uses content information from news story titles, abstractions, categories, and news subcategories to make recommendations that are relevant to user interests. Collaborative filtering leverages other users' behaviour patterns and preferences to generate similar recommendations. Combining content-based filtering and collaborative filtering can improve recall which refers to the system's ability to remember or find relevant recommendations in the top recommendations. According to research conducted by Roy et al. [23], a hybrid method improved recall by 11.5% compared to the collaborative methods. Other researchers, Rostami et al. [24], developed a hybrid food recommender system that can improve recall by 11.8% on average compared to a user-based phase alone. These studies are interesting and worthy of further study and adoption in developing research on news recommender systems.

IV. CONCLUSION

Based on our evaluation results and comparison recall, we conclude that the hybrid model combining content-based filtering and collaborative filtering news recommender systems outperforms the original model. In this study, we used the Microsoft News Dataset, which took a random sample of 50,000 users and analysed their behaviour logs. It reveals that the hybrid model achieves a recall of 0.5 in Recall@5 and 0.6 in Recall@10, surpassing both content-based and collaborative filtering models. The content-based filtering recommender earned a recall of 0.4 in both positions, while the collaborative filtering model lagged with 0.135 in Recall@5 and 0.27 in Recall@10. The most effective hybrid approach offers improved news recommender performance and can recommend the ten best news stories and produce performance with an accuracy of 50,0%. We suggest using another alternative model for hybrid recommenders and other evaluation metrics. Using other evaluation metrics as a guide, researchers can experiment with different parameter values and determine the optimal combination that produces the best results.

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