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Leveraging Machine Learning to Enhance Student Engagement in Campus Applications

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Abstract: Access to essential services is a vital need for students who migrate to other places. While access to essential services is crucial for students relocating, simply providing access falls short of fostering a sense of belonging. Existing platforms lack localized information as well as personalization. This paper proposes an open platform that streamlines access to campus services while offering a personalized experience through machine learning. The platform streamlines access to services such as housing, dining, and marketplace while providing a personalized experience. The platform provides an interface for both students and service providers, allowing providers to gain insights and improve their businesses as well. The proposed system tackles common drawbacks faced by existing recommendation systems by employing a hybrid recommender system. The system follows a service-oriented architecture developed using microservice architecture, which allows services to be independent and makes the platform scalable. The platform addresses limitations of traditional recommendation systems by utilizing a hybrid approach, which results in better accuracy in recommendations than existing systems.

Keywords: Campus Services, Machine Learning, Recommendation systems, hybrid recommendation, personalization, open platform, scalability, service-oriented architecture.

I. INTRODUCTION

As per the recent Census, 54 lakh students migrate within India for higher education. These students often face difficulty in navigating through their new homes and accessing essential services such as housing and dining. Various platforms that aid in enabling access to such services are of no avail as they cater for a wider audience and are insufficient in fulfilling the needs of migrating students. Most of these platforms also lack locale-specific data and personalization.

A platform specifically catered to students could drastically improve their lifestyle and save time spent in trial and error of using services to find ones that satisfy personal needs. This can be achieved by personalization using machine learning techniques such as recommendation systems. Current platforms use recommendation algorithms such as content-based filtering and collaborative filtering. These face certain drawbacks such as the cold start problem, data sparsity, scalability, lack of context-aware recommendations, popularity bias, overspecialization, and poor temporal dynamics. The system proposed in this paper tackles these issues using a hybrid recommendation system comprised of both collaborative and content-based filtering with context-aware filters.

A. Background

With increasing student migration for higher education across India, many face difficulties accessing essential services like housing, dining, and local marketplaces. Existing platforms often lack personalization and contextual awareness, making them ineffective for student-specific needs. This leads to inefficiencies, frustration, and a poor campus experience. Advances in Machine Learning—particularly hybrid recommender systems combining content-based and collaborative filtering—present a powerful solution. These systems can deliver personalized, context-aware suggestions even in data-scarce conditions. When deployed using scalable microservice architecture, they enable efficient, modular, and student-centered platforms. Such intelligent systems can streamline campus resource access, enhance student engagement, and promote sustainability through a unified digital interface.

B. Motivation

As students transition to new educational environments, they are often met with the challenge of navigating unfamiliar services and infrastructure. While digital platforms exist for housing, dining, and second-hand marketplaces, they generally cater to a generic audience and lack features tailored to student-specific needs such as budget constraints,

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proximity to campus, and personalized preferences. This gap results in time-consuming searches, poor service matching, and an overall fragmented campus experience. The motivation behind this work is to bridge this gap by developing a unified platform that intelligently connects students to essential services. By leveraging machine learning, specifically hybrid recommendation systems, the platform can adapt to user behavior and deliver personalized suggestions in real-time. The goal is to create an inclusive, scalable, and data-driven solution that not only enhances accessibility but also improves student satisfaction and engagement across campus life.

C. Objectives

The objective of this research is to create Campus Core, an Android application based on machine learning that centralizes access to essential campus services such as housing, dining, peer-to-peer marketplaces, and academic scheduling. The platform aims to provide a personalized and context-aware experience for students by implementing a hybrid recommendation system that combines content-based and collaborative filtering techniques. Built using a microservice architecture, Campus Core is designed to be modular, scalable, and adaptable to different institutional environments. Through intelligent recommendations and seamless service integration, the application seeks to enhance student engagement, promote sustainability, and streamline daily campus interactions, ultimately improving the overall quality of campus life for students.

D. Contribution

This research presents *Campus Core*, an Android-based platform that integrates multiple essential campus services into a single, student-centric application. The key contributions of this work are as follows:

- Implementation of a Scalable Microservice Architecture enabling modular deployment and independent service updates, ensuring better performance and adaptability across different campuses.
- Introduction of a Unified Platform that addresses fragmented access to student services by streamlining housing searches, dining preferences, and sustainable peer-to-peer exchanges within a single interface
- Development of a Hybrid Recommender System that combines content-based and collaborative filtering with context-aware mechanisms to deliver personalized suggestions for housing, dining, and marketplace services.
- Integration of an ease-to-use interface to improve usability and accessibility so that campus services can be readily accessible to students.

