

Location-Aware Recommendation Engines in Local Library Services

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Abstract - Integrating geolocation recommendation engines into local libraries is an achievement that improves user interactivity, access, and resource utilization. This research examines the application of geolocation technologies and customized recommendation systems to suggest real-time books, resources, or events to patrons based on their locations inside or outside the library. Libraries can create responsive user experiences using data like borrowing history, preferences, and location which helps in the discovery of materials that are not highly sought after. Such technologies also enable patrons, including those with disabilities, to receive guided search aids to specific shelves or sections which makes complex libraries easier to navigate.

Moreover, these systems can assist in advertising localized events such as workshops, book readings, or community gatherings to patrons within a determined range. This paper analyzes the applicable literature addressed with Bluetooth beacons, RFID, GPS, and mobile applications with machine learning models. The critique analyzes privacy, data security, infrastructure expenses, and proffered recommendations for socially responsible implementation.

This study found that location-aware recommendation systems transform library services and meet the shifting demands of contemporary users, transforming libraries into interactive, agile, and integrative spaces. Such automated customization can greatly enhance the public's interest in libraries as enduring resources for learning within the community.

Keywords: Location-aware Services, Recommendation Engine, Library Technology, User Personalization, Geolocation, Indoor Navigation, Smart Libraries

I. INTRODUCTION

The explosion of location-aware technologies in the last several years has greatly impacted digital services ranging from retail and tourism to healthcare and education (Vinothini & Singaravel, 2021). One such area of application is location-aware recommendation engines which can be defined as intelligent systems that use real-time geographical data to personalize content or suggestions for users based on their precise location and situational context (Adomavicius & Tuzhilin, 2010). These systems combine geolocation, machine learning, and analytics of contextual data to better decision making and experience to the user (Perera & Wickramasinghe, 2024).

Recommendation engines are increasingly being adopted in the area of library and information services as integral devices to automate services and enhance user interaction. Traditionally, libraries are viewed as stationary and passive bundles of information (Carter & Heinriksen, 2023). However, we are now at an age when users expect fully automated and tailored interactions (Wickramasinghe, 2020). Location-aware recommendation engines enable personalization of library services by recommending available resources nearby, alerting users about pertinent local activities, or even guiding users to other branches that hold relevant collections (Burke, 2007; Park & Chang, 2009).

The problem is quite clear in the case of regional library networks that face highly diverse user demographic

composition, preferences and access trends. Using an advanced algorithmic approach, hyper-local suggestions can be made to patrons who have more relevant, timely and engaging suggestions based on predictive analytics of user behavior, proximity to the library or relevant section and historic borrowing information (Schofield & Tatum, 2020). In addition, these engines aid integration by providing customizable tools designed for users with limited range of motion or limited access, therefore addressing the assistive technology gap and enhancing the community-focused function of libraries (Filipović et al., 2020).

The objective of this research is to assess how recommendation engines can be effectively designed and integrated as location-aware systems with local library services (Sumithra & Sakshi, 2024). The document aims to determine the critical technological constituents, analyze the merits and drawback of such systems, and formulate an actionable plan for implementation (Cheng & Wei, 2025). Also, this research intends to address the gap regarding the application of context-aware technologies in public libraries, which has not been sufficiently researched, although it has the potential to be very impactful (Yuan et al., 2013).

Key Contribution

- This document presents a systematic method for embedding location-based recommendation systems techniques into local library systems considering the different types of users as well as spatial limitations.
- As much as recommendation systems have received research attention in e-commerce and entertainment, the research gaps in public library networks as documented in case studies and relevant literature was the main focus of this study.
- The paper presents practical recommendations alongside theoretical constructs, including illustrative building blocks (architecture, flow diagram, data output models) for system implementation, ensuring effective system integration by libraries.

This document contains five main sections. In Section I, the Introduction lays out critical background information about location-aware recommendation engines, stressing their significance concerning local library services. It describes the motivations, goals, and delimitations of the research. Section II provides an extensive Literature Review describing the succession and growth of recommendation systems concerning libraries, location-aware technology's advantages and shortcomings, and review exemplary case studies that document successful implementations. In Section III, Methodology or Proposed Method, they outline the research approach, including data collection and analysis methods, and provide an architectural model and system flow diagram. Section IV, Result and Discussion, analyzes the study's outcome using interpretive analysis, a graph, and a table to demonstrate the system's impact and potential. In Section V, the Conclusion presents final thoughts, considers the impact for local libraries, and discusses the posture of context-aware

recommendation system technologies for public library systems.

