RFID Library Checkout System

TRAINING

PROJECT REPORT

Submitted by

Sudhanshu Yadav(23BCS14344)

in partial fulfillment for the award of the degree of

BACHELOR OF ENGINEERING

IN

COMPUTER SCIENCE

Chandigarh University

JUNE – 2025

BONAFIDE CERTIFICATE

Certified that this project report **"RFID Library Checkout System"** is the bonafide work of "**Sudhanshu Yadav (23BCS14344)"** who carried out the project work under my/our supervision.

SIGNATURE	**SIGNATURE**
Dr. Sandeep Singh Kang	Er. Roop Sharma
ASSOCIATE DIRECTOR (CSE-3rd Year)	**SUPERVISOR**

Submitted for the project viva-voce examination held on 25 June 2025

INTERNAL EXAMINER	**EXTERNAL EXAMINER**

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to **Chandigarh University** for providing me with the opportunity to undertake this project titled **"RFID-Based Library Checkout System"**, which has been a significant step in my academic and professional development.
I extend my heartfelt thanks to my respected guide, **Er. Roop Sharma**, [Academic Designation], Department of Computer Science Engineering, for their invaluable guidance, constant encouragement, and unwavering support throughout the duration of this project. Their deep insights, suggestions, and constructive feedback played a vital role in shaping the project and this report.
I am also grateful to **Dr. Sandeep Singh Kang**, Associate Director, CSE – 3rd Year, for providing the necessary academic support and resources, and for fostering an environment conducive to innovation and learning.
My sincere thanks to the library and technical staff of Chandigarh University for their assistance in understanding the practical aspects of RFID integration and for allowing access to the facilities and resources that made this project possible.
Lastly, I would like to thank my peers, family, and friends for their continuous encouragement, motivation, and moral support throughout the development of this project. This project has been a valuable learning experience, allowing me to apply theoretical knowledge to a real-world application, and has strengthened my skills in hardware integration, web development, and system design.

ABSTRACT

The RFID-Based Library Checkout System is an innovative solution designed to automate and modernize the conventional library management process. Traditional library systems often suffer from inefficiencies, manual errors, and time-consuming book issue and return procedures. These limitations can hinder the overall user experience and create unnecessary administrative burdens. To overcome these challenges, this project integrates Radio Frequency Identification (RFID) technology with a robust web-based platform to streamline operations and provide a contactless, secure, and efficient checkout process.

Each book in the library is embedded with an RFID tag, and students are issued RFID-enabled identity cards. When a student scans their card along with a book tag at the RFID reader module, the transaction is authenticated and automatically recorded in the centralized system. The backend of the project is developed using ASP.NET Core Web API, and the database is managed through SQL Server. A dynamic and user-friendly front-end interface built with HTML, CSS, and JavaScript enables both students and administrators to interact with the system in real time.

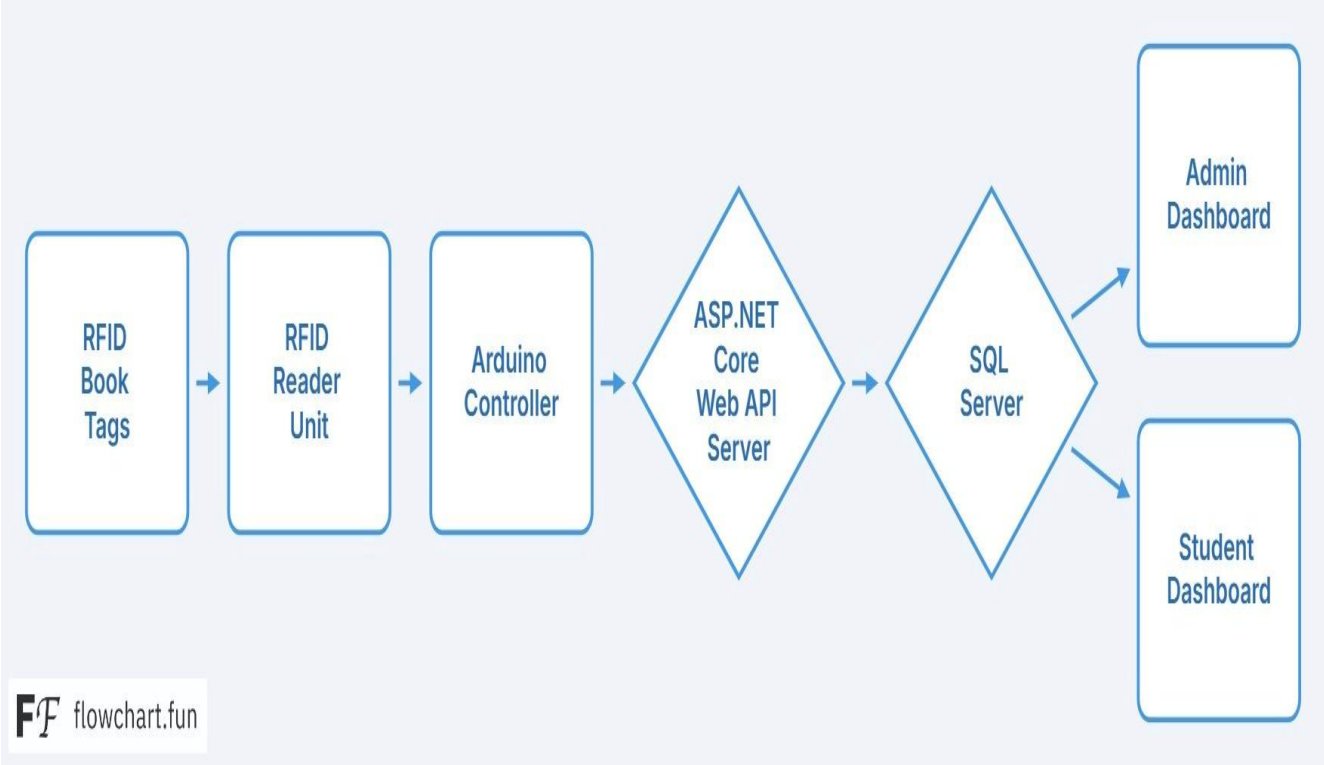
The system not only automates the borrowing and returning of books but also enhances functionality through features such as student and admin dashboards, QR code generation for book information, online book booking, dark mode interface, live search capabilities, due date alerts, and personalized user experiences. By digitizing and securing the transaction records, the system ensures accuracy, traceability, and improved resource management within the library environment.

