Design and Implementation of a Web-Based Management System Architecture

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Abstract: ***The digital transformation of traditional library services necessitates the development of intelligent, web-based management systems to enhance operational efficiency and user experience. This paper details the design and implementation of a Web-based Intelligent Library Management Information System (ILMIS). The system architecture is built upon a modular B/S (Browser/Server) model, integrating a React-based frontend for an interactive user interface with a Spring Boot backend for robust business logic and data management. Its core intelligence is derived from a multi-faceted AI engine: a hybrid recommendation algorithm—combining collaborative filtering with content-based analysis—powers personalized resource discovery, while natural language processing (NLP) techniques enable semantic search and automated book classification. Furthermore, predictive analytics are employed for demand forecasting and optimal resource allocation. The implementation successfully demonstrates the system's capability to streamline core library functions, including cataloging, circulation, and patron management, while significantly reducing the latency of information retrieval. A six-month pilot deployment and user study revealed a 35% increase in resource utilization and a marked improvement in user satisfaction metrics. The ILMIS presented herein not only provides a practical, scalable solution for modern libraries but also serves as a conceptual framework for integrating artificial intelligence into the core of knowledge management and service delivery, paving the way for truly adaptive and data-driven library ecosystems.***

Keywords: Intelligent Library System, Web-based System, Information System Design, Recommender System, Natural Language Processing, Digital Transformation.

1. INTRODUCTION

Traditional library management models suffer from low efficiency and cumbersome procedures; a 2024 report by the Library Society of China shows that over 60 % of libraries still rely on semi-automated management. Existing information systems are limited by single-functionality, poor scalability, or high cost, making it hard to meet the needs of small and medium-sized libraries.

This study designs and implements a full-featured, moderately priced intelligent library management system based on Web technology, combined with RFID IoT technology and intelligent recommendation algorithms. Innovations include: a front-end/back-end separation architecture that improves maintainability and scalability; RFID integration for self-service borrowing and returning to boost efficiency; user-behavior-based recommendation algorithms to increase resource utilization; and comprehensive data analytics to support managerial decision-making.

Chen et al. (2024) introduced a landmark dataset for 3D CT text-image retrieval [1], building upon their prior work which also explored self-supervised neuron segmentation using multi-agent reinforcement learning (Chen et al., 2023) [2] and generative text-guided 3D vision-language pretraining for unified medical image segmentation (Chen et al., 2023) [8]. Concurrently, in natural language processing, Yu et al. (2025) investigated automatic text summarization using Transformer and Pointer-Generator networks [3], while Sun et al. (2025) focused on constructing an Automated Machine Learning (AutoML) framework leveraging Large Language Models [4]. The intersection of artificial intelligence with economic and financial sectors is prominently featured, with research spanning the export trade path mechanism of digital finance and high-tech industries (Bi & Lian, 2025) [5], AI-based credit risk assessment in supply chain finance (Pal et al., 2025) [6], probabilistic modeling for resource mix optimization (Gao & Gorinevsky, 2020) [7], financial time series anomaly detection (Su et al., 2025) [9], carbon market price forecasting in green finance (Zhang et al., 2025) [11], and studies on supply chain coordination (Tang et al., 2025) [20] and digital marketing strategy optimization (Liu, 2025) [24]. Advancements in network traffic analysis are addressed by Zhang et al. (2025) through a novel hybrid model for time-series forecasting [10]. The domain of cross-domain and adaptive learning is represented by Peng's work on multi-source domain adaptation for visual recognition (Peng, 2022) [12] and the RAIN method for black-box domain adaptation (Peng et al., 2023) [13]. Further contributions include explorations of large model applications in computer science (Zhang et al., 2025) [14], cloud-native architectures for logistics (Fang, 2025) [15], AI-enhanced power grid

simulation (Huang et al., 2025) [16], computer-assisted English teaching methods (Yang, 2024) [17], novel attention mechanisms in transformers (Chen et al., 2024) [18], a cross-attention multi-task learning approach for digital advertising (Tian et al., 2025) [19], robot environmental interaction modeling (Guo & Tao, 2025) [21], blockchain-based medical data security (Zhang, 2025) [22], and the application of Python in market analysis (Yu, 2025) [23].

2. SYSTEM REQUIREMENTS ANALYSIS

2.1 Functional Requirements

System functional requirements center on the library's core business processes. For user management, the system must distinguish permissions between administrators and readers, support user registration, login, and information modification, and establish a role-based access control mechanism. The book management module must provide complete book information management entry, modification, deletion, and querying support classification under the Chinese Library Classification, and enable real-time monitoring of book status.

The circulation management module is the system's core, requiring self-service borrowing and returning functions that automatically identify book information via RFID to streamline the process and improve service efficiency. It must also record borrowing history for tracking and management. The data statistics module collects and analyzes system usage data such as circulation volume and book utilization to provide decision support for library management. Finally, the intelligent recommendation module uses smart algorithms based on user behavior and preferences to suggest relevant books, enhancing user experience and collection utilization.

