

Optimizing E-Library Engagement with Hybrid Recommender System

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Abstract - With growing reliance on digital libraries, personalized recommendation systems have become essential for enhancing user experience and resource accessibility. This study presents a hybrid recommender model designed to optimize e-library engagement among university students by providing tailored book suggestions based on user preferences and activity patterns. The model integrates Cosine Similarity and Term Frequency-Inverse Document Frequency (TF-IDF) to enhance the accuracy and relevance of recommendations. The system was developed using Python with Django framework for backend and JavaScript with the React framework for the frontend interface. To assess its effectiveness, a structured questionnaire was distributed via Google Forms to 120 randomly selected students, evaluating key performance indicators such as recommendation accuracy, usability, and overall user satisfaction. Experimental results indicate that the model achieved a 95% accuracy rate in recommendations, with participants expressing high satisfaction regarding its precision and ease of use. These findings underscore the significance of hybrid recommender systems in advancing e-library accessibility, promoting user engagement, and facilitating seamless knowledge discovery.

Keywords: E-Library, Personalized Recommendation Systems, E-library, Open Library

I. INTRODUCTION

The proliferation of digital information and e-commerce has significantly increased the adoption of recommendation systems (RS) over the past decade. These systems leverage advanced data analysis techniques to help users identify relevant items within vast datasets [1]. In the academic domain, RS have proven essential in scientific libraries, enabling efficient discovery of research materials. Libraries, as critical hubs of knowledge, have undergone a digital transformation, integrating expert systems and artificial intelligence to enhance information management [2]. This shift has given rise to Digital Library Systems (DLS), which merge the functionalities of traditional libraries with distributed information systems [3].

Despite these advancements, many libraries still lack intelligent recommendation mechanisms, relying on passive user interactions that fail to meet the growing demand for personalized and dynamic services [4]. Without effective search and recommendation tools, students face challenges in navigating vast academic resources, particularly in interdisciplinary studies where access to department-specific e-libraries may be limited.

This study addresses these challenges by exploring the implementation of a hybrid recommendation system tailored to the evolving needs of students at Obafemi Awolowo University. By leveraging user data and personalized recommendation algorithms, the proposed system enhances resource discoverability, ensuring equitable access to relevant academic materials across disciplines. This approach aligns with the broader goal of improving digital library accessibility and user engagement through intelligent, data-driven solutions [2].

University e-library systems often operate in isolated departmental silos, limiting accessibility for students engaged in interdisciplinary studies. This fragmented structure leads to unequal resource distribution and increases the time required to locate relevant academic materials. Despite advancements in digital technology, many existing systems fail to leverage intelligent recommendation techniques, resulting in inefficient search experiences and a lack of personalized book suggestions. This study proposes the development of a centralized e-library system incorporating an advanced recommender model, enabling students to access resources based on their primary academic interests while allowing for expanded recommendations tailored to their fields of study.

II. REVIEW OF RELATED WORKS

This section systematically reviews prior research in areas such as automation and library management, recommendation systems, machine learning for predictive analytics, and web-based digital libraries, while underscoring the need for a centralized,

intelligent e-library system that enhances search efficiency and resource accessibility through personalized recommendations.

Automation played a crucial role in streamlining library operations, reducing manual workload, and enhancing accessibility. The work of [5] integrated IoT and RFID technology to automate the book return process, significantly reducing human intervention and improving efficiency. Similarly, [6] designed a robotic assistant with a laser pointer to help users locate books. However, its functionality was hindered in crowded spaces, highlighting the need for enhanced navigation features. In the work of [7], a web-based integrated library system incorporating security features was developed, but performance overhead issues limited its efficiency. These studies illustrate the benefits of automation in library management but fail to address the need for user-centric, intelligent retrieval systems that go beyond process optimization to improve search and recommendation capabilities.

