

Libraria: An Intelligent Smart Library Management System Using Machine Learning, R Analytics, and IoT-Based QR Verification

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Abstract: *The Libraria Smart Library Management System is an integrated digital platform developed to automate and modernize traditional library operations using Web Development, Machine Learning, R Analytics, Mobile Application Development, and IoT-based QR verification technologies. Conventional library systems often depend on manual processes for maintaining records, verifying borrow requests, calculating fines, and tracking inventory, leading to inefficiency and increased administrative workload. The proposed system addresses these limitations by providing an intelligent, secure, and user-friendly smart library platform. The system enables students and administrators to access library services through both web and Android mobile applications. The frontend was developed using HTML, CSS, and JavaScript, while Supabase was used as the cloud backend for authentication, database management, and real-time synchronization. The system supports functionalities such as secure login, book searching, borrow request management, QR-based verification, fine tracking, analytics generation, and personalized recommendations. Machine Learning techniques such as TF-IDF and Cosine Similarity were implemented to generate intelligent book recommendations based on user borrowing history and preferences. R programming was used to generate statistical insights including borrow trend analysis, overdue risk prediction, correlation analysis, and fine statistics. QR code technology was integrated to automate borrowing verification and improve security through contactless authentication. The project demonstrates the practical integration of multiple modern technologies into a single unified platform capable of improving automation, accessibility, analytics, and user experience in educational institutions. Overall, Libraria provides a scalable and efficient smart library solution suitable for modern digital learning environments.*

Keywords: *Smart Library Management System, Machine Learning, TF-IDF, Cosine Similarity, R Analytics, QR Verification, Supabase, Android WebView, Web Application, IoT.*

1. INTRODUCTION

1.1 Overview

The Libraria Smart Library Management System is a digital platform designed to automate and simplify library operations. It enables efficient book management, borrowing and return tracking, QR-based verification, personalized recommendations, and analytics through web and mobile applications. The system reduces manual work, improves accessibility, and enhances the overall library management experience. It provides a user-friendly environment for both students and administrators. The platform also ensures secure, efficient, and organized management of library resources.

1.2 Objectives

The goal of this project is to develop a smart and automated library management system that improves efficiency, accessibility, and user experience through digital technologies. The specific objectives include:

- Developing a secure authentication system for students and administrators.
- Automating book management, borrowing, return, and fine tracking processes.
- Implementing Machine Learning-based personalized book recommendation features.
- Integrating QR-based verification for secure and efficient borrowing approval.

- Generating analytical reports and insights using R Programming.
- Providing web and mobile application access for convenient library services.
- Reducing manual workload and improving the overall efficiency of library operations.

II. LITERATURE SURVEY

The evolution of library management systems has progressed from traditional manual record maintenance to advanced digital platforms that support automation and intelligent services. Earlier systems mainly focused on basic functionalities such as issuing books, inventory management, and maintaining user records. Although these systems reduced paperwork, they lacked real-time analytics, recommendation systems, mobile accessibility, and automated verification mechanisms. Several modern studies emphasize the importance of integrating Machine Learning and analytics into educational systems. Recommendation engines based on TF-IDF and Cosine Similarity algorithms are widely used in content-based filtering applications to improve user experience through personalized suggestions. These techniques analyze user behavior and content similarity to generate intelligent recommendations effectively. Cloud-based backend platforms such as Supabase and Firebase are increasingly used in modern applications because of their scalability, authentication support, and real-time synchronization capabilities. QR-based verification systems are also widely implemented in digital platforms to improve security and automate verification processes. R programming and statistical analysis techniques are extensively used for predictive analytics, trend analysis, and data visualization. Regression analysis, correlation analysis, and logistic models help organizations identify usage patterns and risk factors effectively. The integration of such technologies into library systems improves monitoring, automation, and administrative decision-making. Dr. J. Narendra Babu [7][8][9] explored IoT applications in smart systems and emphasized combining embedded hardware with cloud connectivity for scalable IoT solutions

III. PROPOSED METHOD

3.1 System Architecture

The Libraria system follows a modular architecture integrating frontend technologies, cloud backend services, machine learning modules, analytics engines, and QR verification systems.