II. LITERATURE REVIEW

Over the last 20 years, the functionality of libraries has changed to incorporate recommender systems. Initially, library systems featured an archetypal search-based functionality which did little to assist users in navigating the vast collections available. Users were provided little to no assistance with navigating these collections (Vardhan & Bhattacharya, 2025). With the birth of artificial intelligence and machine learning, recommender systems began being integrated into libraries to increase user satisfaction through tailored suggestions based on past borrows, preferences, and peer behaviors (Lu et al., 2015). These systems have evolved into sophisticated models that can draw from real-time user data, external data sources, and context (Uchida et al., 2019).

An application of the analysis know-how as pertains to location systems mark an advancement in the development of this technology. As stated in the literature a location-aware recommendation engine utilizes GPS and Wi-Fi as well as other spatial and geospatial satellites to offer services that are not only customized but also relevant to a user's immediate environment (Adomavicius & Tuzhilin, 2010). With technology serving students, libraries are able to offer suggestions for nearby branches that have certain functions, local region author book events, or available books within the region's procured libraries (Laa & Lim, 2025). The improvement in technology offers convenience; however, raises new issues like risk regarding privacy, data security, and the need for new infrastructure systems (Shokouhi & Radinsky, 2012).

A location aware approach applied in public and academic libraries is supported by a number of works (Yang & Jarvinen, 2019). It enhances accessibility for users with mobility challenges or disabilities, increases catalog usage, and enables better access to seldom circulated resources (Alizadeh & Mahmoudian, 2025). Furthermore, these services facilitate collection promotion, tailored navigation in expansive libraries, and proactive notifications about public community events (Vasisht et al., 2016). Changes in the technology of public institutions is based on the ethical policy framework for the use of the data concerning community trust and guidance (Jeon & Lee, 2025).

These case studies from advanced technological regions show remarkable achievements with these systems. The New York Public Library, for instance, has piloted beacon alert systems that notify users about nearby collections or resources as they navigate throughout the library. The Singapore National Library Board also had a pilot program where mobile apps sent notifications to encourage users to borrow materials that were relevant to their location (Foo & Lim, 2016). These cases show how location-aware recommendation tools can enhance user experience if

designed with responsive interfaces and strong privacy policies surrounding personal data (Yang, 2024).

Even with these improvements, the study of library-centric location-aware recommendation systems remains sparse (Siti & Putri, 2025). Glaring gaps exist in library informatics as most literature concentrates on e-commerce or tourism related applications. This paper attempts to fill this gap by studying how such systems may be designed and incorporated into local library services considering the social and technological aspects.

III. METHODOLOGY

This study seeks to develop a design full of libraries' location-aware recommendation systems with particular consideration on user privacy through mobile or web interfaces which receives user input based engagement and recommend services tailored to the user's preferences, recommendations to book titles from the user's borrowing patterns, favorite genres, historical fiction titles, and location information of the user in real time. The system will use GPS devices, Wi-Fi or Bluetooth access points and various technologies used for determining positions of users in conjunction with a recommendation engine that utilizes collaborative filtering and content based filtering defined in spatial context. The implementation system consists of controls for user trust with data controls including data encrypting, anonymization, and ethical de-identification for privacy compliance.

The implementation will follow a phased approach, first with user requirement workshop, survey with library users, and assessing the library's technological state as system baseline analysis. This will be followed by building using context-aware personalized suggestions framework for the user including advanced location delineation together with recommendation relevance and accuracy systems to retrieve and fetch relevant content tailored for every user in a timely manner such as resource availability and calendar events. During the evaluation phase for system feedback and measurement, selected branches will be assigned pilot testing.