II. RELATED WORK

In recent years, digital platforms designed to support student needs on campus have gained attention. These platforms focus on various domains like housing, dining, peer-to-peer resource sharing, and academic scheduling, each addressing different facets of the student experience. However, most existing solutions are limited in scope, lack personalization, or do not fully integrate various student services into one accessible platform. Below is a review of relevant works that inform the design and objectives of Campus Core.

Housing Platforms for Students- Multiple platforms focus on assisting students in finding housing, both on and off campus. Applications like Uniplaces and HousingAnywhere provide databases of available housing options but often lack personalization features tailored to the specific preferences of each student. Studies have shown that students benefit from platforms offering personalized search options that accommodate unique preferences such as location, budget, and housing type (Smith & Johnson, 2020). Campus Core enhances this concept by integrating personalized filters and Google Maps functionality to streamline the housing search process based on individual preferences [1].

Dining Recommendation Systems-Dining platforms like Yelp and Zomato offer extensive restaurant and food service options, incorporating user reviews and ratings to inform decisions. However, these applications are not tailored to the specific needs of student populations, such as cost-effective meal options, proximity to campus, or dietary requirements. Recent research emphasizes the effectiveness of recommendation algorithms, such as collaborative filtering, in tailoring food choices to user preferences (Lee & Kim, 2019). Campus Core leverages collaborative filtering to suggest dining options based on students past interactions, providing a more curated dining experience for campus life [2].

Peer-to-Peer Marketplaces for Students-Platforms like Facebook Marketplace and Letgo allow users to buy and sell items locally but are not exclusively designed for students. Student-specific needs, like affordable textbooks or stationery, are often overlooked. CampusHub (Gomez et al., 2021) explored the potential for a dedicated marketplace for students, focusing on sustainable consumption within college communities. While effective, it lacked user-friendly integration with other student services. By incorporating a Marketplace module within Campus Core, students can access a campus-specific marketplace that fosters a culture of reusability, contributing to an eco-friendly environment [3].

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Automated Timetable Generation for Academic Staff-Automated scheduling has been a subject of academic research for many years. Studies by Rodriguez et al. (2018) on timetable optimization show the benefits of automated systems in balancing workloads and improving scheduling efficiency. However, these solutions are often institution-specific, limiting their scalability across different colleges. By including an automatic timetable generator in Campus Core, academic staff can efficiently manage their schedules with optimized teaching hours, ensuring balanced workloads while reducing administrative effort [4].

Machine Learning in Campus-Centric Applications-The application of machine learning to enhance student services has gained traction in recent research. For example, UniversityConnect (2022) applies machine learning to recommend campus events based on students' past preferences, creating a personalized experience. However, this application does not extend to essential services like housing, dining, or marketplace activities. Campus Core fills this gap by leveraging machine learning to personalize recommendations across all modules, creating a comprehensive solution that adapts to the evolving needs of students [5].

Integration with Government Initiatives and Open Platforms-With initiatives like the Open Network for Digital Commerce (ONDC), the Indian government aims to provide a more inclusive e-commerce ecosystem. Research into ONDC (Kumar & Sen, 2022) highlights the potential for third-party integration to expand service reach, especially for underserved communities. Campus Core aligns with this initiative by exploring integration with ONDC, which will enhance platform reach and provide students with a wider range of local service options [6].

Student Social Integration Platforms-Many platforms, such as Meetup and Eventbrite, facilitate event discovery and social integration by allowing users to explore local gatherings. However, these are not specifically designed with college students in mind, nor do they cater to on-campus events or club activities that foster community building among students (Patel & Sharma, 2021). Research indicates that students benefit from platforms tailored to promote social integration within a campus setting, as these enhance academic success and personal well-being (Johnson, 2019). While Campus Core focuses on essential services, its dining and marketplace modules inherently support social interaction by introducing students to shared spaces, local events, and peer-driven exchanges. This indirect support for social integration provides students a greater sense of belonging within the campus community [7].