Recommender systems have emerged as a key solution to addressing the challenge of resource discovery in digital libraries. A TF-IDF-based content recommendation system was implemented in [2], achieving 80% accuracy in book suggestions. While this approach improved personalization, it was limited to content-based filtering, which struggles with sparsity and cold-start problems. Also, a hybrid recommender system combining ontology-based, cluster-based, and interest-based techniques was developed [8]. Despite improving recommendation quality, challenges with terminology mismatches persisted. The work of [9] introduced a Probabilistic Memory-based Collaborative Filtering (PMCF) model to tackle the “new user problem” by querying users for additional information. These studies demonstrate advancements in recommendation models but highlight a gap in fully integrated, personalized systems that adapt dynamically to users’ evolving academic interests.

Machine learning has been applied to optimize various aspects of digital library systems, particularly in resource availability prediction and information retrieval. [10] employed machine learning models, including Random Forest, SVM, and ANN, to predict book availability, with ANN achieving the highest accuracy (91%). However, dataset imbalance limited the effectiveness of predictions for less frequently borrowed books. [11] explored content-based filtering with agent-learning strategies, leveraging multi-agent collaboration to improve search outcomes. While these models demonstrate the potential of AI-driven analytics, existing studies lack an emphasis on integrating machine learning with recommender systems to create a more personalized and efficient e-library experience.

The shift toward web-based digital library systems has improved accessibility but often lacks intelligent recommendation mechanisms. A web-based e-library platform for multimedia resources was developed in [12], addressing challenges related to physical space and availability. Shazad and Alwozaibi (2017) designed HodHood, a single-page Islamic Sciences e-library application, improving searchability through modern web technologies. While these systems provide enhanced access to digital resources, they do not incorporate advanced recommendation features tailored to users’ academic interests, leading to inefficient resource discovery.

Existing studies have demonstrated progress in automation, recommendation models, machine learning, and digital accessibility; however, a pressing gap remains in the development of a unified, intelligent e-library system that reduces search time and enhances accessibility through personalized recommendations. It is noted that in most universities, the separation of departmental e-libraries presents a significant challenge for students navigating multiple disciplines, highlighting a pressing need for a more integrated and intelligent e-library system that reduces search time and enhances resource accessibility through personalized recommendations. Also, current systems either lack robust recommendation models, rely on limited filtering techniques, or fail to integrate AI-driven analytics for dynamic personalization. Additionally, a preliminary investigation was conducted on existing departmental e-libraries at Obafemi Awolowo University. The findings revealed that each department operated separate repositories, leading to fragmented access to learning materials, particularly for students engaged in interdisciplinary studies. The existing systems were noted to lack personalized recommendation mechanisms, resulting in an inefficient and suboptimal user experience. In addressing the gaps, this study proposes a centralized e-library system incorporating an advanced recommender model that enables students to access resources based on their primary academic interests, receive expanded recommendations tailored to additional fields of study, and benefit from adaptive machine learning models that improve recommendations based on evolving user preferences.

III. METHODOLOGY

This section relates the methods used in this study. The data set from the Open Library API was used. Open Library API is a publicly available repository that provides extensive book-related metadata, including titles, authors, and genres.

A. Collaborative Filtering (CF) Method

Collaborative Filtering focuses on user interactions with the system, such as the books they have rated or viewed. The CF method uses these interactions to predict books that a user might like based on the preferences of similar users. Specifically, CF identifies patterns in the behavior of users who have similar tastes and recommends books accordingly. The predicted rating for a user u and a book i , denoted $\hat{r}_{u,i}$, is calculated as:

$$\hat{r}_{u,i} = \bar{r}_u + \frac{\sum_{v \in U} w(u,v) \cdot (r_{v,i} - \bar{r}_v)}{\sum_{v \in U} |w(u,v)|}$$

$\bar{r}_u$ is the average rating of user u

$r_{v,i}$ is the rating given by a similar user v for item i

$w(u,v)$ is the similarity between users u and v
 U is the set of users who have rated item i

This approach ensures that recommendations are driven by user behavior and provides personalized suggestions based on the preferences of similar users.