This project demonstrates the effective integration of hardware and software technologies to build a smart and scalable solution for library automation. It contributes toward reducing operational delays, enhancing data security, and improving access to educational resources, thereby setting a foundation for the development of future-ready digital libraries.

GRAPHICAL ABSTRACT

The architecture of the RFID-Based Library Checkout System integrates both hardware and software components to create an efficient and automated library management solution. The system workflow is described below:

1. **RFID Book Tags**
   - Each book is embedded with an RFID tag that uniquely identifies it.
2. **RFID Reader Unit**
   - Reads the RFID tag data from books and student RFID cards during issue/return operations.
3. **Arduino Controller**
   - Acts as a bridge between the RFID hardware and the software system.
   - Transfers scanned data to the server using serial or HTTP communication.
4. **ASP.NET Core Web API Server**
   - Handles backend processing such as:
     - Authentication and authorization
     - Book issuance and return logic
     - QR code generation for books
5. **SQL Server Database**
   - Stores and manages all records including:
     - Book information
     - Student data
     - Transaction logs
6. **Admin Dashboard**
   - Enables administrators to:
     - Add/manage books and student accounts
     - View and monitor book issue/return history
7. **Student Dashboard**
   - Allows students to:
     - Search and borrow books
     - View due dates
     - Return books and access book purchase options


RFID
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Dashboard
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CHAPTER 1 – INTRODUCTION

1.1. Identification of Client and Need

In modern educational institutions, libraries play a vital role in supporting learning and research activities. However, traditional library systems often suffer from inefficiencies such as long queues for issuing and returning books, misplaced records, manual errors, and lack of real-time inventory tracking. The client for this project is the university library system itself — specifically aimed at providing students, faculty, and library staff with a more efficient, automated, and user-friendly method for managing book checkouts and returns.
The need for automation in library operations is driven by the increasing number of students and books, the necessity of reducing human error, and the growing expectation for digital, contactless services. An RFID-based solution allows the identification and tracking of books and users with minimal human intervention, resulting in improved operational efficiency and data accuracy**.**

1.2. Relevant Contemporary Issues

With the shift toward digital transformation across educational services, manual library operations are becoming outdated. Current issues faced by libraries include delays in book processing, mismanagement of inventory, lack of accountability, and difficulty in tracking overdue books. Furthermore, post-pandemic hygiene concerns have accelerated the need for contactless services. RFID technology, when integrated with modern software platforms, addresses these issues by offering real-time automation, reduced physical contact, and robust tracking features.

1.3. Problem Identification

The primary problem identified is the inefficiency and inaccuracy in traditional, manual book issue and return systems in libraries. Manual entry can lead to frequent human errors, lost books, duplicate records, and difficulty in generating accurate reports. Additionally, students face long wait times due to slow processing, and administrators struggle with tracking overdue returns or stolen items. These challenges indicate the urgent need for a smart, scalable, and reliable solution**.**

1.4. Task Identification

The successful implementation of the RFID-Based Library Checkout System requires several tasks to be completed systematically:

2 Selection and configuration of appropriate RFID hardware (tags, readers, microcontroller)
3 Designing a real-time communication mechanism between hardware and software (Arduino to server)
4 Development of a web application using ASP.NET Core for admin and student dashboards
5 Integration of SQL Server for backend storage of books, transactions, and user data
6 Implementation of features like QR code generation, online booking, soft/hard copy purchase, and due-date alerts
7 Testing and validation of hardware-software interaction and user interfaces

1.5. Project Timeline

The timeline for this project is divided into multiple phases, each corresponding to the completion of critical modules. The approximate timeline is shown below:Day 1: Requirement analysis, tool selection, architecture planning

Phase	**Duration**
Requirement Analysis	Day 1
RFID Hardware Setup	Day 2-3
Backend development(API)	Day 4-5
Frontend Dashboard Design	Day 5
Database Integrations	Day 6-7
Testing and Validations	Day 8
Final integration And Report	Day 9

CHAPTER 2 - LITERATURE SURVEY

2.1. Timeline of the Reported Problem as Investigated Throughout the World

The challenges associated with manual library management systems have been reported for decades. Initially, libraries relied on physical record books, which later transitioned to barcode-based systems in the 1980s and 1990s. However, barcode systems required line-of-sight scanning and were vulnerable to damage or duplication.