Campus Resource Management Systems-Comprehensive resource management platforms, like Campus Management Corp and Blackboard, often serve educational institutions by providing tools for handling administrative, academic, and student service tasks. These platforms primarily focus on institutional needs rather than personalized student-centric features, leaving students to navigate resources independently (Singh & Verma, 2020). By contrast, Campus Core is built specifically with student needs in mind, streamlining access to housing, dining, and marketplace resources through a single, cohesive platform. This approach not only improves efficiency for students but also empowers campus businesses by connecting them directly with their target demographic [8].

Student Service Aggregators-Platforms like Unidays and StudentBeans aggregate discounts and student-specific offers, providing access to services and resources students frequently use. While effective for finding deals, these platforms are limited in scope, typically lacking tools for essential needs like housing and dining, or options for peer-to-peer engagement (Brown & Lee, 2021). Research highlights that students benefit from platforms that holistically address academic, social, and logistical needs (Martin, 2020). Campus Core goes beyond aggregation by directly integrating housing, dining, and a sustainable marketplace, creating a streamlined, all-in-one resource that supports students in managing their daily needs within a single platform [9].

Sustainable Campus Initiatives-Many institutions have embraced digital platforms aimed at promoting sustainability, such as Freecycle and OLIO, which facilitate resource-sharing and waste reduction by enabling users to give away or trade items (Nguyen et al., 2018). However, these platforms are often decentralized and lack campus-specific features. Studies suggest that localized, peer-to-peer exchanges improve sustainability practices and reduce waste in closed communities (Wang & Chen, 2020). The Marketplace module within Campus Core aligns with these objectives by allowing students to buy, sell, or trade items on campus, fostering a sustainable ecosystem and encouraging responsible consumption directly within the campus community [10].

While these related works contribute significantly to enhancing student life, they are often limited by their single-domain focus, lack of personalization, or regional constraints. Campus Core addresses these limitations by integrating multiple essential services—housing, dining, marketplace, and scheduling—into a single, machine-learning-powered platform. By providing tailored recommendations and exploring government-backed integrations, Campus Core aspires to deliver a cohesive, localized solution tailored specifically for the Indian student population.