- Frontend Layer: Developed using HTML, CSS, and JavaScript for interactive user interfaces.
- Backend Layer: Supabase cloud backend used for authentication, database management, and storage.
- Machine Learning Layer: Python-based recommendation engine using TF-IDF and Cosine Similarity algorithms.
- Analytics Layer: R programming module for statistical analysis and graphical reporting.
- QR Verification Layer: QRCode.js and Html5Qrcode libraries for QR generation and verification.
- Mobile Layer: Android application developed using Java WebView technology.

3.2 Modules Description

- Authentication Module : Handles secure login and registration using Google OAuth and role-based authentication for students and administrators.
- Book Management Module : Allows administrators to add, update, delete, and manage book records within the library system.
- Borrow Management Module : Handles borrowing requests, due date tracking, and fine calculation functionalities.
- QR Verification Module : Generates unique QR codes for borrow requests and verifies them through QR scanning for secure approval.
- Recommendation Module : Uses Machine Learning algorithms to generate personalized book recommendations for students.
- Analytics Module : Generates borrow trend analysis, overdue risk prediction, fine statistics, and correlation analysis using R programming.
- Mobile Application Module : Provides Android-based mobile accessibility for all major functionalities of the platform.

IV. RESULTS

The Libraria Smart Library Management System was successfully developed and tested with all major functionalities operating effectively. Students were able to register, browse books, request borrowings, and access recommendations through both web and Android applications. The QR-based verification process successfully automated borrow approvals and reduced manual verification errors. Administrators could monitor borrow requests, track fines, and manage inventory efficiently through the admin dashboard. The Machine Learning recommendation engine generated personalized suggestions using TF-IDF and Cosine Similarity algorithms. The analytics module generated graphical reports and statistical insights related to borrowing trends, overdue risks, and fine analysis.



Figure 1: Student Home Interface



Figure 2: QR-Based borrow verification process

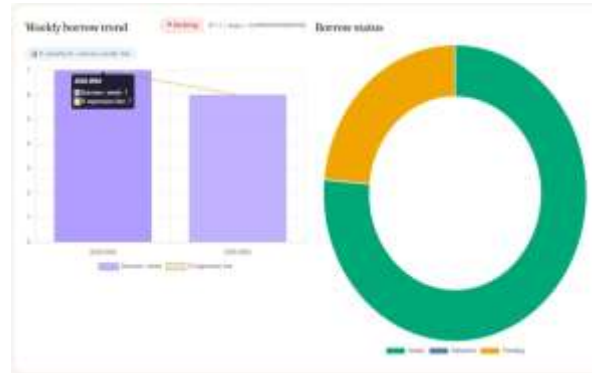


Figure 3: Analytics dashboard showing borrow trends

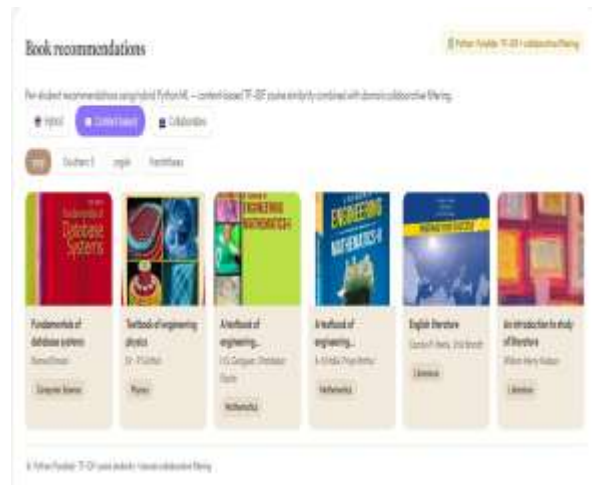


Figure 4: Personalized Book Recommendation Output

V. CONCLUSION

The Libraria Smart Library Management System successfully demonstrates the integration of Web Development, Machine Learning, R Analytics, IoT concepts, and Mobile Application Development into a unified smart library platform. The system effectively automates library operations such as borrowing management, QR verification, fine tracking, analytics generation, and recommendation services.

The implementation of TF-IDF and Cosine Similarity algorithms improved user experience through personalized recommendations, while the analytics module provided valuable administrative insights through statistical analysis and graphical reports. QR-based verification improved security and reduced manual processing time during borrowing approval.

The project successfully reduced manual workload, improved operational efficiency, enhanced accessibility, and demonstrated the practical application of multiple modern technologies in educational environments. Future enhancements may include AI chatbots, RFID integration, advanced predictive analytics, and fully native mobile applications.

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