B. Content-Based Filtering (CBF) Method

Content-Based Filtering, on the other hand, focuses on the attributes of the books themselves and how they match the user's stated preferences. Each book is represented by a vector of features (e.g., genre, author, title), while each user has a preference vector derived from their profile (e.g., academic discipline and additional interests). The system calculates the similarity between a user's profile and a book's attributes using cosine similarity:

$$(u,i) = \frac{\vec{u} \cdot \vec{i}}{|\vec{u}| |\vec{i}|} = \frac{\sum_{j=1}^n p_j \cdot f_j}{\sqrt{\sum_{j=1}^n p_j^2} \sqrt{\sum_{j=1}^n f_j^2}}$$

This score reflects how well the book matches the user's interests, helping the system recommend books that align with the user's profile. CBF ensures that book suggestions are based on the content that matches the user's preferences.

C. Hybrid Approach

To leverage the strengths of both Collaborative Filtering and Content-Based Filtering, we implemented a hybrid recommendation model that combines the two approaches. The final recommendation score for a user u and a book i is calculated as a weighted combination of the CF and CBF scores:

$$Score_{u,i} = \alpha \cdot \hat{r}_{u,i} + (1 - \alpha) \cdot s(u,i)$$

Where:

$\hat{r}_{u,i}$ is the predicted rating from CF ,

u,i

$s(u,i)$ is the similarity score from CBF

α is a weighting factor that determines the contribution of each method

This hybrid approach allows the system to provide more comprehensive recommendations by considering both the user's interaction history (via CF) and their explicit preferences (via CBF). The weight can be adjusted to prioritize either method, depending on the user's behavior or the specific recommendation context. The hybrid recommendation system was implemented using Python (Django) for the backend and JavaScript (React.JS) for the frontend. The system's backend manages user data, including interaction history (rated and viewed books), and dynamically updates user profiles during registration and usage. For personalized recommendations, the system applies a combination of cosine similarity and Term Frequency-Inverse Document Frequency (TF-IDF) to match user preferences with book metadata. TF-IDF helps quantify the relevance of terms in book descriptions, enabling the system to recommend books that align with user interests.

To maintain data accuracy and diversity, the system was designed to automatically update its local database by periodically retrieving new book records from the API, ensuring that the recommendation system remained current and consistent. A periodic task to add new books into the local database from the Open Library API was created in the backend to ensure consistent and updated book records in the database. Figure 1 depicts the proposed recommendation system architecture that personalizes book suggestions using a hybrid approach, combining collaborative filtering (user behavior) and content-based filtering (book content and user interests).

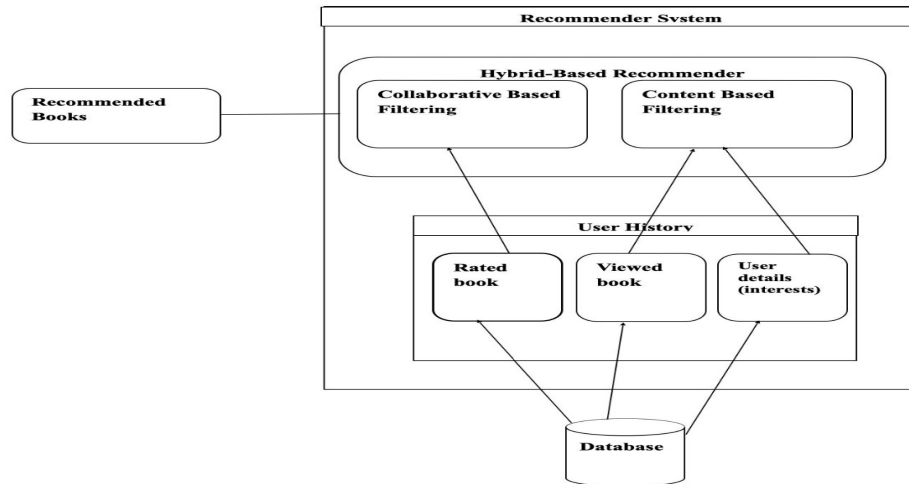


Fig 1: Proposed E-library Recommender Model

The user history module stores user interactions, including rated books (explicit preferences), viewed books (implicit feedback), and user details/interests (main and additional interests). The database acts as a repository for user interactions and preferences. Collaborative filtering finds similarities between users and recommends books based on shared preferences. Content-Based Filtering suggests books by analyzing a user's academic and additional interests. By combining both methods, the proposed system bridges the divide between traditional library searches and modern expectations for intelligent, personalized resource discovery. The system delivers efficient, relevant, and personalized book recommendations, improving search time and accessibility for students. The class diagram is as shown in Figure 2. The diagram defines key system components and their