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III. PROPOSED METHODOLOGY

A. System Architecture

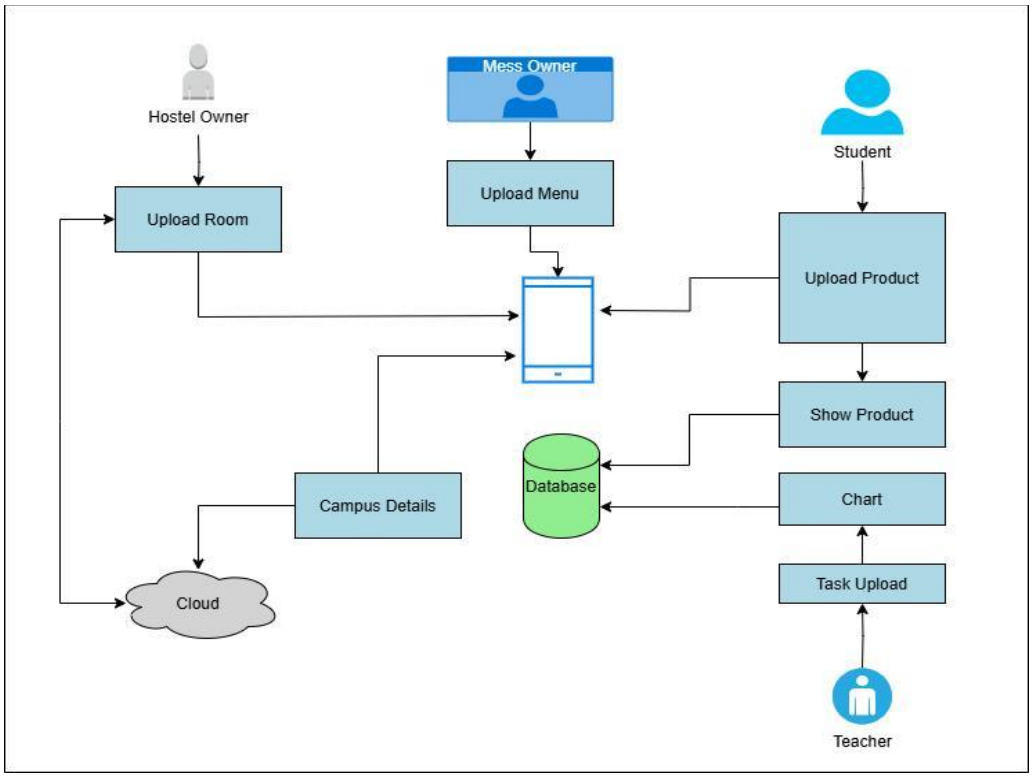

Fig. 1 System Architecture

The proposed system comprises of users with multiple roles that access the particular modules based on their specific task. These roles include hostel owners, mess owners, students, and teachers, each interacting with the system through distinct functionalities such as uploading menus, rooms, tasks, or viewing available services. The backend follows a microservice architecture with each service deployed independently and communicating via function calls. This ensures scalability, modular development, and fault isolation. All data transactions flow through a centralized database, while the integration of machine learning modules enhances personalization for students. The system also utilizes cloud infrastructure to manage campus details and ensure reliable data access across modules, enabling a seamless and intelligent user experience.

B. Proposed Algorithm

The proposed system comprises a hybrid recommender that allows context-aware recommendations using content-based filtering and collaborative filtering.

Content-Based Filtering (CBF)

Content-based filtering (CBF) is a recommender system technique that utilizes item features to personalize suggestions for users. By analysing attributes like genre, keywords, and user interactions, CBF constructs user and item profiles. These profiles are then compared to identify items with similar characteristics to those previously interacted with by the user.

This user-centric approach allows CBF to make recommendations independent of other users' behaviours, making it valuable in scenarios with limited user interaction data. However, a potential drawback of CBF is its inability to capture serendipitous discoveries that can arise from collaborative filtering methods.

Collaborative Filtering (CF)

Collaborative filtering (CF) is a well-established recommender system approach that leverages the wisdom of the crowd to generate personalized recommendations. Unlike content-based filtering, CF forgoes explicit item features, instead focusing on identifying users with similar historical interactions or preferences.

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This is achieved through various similarity measures, which quantify the degree to which users' past behaviours align. By analysing these user-to-user correlations, CF recommends items that have been enjoyed by similar users, fostering a sense of discovery and catering to individual taste.

However, CF's effectiveness is inherently tied to the richness of available user interaction data, potentially suffering from sparsity issues in cold-start scenarios.

C. Algorithm

Input:

- User interaction history
- Listing data with features
- User location data
- Ratings matrix R

Output:

- Top n recommended listings tailored to the user's preferences and engagement profile

1. Generate user preference embeddings using Word2Vec model and store them in vector datastore. A user i's profile is denoted as u_i.
2. Generate listing features embeddings using Word2Vec model and store them in vector datastore. A listing j's feature vector is denoted as l_j.
3. Create a list of n listings using location-based filtering.
4. Calculate Cosine Similarity values for each listing with the user profile u_i:

$$\text{similarity}(u_i, l_j) = \frac{u_i \cdot l_j}{\|u_i\|\|l_j\|} = \frac{\sum_{k=1}^{n} u_{ik} \cdot l_{jk}}{\sqrt{\sum_{k=1}^{n} u_{ik}^2} \cdot \sqrt{\sum_{k=1}^{n} l_{jk}^2}}$$

5. Select top n recommendations with highest cosine similarity values.
6. Create ratings matrix R where r_{ij} is the user-listing rating vector.
7. Factorize R into two latent factor matrices, P (user factors) and Q (listing factors), using Singular Value Decomposition (SVD):

$$R \approx P \cdot Q^T$$

8. Predict the rating user i would give to listing j by computing the dot product of their respective latent factors:

$$\hat{r}_{ij} = p_i \cdot q_j^T$$

9. Combine the content-based similarity score and the collaborative filtering prediction using a weighted average:

$$\text{hybrid}(i, j) = \alpha \cdot \text{similarity}(u_i, l_j) + (1 - \alpha) \cdot \text{prediction}(i, j)$$

10. Sort the initial content-based candidate list generated according to their hybrid scores.

D. Deployment

Campus Core is deployed as both an Android and web application, ensuring broad accessibility across devices. The Android app is developed using Android Studio, while the web application is built with modern web development technologies to deliver a responsive user experience. Both platforms connect to a common backend via RESTful APIs for real-time data synchronization. The hybrid recommendation engine operates as a backend service with access to user embeddings and rating data, enabling personalized content delivery. Secure authentication and centralized database management ensure data integrity, while version control and periodic deployments support maintainability.