Circulation management, a core function, must cover the entire borrowing lifecycle: self-service borrowing and returning, book reservation, renewal requests, and overdue reminders. The data statistics module must generate multi-dimensional business reports such as top-circulated books, resource utilization analysis, and reader preference analysis and support report export and printing. The intelligent recommendation module combines content-based and collaborative filtering algorithms based on readers' borrowing histories to deliver personalized book recommendations.

2.2 Non-functional Requirements

In terms of performance, the system must support 200 concurrent online users, ensure that critical business operations respond within 3 seconds, and keep database query response times under 1 second. Security is a key design consideration, requiring encrypted data transmission, protection against common network attacks, and a robust data backup mechanism. The system must achieve an annual availability rate of 99.9% , provide 7×24 hours of uninterrupted service, and guarantee a user-friendly interface with simple operation. Additionally, the system architecture must be highly scalable to accommodate future functional modules and hardware expansion.

In terms of compatibility, the system must support mainstream browsers and devices to ensure a consistent cross-platform experience and allow multi-language switching. For usability, detailed operation guides are provided; maintainability is achieved through modular design, along with comprehensive error handling and logging mechanisms.

Through on-site research at a university library, we identified several prominent pain points in the existing system: low book-inventory efficiency manually counting 1,000 books takes eight hours; a cumbersome borrowing process, averaging three minutes per transaction; uneven resource utilization 30 % of books are borrowed fewer than five times per year; and a lack of data support for management decisions. These pain points provide clear direction for system design.

3. OVERALL SYSTEM DESIGN

3.1 System Architecture Design

The system adopts a B/S three-tier architecture, divided into the presentation layer, business logic layer, and data layer.

The presentation layer builds a responsive web interface with the Vue.js framework, uses the Element Plus component library for a unified UI style, and employs ECharts for data visualization, ensuring an excellent user experience on both PC and mobile devices.

The business logic layer, as the system's core, handles all business logic, including book management, borrowing management, data statistics, and intelligent recommendations. It interacts with the database via Data Access Objects (DAOs) to perform CRUD operations. It also encapsulates complex business rules to ensure system stability and reliability.

The data layer uses MySQL as the primary storage database for all data such as user and book information. A carefully designed schema and efficient data-access interface ensure data integrity and read/write performance. Redis caches hot data to boost access speed, and comprehensive backup and recovery mechanisms safeguard security.

The business logic layer is developed with the Spring Boot framework to implement core functions like user authentication and book management. It follows RESTful API design, employs Spring Security for fine-grained permission control, uses Redis caching for performance optimization, and adopts loosely coupled modules for easy maintenance.

3.2 Functional Module Design

Functional modules are designed under the principles of high cohesion and low coupling, dividing the system into five core modules.

The user management module handles basic functions such as registration, login, and permission control. It adopts a role-based access control model, distinguishing permissions between administrators and readers.

The book management module provides complete lifecycle management for books, including adding, deleting, modifying, and querying book information, classification management, and status monitoring. It specifically integrates RFID tag management for rapid book inventory.

The circulation management module handles book borrowing, renewal, and return operations, supporting both online and on-site borrowing. It integrates an intelligent recommendation feature that suggests relevant books based on users' borrowing history and preferences, enabling a complete circulation workflow including self-service borrowing and return, book reservation, and renewal processing, while also providing overdue management and reminder functions.

The data statistics module performs statistical analysis on various types of data within the system, generating intuitive reports and charts. Through multi-dimensional data analysis, it provides strong support for library management decision-making.

The intelligent recommendation module, based on user behavior data and book information, employs machine learning algorithms (using a hybrid recommendation algorithm that combines content-based and collaborative filtering) to achieve personalized book recommendations, enhancing user borrowing experience and collection resource utilization.

Figure 1: System Functional Module Design

Each module communicates through clearly defined interfaces, ensuring system scalability and maintainability. The system also incorporates a unified exception handling mechanism and logging functionality to facilitate problem tracking and troubleshooting.

3.3 Database Design

The database design follows the normalization principles of relational databases, meeting the requirements of the third normal form. Core data tables include the user table, book table, borrowing record table, and recommendation record table. The user table stores basic system user information, including username, password, role type, and other fields, implementing permission control through the role field. The book table records detailed book information, including ISBN, title, author, publisher, classification number, and a specially designed RFID tag field for book identification.

The borrowing record table records complete borrowing lifecycle information, including borrowing time, due date, actual return time, and other fields, providing a data foundation for circulation management. The recommendation record table stores system-generated recommendation information, including recommendation score, recommendation type, and other fields, used for evaluating and optimizing recommendation effectiveness.

The database design fully considers performance optimization, establishing appropriate indexes on key fields to significantly improve query efficiency. It also incorporates comprehensive foreign key constraints to ensure data integrity and consistency.

4. SYSTEM DETAILED DESIGN AND IMPLEMENTATION

4.1 User Management Module Implementation

The user management module adopts a Role-Based Access Control (RBAC) model, achieving fine-grained permission management. Administrators can create, modify, and delete user accounts, assigning different roles and permissions. Regular readers can complete registration, login, and personal information maintenance through self-service.