interactions, having four main classes as follows: User class—represents students or faculty members, storing details like username, email, interests, and reading history. It provides methods for login, logout, profile updates, and book requests. Book class—represents digital books with attributes like ISBN, title, author, and publication date. Methods allow searching, viewing, saving, and rating books. Library class—represents the e-library system, managing book collections and borrowing history. It includes methods for searching, browsing, and adding books. Recommendation class—handles book recommendations, storing suggested books and reasons for recommendations. It includes methods for generating and viewing recommendations. This class diagram structures the system to efficiently manage users, books, library functions, and personalized recommendations.

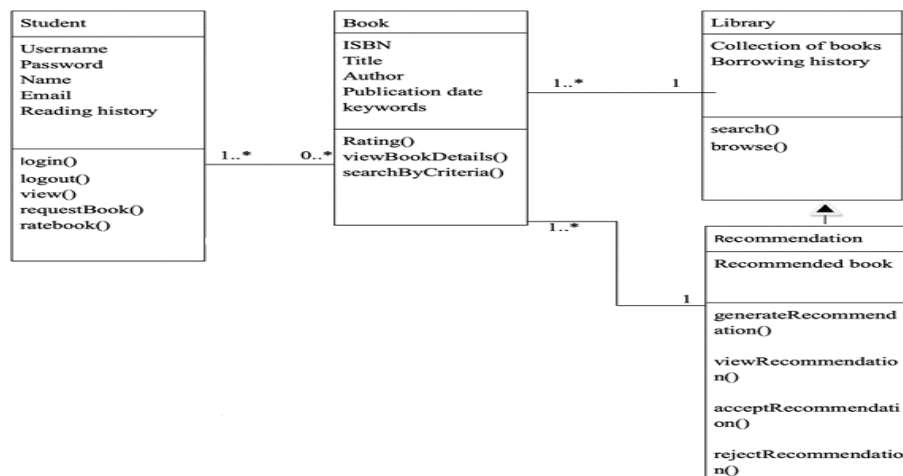


Fig 2: Class Diagram for the E-library Recommender Model

IV. TESTING

The system incorporates content-based filtering, collaborative filtering, and a hybrid approach to offer personalized book recommendations to users. The user profile and interests were captured during registration, the book data source is from Open Library, and the future improvements that can be made to enhance the system further. In the user profile registration, users are required to provide their main course of interest, ensuring that the recommendation system tailors book

suggestions to their academic interests. After a successful login, users have the flexibility to update and modify their main interest and add other interests within their profile settings. This feature empowers users to explore a diverse range of book recommendations, transcending their academic pursuits and making the system more versatile and accommodating to individual preferences, as depicted in Figures 3 and 4.