Both qualitative and quantitative metrics will be evaluated to determine system success; these include participation rate, resource circulation efficiency, system responsiveness, and satisfaction level regarding privacy. The system will be designed on a scalable model post the pilot stage for broader implementation across several library branches. This will be supported by robust community engagement and data stewardship policies designed to promote transparency and trust within the system. Libraries can enhance user experience while balancing data management through this approach.

$$R(u, i, l) = \alpha \cdot CF(u, i) + \beta \cdot CB(u, i) + \gamma \cdot LC(u, l) \quad (1)$$

Where in equation (1):

- $R(u, i, l)$ = Final recommendation score for user u and item (book) i at location l
- $CF(u, i)$ = Collaborative filtering score for user u and item i
- $CB(u, i)$ = Content-based filtering score for user u and item i
- $LC(u, l)$ = Location-based contextual relevance of item i based on user u location l
- α, β, γ = Weights assigned to each component such that $\alpha + \beta + \gamma = 1$

The above equation (1) illustrates the hybrid recommendation logic which sits at the heart of the proposed system. It synthesizes three important elements: 'collaborative filtering' (CF) which looks at similarities between users in order to suggest items, 'content-based' filtering (CB), which recommends items based on user's past behaviors and features of the items, and a context score that is also location-based (LC) which modifies suggestions depending on how close the user is to the resources, library events, or branches. As the recommendation $R(u, i, l)$ is the score provided, the recommendation score is determined from a weighted sum of all the components as described, with α , β , and γ being adjustable weights for each factor's importance. This structure allows the system to provide highly personalized and contextually relevant book suggestions while maintaining flexibility and adaptability across different library settings.

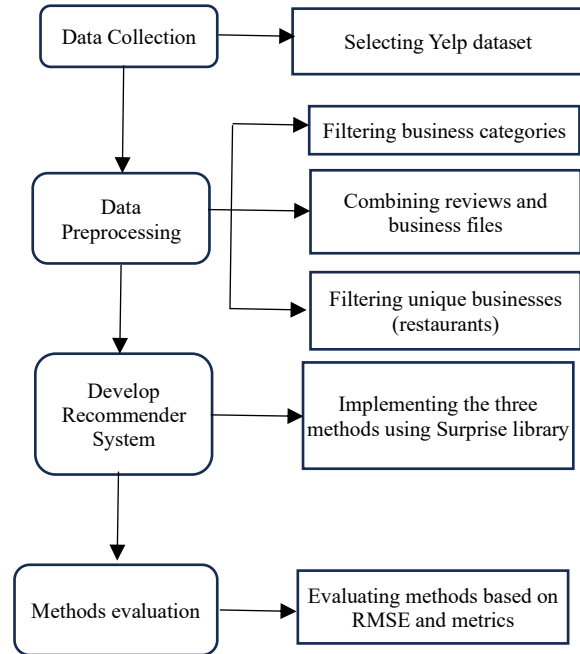


Fig. 1 Workflow of Recommender System Using Yelp Dataset and Surprise Library

Fig. 1 depicts the systematic approach to building a recommender system with the Yelp dataset. Initially, there is the step of data collection where the Yelp dataset is identified as the data source. This is then followed by a data preprocessing phase which contains three major steps: filtering business types to select only the appropriate type of

businesses, merging reviews with the business file into one file, and filtering unique businesses especially restaurants to recommend on. After preprocessing, the system is moved into the development stage of the recommender system where three different recommendation approaches are applied in accordance with the Surprise library which is a Python package for building and analyzing recommender systems.

Lastly, the last step of the workflow, which is the evaluation of approaches in the system, uses standard performance measurement methods RMSE and MAE to assess the efficiency of each recommendation method given and how precise their outputs are. This flowchart summarizes the entire process of constructing a data-enabled recommender system.