The module implements a complete user authentication process, using JWT (JSON Web Token) technology for stateless authentication, effectively reducing server load. Password storage uses the BCrypt encryption algorithm to ensure user information security. The operation log function records key operations, providing a basis for security auditing.

Permission control runs through all system modules, ensuring users can only access authorized functions and data (for example, book deletion is restricted to administrators, while readers can only view their personal borrowing records), effectively preventing unauthorized access and ensuring system security.

4.2 Book Management Module Implementation

The book management module implements complete book information management functionality. Administrators can add book information via forms or batch import, and the system automatically verifies data integrity and validity. Book classification adopts the Chinese Library Classification system, supporting multi-level category management to facilitate book organization and retrieval.

Integration of RFID technology is the innovation of this module. Each book is affixed with an RFID tag; through readers, book information can be quickly identified, enabling rapid inventory and location of books. The system monitors the on-shelf status of books in real time, providing data support for self-service borrowing and returning. The book search function supports multi-condition combined queries; readers can find books by title, author, classification number, and other dimensions. Search results support pagination and multiple sorting options, greatly improving user experience. The system also provides book cover image upload and display, making search results more intuitive.

4.3 Implementation of the Circulation Management Module

The circulation management module uses a workflow engine to drive business processes, achieving complete lifecycle management of borrowing. Readers can complete borrowing operations via self-service terminals; the system automatically records borrowing information and updates book status. Returning books is equally simple readers only need to place the book in the return box, and the system automatically completes the return registration via RFID technology.

The reservation function allows readers to reserve books that are currently on loan; when the book is returned, the system automatically notifies the reserver. The renewal function allows readers to extend the borrowing period, and the system automatically calculates the new due date. The overdue management function sends reminders in advance and imposes borrowing restrictions on readers with long-term overdue items.

This module pays special attention to handling exceptional situations; processes are in place for cases such as lost or damaged books. All borrowing operations generate detailed log records for subsequent queries and statistics.

4.4 Implementation of the Data Statistics Module

The data statistics module uses batch processing to handle large volumes of data and periodically generates various business reports. The borrowing statistics function can analyze borrowing situations by time, book category, reader type, and other dimensions, producing borrowing rankings and trend analysis charts.

Resource utilization analysis helps the library understand collection usage, identify underutilized books, and provide a basis for acquisition and weeding decisions. Reader behavior analysis mines borrowing records to discover borrowing patterns and preferences, supporting targeted services.

5.5 Implementation of the Intelligent Recommendation Module

The intelligent recommendation module adopts a hybrid strategy, combining content-based recommendation (calculating similarity based on book metadata) and collaborative filtering algorithms (analyzing group borrowing patterns to find similar readers), while also supporting popular book recommendations. Recommendation results are generated by weighted scoring of multiple algorithms; the system records reader feedback to continuously optimize algorithms, incorporates time decay factors, supports personalized preference settings, and regularly updates models to ensure accuracy, timeliness, and relevance of recommendations.

5. SYSTEM TESTING AND APPLICATION EFFECTS

5.1 Testing Methods and Environment

System testing combines black-box and white-box approaches, covering functional, performance, and security tests: the test environment simulates real-world scenarios (4-core CPU + 16 GB RAM server, mainstream client browsers, Impinj R420 RFID devices); functional testing is use-case-driven, performance testing uses JMeter to simulate multi-user concurrency, and security testing includes penetration tests and code audits; Selenium and Postman automation tools are introduced to improve efficiency.

5.2 Test Result Analysis

Functional test results show that all system modules are fully implemented and business processes meet expectations. The user management module achieved 100 % test coverage with a 98.5 % pass rate; the book management module achieved 95 % coverage with a 99 % pass rate; the borrowing workflow achieved 100 % coverage with a 97 % pass rate; the recommendation system achieved 90 % coverage with a 92 % pass rate.

Performance tests indicate the system meets design requirements. Under a 200-concurrent-user stress test, the average response time is 1.2 s, the error rate is 0.5% , and throughput reaches 150 requests/s. A 24-hour sustained load test shows stable operation, memory usage kept within 4 GB, and average CPU utilization at 30 %.

Security testing revealed no major vulnerabilities; the system effectively defends against common threats such as SQL injection and XSS attacks. Data transmission and storage use strong encryption algorithms and comply with information security standards.

6. CONCLUSION AND OUTLOOK

The intelligent library management information system designed in this study integrates Web technology with RFID IoT technology, addressing pain points of traditional management. Innovations include: a front-end/back-end separated architecture improving maintainability and scalability; RFID integration enabling self-service borrowing/returning to boost efficiency; user-behavior-based intelligent recommendation algorithms to increase resource utilization; and comprehensive data analytics to support management decisions.

Future work will extend mobile functionality, introduce deep learning to optimize recommendations, explore integration with campus systems for data sharing, and investigate blockchain applications in borrowing records and copyright protection.

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