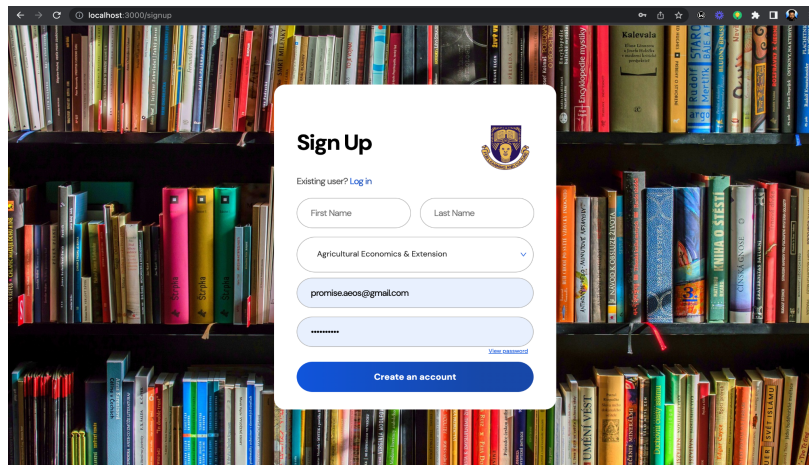


Fig 3: Registration/Sign Up page

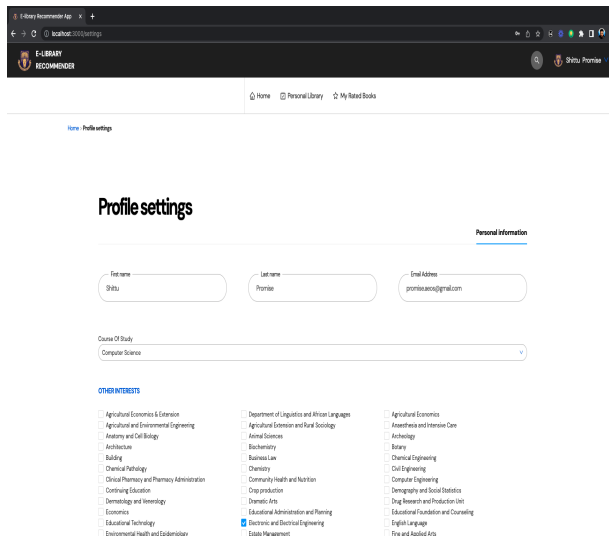


Fig 4: Profile Settings Page

Rigorous testing was conducted using a diverse dataset of books. The results are presented as follows: A content-based filtering algorithm recommends books based on the similarity between the user's recently

viewed book and other books in the system by calculating the cosine similarity scores for title and interest matches, generating a rank score representing the similarity. In the most recent update, we have introduced a condition that includes only book recommendations with a rank score greater than 0.5. This adjustment ensures that the recommendations provided are highly relevant and valuable to the user. Collaborative filtering suggests books based on the preferences and activities of other users who share similar interests. By analyzing the user's recently saved book and comparing it with other users' book choices, the system generates a rank score to assess similarity. Similar to content-based filtering, the collaborative filtering algorithm now filters recommendations based on a rank score threshold of 0.5. This modification successfully provides relevant and meaningful book recommendations to the user. The hybrid recommender combines content-based and collaborative filtering techniques to deliver enhanced recommendations. By leveraging the strengths of both approaches, the hybrid recommender ensures that only the most relevant and high-quality book suggestions are presented to the users. The filtering of recommendations based on a rank score greater than

0.5 has significantly improved the performance and accuracy of the hybrid recommender. The results of the recommendations with pagination capabilities are as presented in Figures 5 and 6.