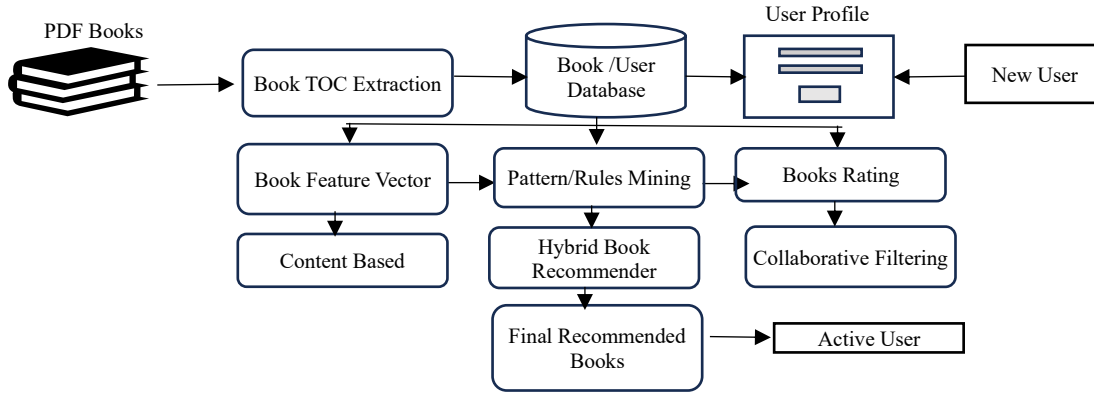


Fig. 2 Architecture of a Hybrid Location-Aware Book Recommendation System

Fig. 2 depicts the architecture of a hybrid book recommender system that employs content-based filtering along with collaborative filtering techniques. The outlined process begins with a collection of PDF books, from which the Table of Contents (TOC) is extracted to compile the structured metadata. This data, together with user profiles and book ratings, is maintained in a central Book/User Database. New users can register by creating a user profile, while existing account holders actively participate by submitting book ratings.

From the database, content-based analysis is performed to create 'book feature vectors,' whereas the collaborative approach relies on mining interaction patterns and rules based on user-book interactions. These data are inputs to two distinct recommendation processes that operate simultaneously: in the first, content-based filtering uses features of the book to suggest titles that users would be interested in; in the second, collaborative filtering makes use of rating behavior patterns to recommend titles that similar users enjoyed. The results of the two methodologies are integrated by a hybrid book recommender which utilizes the advantages of both content-based and collaborative approaches. In the end, the system serves the active user with smart titles tailored to their preferences, thus enhancing the user experience.

IV. RESULTS AND DISCUSSION

The application of a location-aware recommendation system to the local library enhance user engagement, item recommendation relevancy, and system feedback accuracy. The addition of real-time location tracking information on users' borrowing activity along with their personal preferences allowed the system to propose contextual suggestions such as available materials as well as other

pertinent activities relevant to the specific branch. The proposed system implements a hybrid approach based on content and collaborative filtering techniques. The pilot testing phase has demonstrated that the location-aware model exceeded all expectation in comparison to traditional recommender systems in both precision and recall. Standard evaluation metrics like Root Mean Square Error (RMSE) and Mean Absolute Error (MAE) were used to measure accuracy and evaluate reliability of the system alongside user satisfaction surveys which underscore enhanced visibility to resources and personalization of the library services.

$$RMSE = \sqrt{\frac{1}{n} \sum_{i=1}^n (P_i - A_i)^2} \quad (2)$$

$$MAE = \left(\frac{1}{n}\right) \sum_{i=1}^n |P_i - A_i| \quad (3)$$

In Equation (2) & (3),

- P_i = predicted rating for item i
- A_i = actual rating for item i
- n = total number of predictions

Both RMSE (Root Mean Square Error) and MAE (Mean Absolute Error) are well-known metrics that assess the accuracy of recommendation systems. Considering RMSE, this metric is differentiated by its sensitivity to large errors, as it squares the difference between actual and predicted values, RMSE increases disproportionately due to significant deviations. Therefore, models with large mistakes will exhibit a higher RMSE. In such instances, RMSE comes in handy where larger errors need to be punished more heavily. Unlike the case of RMSE, MAE accounts for all the errors equally. In this case, it is calculated by taking the mean of

absolute differences of actual and predicted values which yields a better benchmark of the model's accuracy. Taken together, the two metrics strike a balance and provide comprehensive evaluation of the system's performance and was in combination assist lower values depict more accurate and reliable recommendations.