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IV. RESULTS

A. Interface

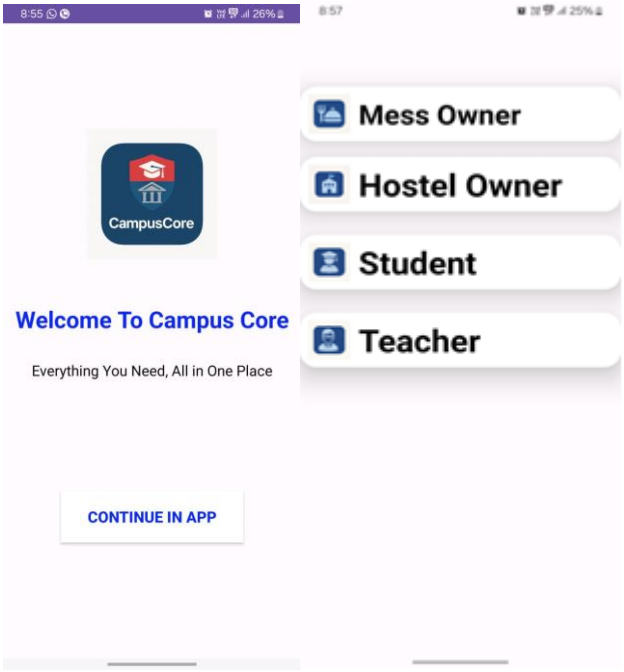

Fig. 2: Depicts the application's main interface, highlighting a range of services presented through clear and appealing design elements that enhance user interaction and ease of navigation.

B. Performance

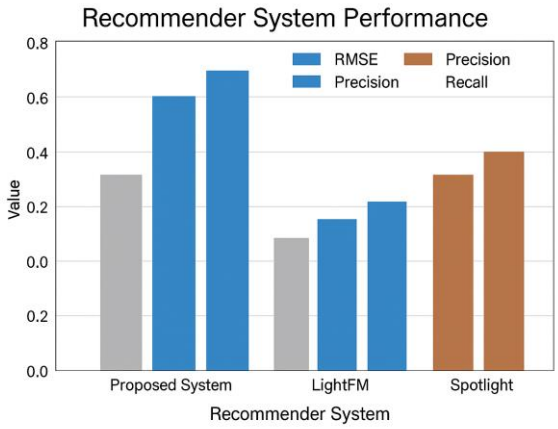

Fig. 3: Performance graph

The proposed system, which utilizes a hybrid model combining content-based and collaborative filtering techniques, demonstrates superior performance across key evaluation metrics. It achieves the lowest RMSE (0.0106), the highest precision (0.7952), and a strong recall (0.4589), highlighting its accuracy and effectiveness in providing relevant recommendations. This hybrid approach successfully overcomes common limitations found in traditional recommender systems, such as the cold-start problem, overspecialization, and data sparsity. By fusing the strengths of both filtering methods, the system ensures a more diverse and personalized user experience, effectively tailoring suggestions to individual preferences.

The Campus Core platform stands out as a valuable and student-focused application, emphasizing personalization and usability. By leveraging machine learning, it simplifies access to critical campus services such as housing, dining, and

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peer-to-peer item exchanges. The platform's adaptability allows for future expansion, incorporating new services based on user needs—such as campus laundry or fitness facilities. Integration with government initiatives like ONDC further extends its utility, connecting students with local vendors and enriching campus life. This user-driven, collaborative system positions it as a comprehensive solution designed to empower students and enhance their everyday experiences.

V. FUTURE WORK

Future enhancements will focus on improving personalization and expanding the platform's accessibility. Integrating adaptive machine learning models can further tailor recommendations based on evolving student behaviour. Collaborations with local vendors may enable location-specific offers, enhancing student engagement. Additionally, real-time updates for housing and dining, as well as integration with government platforms like ONDC, could extend the app's utility and inclusivity across campuses.

VI. CONCLUSION

Many existing campus platforms fall short in delivering personalized, adaptive, and student-specific services, often resulting in fragmented user experiences. Campus Core addresses these challenges by integrating key services—including housing, dining, marketplace, and academic scheduling—into a unified, intelligent application tailored for student life. By applying machine learning techniques such as collaborative filtering in the dining module and cosine similarity for housing recommendations, the platform offers content that evolves with individual user preferences. These models help predict and prioritize resources based on behavioral patterns, making the interface more intuitive and responsive. The result is an engaging, efficient, and scalable solution that not only simplifies daily campus life but also promotes higher student involvement and satisfaction through targeted, data-driven services.

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