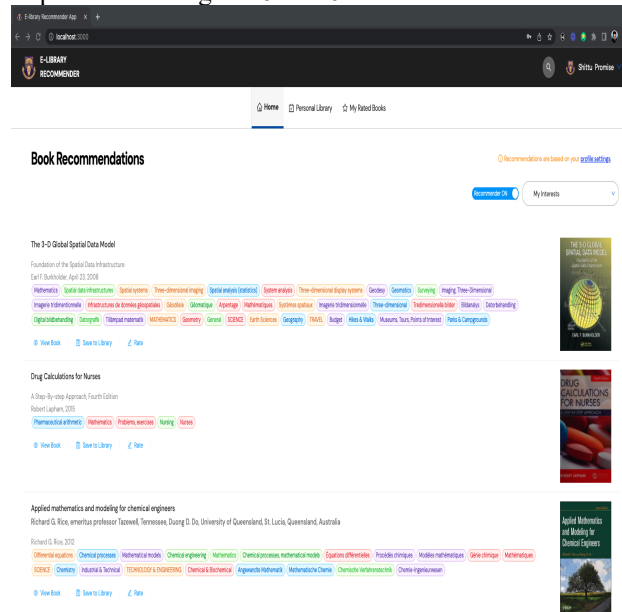


Fig 5: Result Recommendations Page

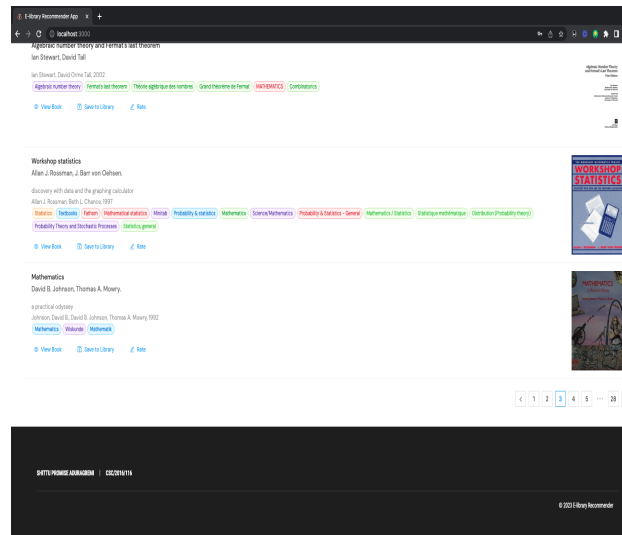


Fig 6: Results with Pagination

The system filters recommendations based on a rank score threshold, ensuring that only the most relevant and valuable suggestions are included. This approach further enhances personalization, accuracy, and performance. The integration of user profiles and interests during registration and the ability to update them later in the profile settings significantly contribute to the system's ability to cater to individual preferences. Users can explore a wide range of book recommendations tailored to their academic pursuits and additional interests. Utilizing the Open Library

API as the book data source guarantees a diverse and comprehensive collection of books across various genres and subjects. This choice of data source enriches the quality and variety of book recommendations provided to the users and enables the implementation of a search functionality to query the populated database as seen in Figure 7. Users can save books to their personal library to serve as their own personal collection of books. A confirmation pop-up shows if a user really wants to add a book to his/her personal library on clicking the “save book button.”. Users can also rate books by adding comments on a particular book. A form to enter a comment text is displayed when a user clicks to rate a book. Users can also see an organized list of rated books in a separate section of the app sorted by recently rated ones, as seen in Figure 8.