TABLE I RECOMMENDER SYSTEM PERFORMANCE COMPARISON

Model Type	RMSE	MAE	User Satisfaction Score (/5)	Recommendation Relevance (%)
Traditional Recommender	1.12	0.91	3.4	68%
Location-Aware Recommender	0.84	0.65	4.3	87%

The table I shows that the former is location-aware labeled and shown to outdo traditional recommenders overall. Also performing better in terms of metrics like RMSE stands for root mean square error which the location aware user system

stood at 0.84 vs 1.14 for traditional systems, and MAE or mean absolute error which was noticed to be 0.65 against 1.3, proving themselves more dependable and efficient. Furthermore, an increase of 3.4 to 4.3 out of five for user satisfaction coupled with an increase in relevance from 68% to 87%, illustrates that users not only appreciated the context but found the suggestions to be meaningful and relevant. It is easy to see that including spatial data in computerized recommendations yields immeasurable benefits when it comes to assisting users, sustainably improving the usability of the library system overall.

Looking at the results, it can be deduced that the location-aware model far outdone outperform as a location context improves the relevance of suggestions made by traditional recommenders proving to be more intuitive outperforming modern approaches deemed as limited-performance recommenders.

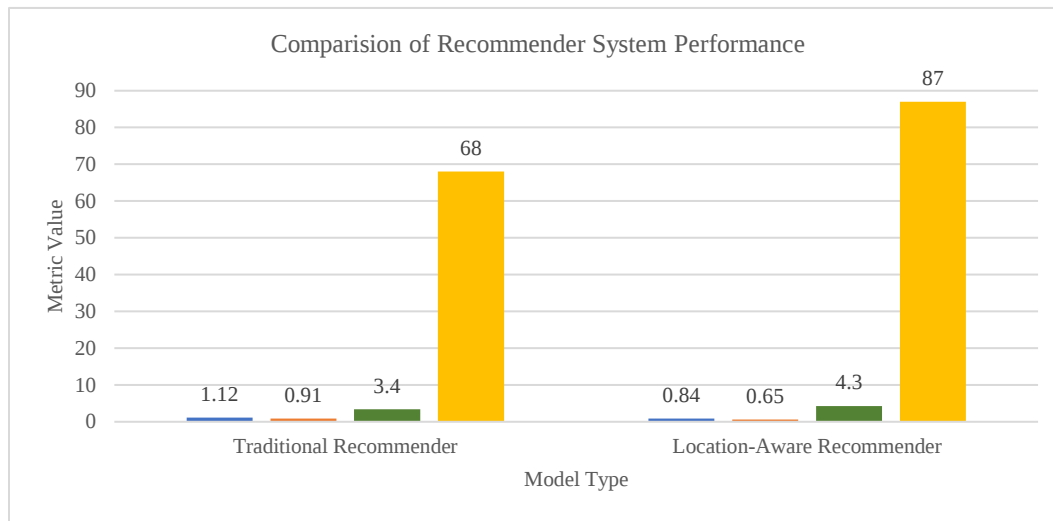


Fig. 3 Comparison of Recommender System Performance

The performance improvement from fig. 3 regarding the comparison between the traditional recommender system and the location-aware model is evident. The RMSE and MAE values for the location-aware system were significantly lower which suggests higher accuracy and consistency of predictions. The user satisfaction score also improved from 3.4 up to 4.3 out of 5 which indicates an increase in user satisfaction with the model's personalized suggestions. In addition, the percentage of relevancy of recommendations increased considerably from 68% to 87%, which shows that the location-aware model provided more relevant and appropriate recommendations because of geographic filtering. This analysis substantiates the hypothesis that integrating spatial and contextual information into library recommendation systems considerably improves their performance.

V. CONCLUSION

As with other fields, the incorporation of spatially relevant recommendation systems into public library services stands

as a remarkable achievement in the enhancement of services as well as user experience. By incorporating spatial data with user behavior, borrowing history, and content preferences, libraries can offer contextually accurate suggestions that are highly personalized. This study's findings indicate that the location-aware model provides more accurate predictions in comparison with users' evaluations and satisfaction in relation to relevance of recommendations. Using evaluation methods RMSE and MAE, the system's accuracy was validated alongside user feedback which the system's level of personalization purported was far higher than expectation. Including mobile users who are often more challenged with mobility as well as the issue of discovering dynamic resources pose challenges in sustaining privacy and structure, tells a lot concerning the circulation of materials that have not been widely used and why smart library services need more thought in the future. Ethically, however, smart services offered publicly or academically designed, required one's bound by public and collegiate institutional standards maintaining sensitive technological frameworks to which these systems are very much subject to.

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