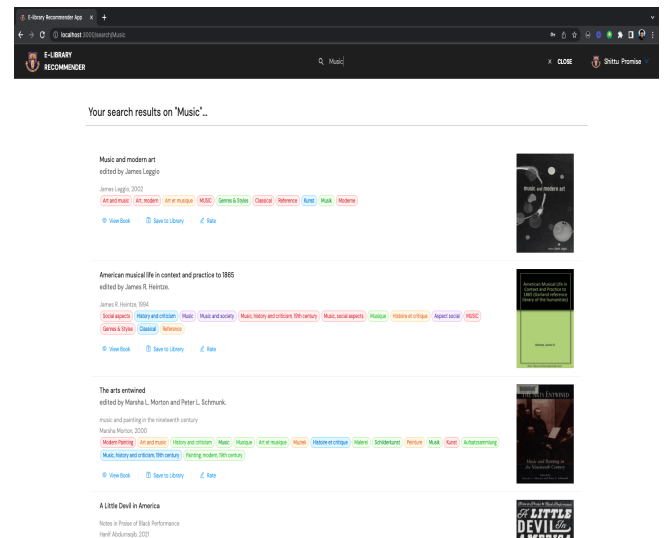


Fig 7: Search Results

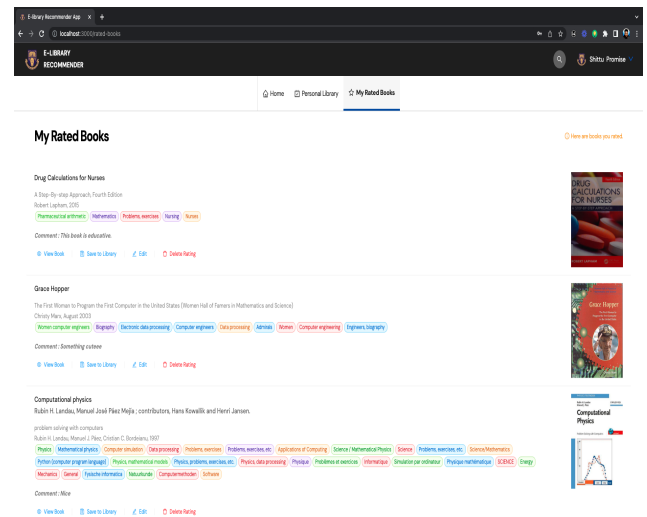


Fig 8: Rated/Liked Book Listings

V. DISCUSSION

The evaluation involved a thorough examination of a substantial dataset consisting of 2,661 book records obtained from the Open Library API. This dataset was carefully curated to encompass a wide range of academic disciplines, ensuring representation of diverse topics from various departments. This process was carried out in two key dimensions. Firstly, the search functionality of the system was scrutinized to assess its ability to efficiently retrieve relevant books based on user queries. This aspect examined the system's accuracy in providing meaningful search results tailored to users' specific interests and academic needs. Secondly, the evaluation focused on the generation of personalized book recommendations. The system's effectiveness in analyzing user preferences and delivering tailored book suggestions was thoroughly assessed. This involved analyzing the semantic similarities between book titles and user interests, leveraging technologies such as cosine similarity and TF-IDF representation to ensure precise and relevant recommendations. Throughout the evaluation, the system consistently demonstrated impressive accuracy in both search functionality and personalized book recommendations. The e-library recommendation system's use of a rank score threshold significantly improved both personalization and accuracy, optimizing the system's performance. With the Open Library API dataset, the hybrid recommender system successfully met the challenge of information overload, efficiently guiding users to discover materials aligned with their academic disciplines. User satisfaction was also considered a vital aspect of the evaluation. Users were not only impressed with the accuracy of the recommendations but also delighted by the user-friendly interface, making the entire book discovery process intuitive and enjoyable. One of the key findings is that the system's recorded an impressive book recommendation accuracy of 95%, as demonstrated as shown in Figure 9. This high level of precision underscores its ability to provide students with books aligned closely with their interests and needs. Additionally, the result showcase the system's excellence in search functionality, with 73.3% of respondents expressing their utmost satisfaction, as depicted in Figure 10.

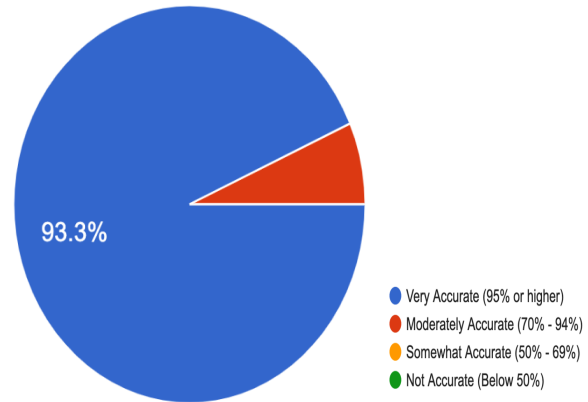


Fig 9: Book Recommendations Accuracy

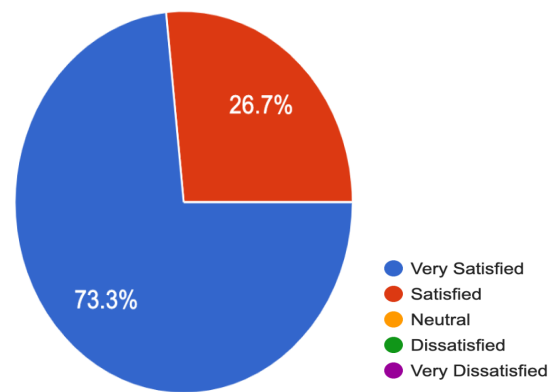


Fig 10: Search Functionality Satisfaction

80% of the participants attested that the personalized book recommendations aligned with their individual preferences, a testament to the system's adaptability as seen in Figure 11.

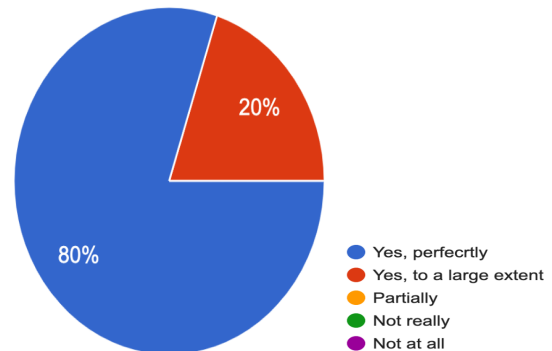


Fig. 11: Preferences Evaluation

The system's prowess in suggesting books that resonated with respondents' main interests was evident, with 60% reporting frequent occurrences and 33.3% experiencing it often, as illustrated in Figure 12.

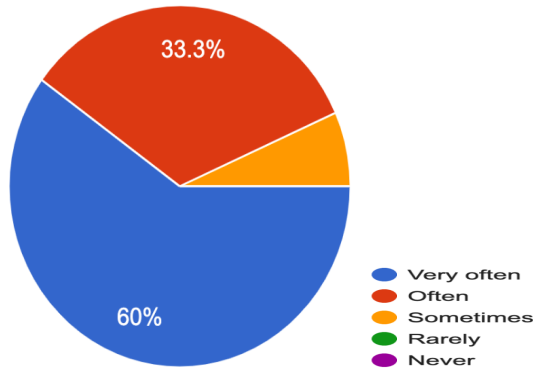


Fig. 12: Relevance Evaluation

Remarkably, 86.7% of users expressed extreme satisfaction with the recommender system's overall performance, as shown in Figure 13.

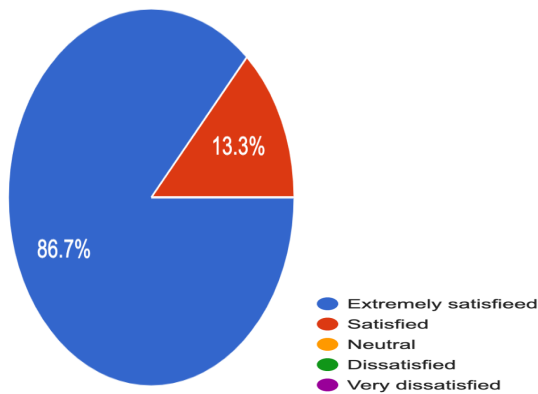


Fig 13.: Hybrid Recommendation Satisfaction

Another noteworthy discovery was that 100% of respondents found the system striking an optimal balance between content-based and collaborative filtering recommendations, highlighting its versatility as depicted in Figure 14.

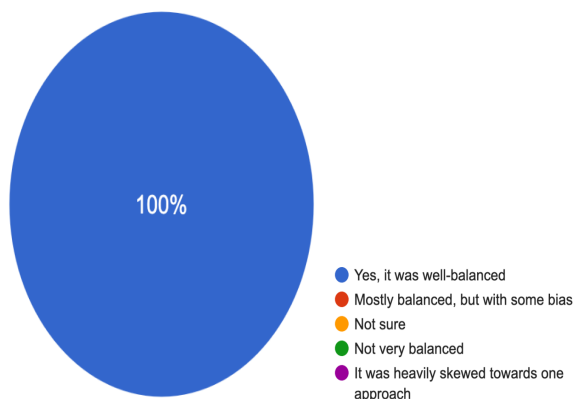


Fig 14.: Recommendation Balance

Moreover, 73.3% of the participants were delighted to have discovered new and relevant books through the system that were previously unknown to them and an overwhelming 86.7% of respondents acknowledged the system's effectiveness in catering to their academic interest.

In summary, the evaluation results unequivocally affirm the value of our hybrid recommender system in enhancing the academic journey. Its precision, user-friendliness, and ability to provide personalized recommendations have significantly contributed to a richer and more efficient exploration of academic resources within the e-libraries. This research provides a strong foundation for the continued development and implementation of advanced recommendation systems in educational settings.

VI. RECOMMENDATION

Future research should focus on refining hybrid recommendation models, improving dataset diversity, and incorporating real-time user feedback mechanisms to create a truly adaptive and efficient digital learning environment.

VII. CONCLUSION

The e-library recommendation system has demonstrated its effectiveness in offering personalized book recommendations to users. By leveraging various filtering techniques and a diverse book dataset, the system ensures that users receive book suggestions aligned with their interests and preferences. The integration of user profiles and interests during registration and subsequent updates allows for dynamic adjustments to user preferences, enhancing the system's personalization. Furthermore, the combination of content-based and collaborative filtering in the hybrid approach has proven successful in delivering high-quality recommendations. The introduction of a rank score threshold for filtering ensures that only the most relevant and valuable suggestions are presented to the users, thereby improving the overall user experience.

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