By the early 2000s, libraries across Europe and North America began adopting **RFID (Radio Frequency Identification)** to improve operational efficiency. Institutions like the **Singapore National Library Board** and **University of Cambridge** implemented RFID to streamline book tracking and automate check-ins and check-outs. In India, prominent institutions such as **IIT Delhi** and **IIM Ahmedabad** gradually adopted RFID-based systems over the last two decades, reporting reduced manpower requirements and improved transaction accuracy.

Despite these developments, many smaller institutions and universities still rely on manual or semi-automated systems due to budget constraints or lack of technical expertise, leading to the persistence of operational inefficiencies.

2.2 Bibliometric Analysis

A review of academic literature reveals a steady increase in publications related to RFID applications in library and inventory systems. Journals such as **IEEE Transactions on Automation Science and Engineering**, **Library Hi Tech**, and **International Journal of Computer Applications** have consistently published research on RFID system integration.

Most papers discuss the benefits of RFID in terms of:

- Contactless operation
- Real-time tracking
- Integration with databases
- Enhanced security

However, drawbacks commonly noted include:

- High initial cost
- Hardware compatibility issues
- Data privacy concerns

- Need for skilled maintenance

Recent studies also explore hybrid models combining **RFID with QR codes, cloud-based dashboards, and IoT** to expand functionality, which aligns closely with the objectives of this project.

2.3 Proposed Solutions by Different Researchers

Various solutions have been proposed to address library inefficiencies:

- **Deshmukh et al. (2017)** proposed a barcode and fingerprint-based hybrid system but found it limited in scalability.
- **Waghmare et al. (2018)** designed a low-cost RFID-enabled library with Arduino Uno and passive RFID readers for small academic setups.
- **Zhang and Wang (2020)** explored a cloud-integrated RFID solution using ESP32 for real-time sync and analytics.
- **Mukherjee et al. (2022)** suggested adding blockchain to track book lending history securely.

While these systems addressed individual pain points, few provided a comprehensive student-admin dashboard integration, online booking, and payment options — which this current project attempts to solve.

2.4 Summary Linking Literature Review with Project

The review confirms that RFID-based systems enhance the efficiency, accuracy, and usability of library operations. However, existing solutions often lack full-stack integration, user personalization, and real-time interactivity between hardware and software components.

This project leverages insights from prior research while introducing:

- A full-stack implementation (Arduino + ASP.NET Core + SQL Server)
- Dual dashboards for students and admins
- Online booking and soft/hard copy options
- Return alerts and QR integration

Hence, it extends current research by implementing a complete hybrid model fit for modern academic environments.

2.5 Problem Definition

The traditional manual system of managing library operations is time-consuming, error-prone, and inefficient. It suffers from delays in transaction processing, record mismatches, lost or untraceable books, and lack of real-time visibility.

The core problem is the absence of a smart, unified system that integrates **hardware (RFID)** with a scalable **software backend** and a user-friendly **web interface** to support:

- Accurate book tracking
- Faster check-in/check-out
- Student-specific services
- Admin-level monitoring

This project is designed to provide an effective solution that not only digitizes but **automates** the library process using modern tools.

2.6 Goals and Objectives

The project aims to design and implement a scalable, secure, and easy-to-use RFID-based system for educational library checkouts. The objectives include:

- To develop a hybrid hardware-software system using RFID and ASP.NET Core.
- To eliminate manual entry errors by automating book transactions.
- To create dashboards for students and admins with role-specific functionalities.
- To provide online book booking with options for both soft and hard copy purchases.
- To include features such as QR code generation, live search, dark mode, and return reminders.
- To ensure real-time synchronization and data validation using SQL Server.

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CHAPTER 3 - DESIGN FLOW / PROCESS

3.1 Concept Generation

The initial concept of this project was inspired by the need to modernize the traditional library management system through automation. The core idea was to use RFID technology to eliminate manual book entries and speed up the process of issuing and returning books. The concept evolved further with the inclusion of an interactive web-based interface to enhance usability for both students and administrators. The system was envisioned as a comprehensive platform integrating hardware (RFID, Arduino) and software (ASP.NET Core, SQL Server, HTML/CSS/JS) to create a seamless end-to-end experience.

3.2 Evaluation & Selection of Specifications / Features

After analyzing various academic systems and user requirements, the following features and specifications were selected for the system:

- RFID-enabled Identification: For both students and books to allow quick, contactless scanning.
- Arduino UNO/ESP32: As the hardware microcontroller to interface with RFID reader and communicate with the backend.
- ASP.NET Core Web API: For building a scalable and secure backend with RESTful endpoints.
- SQL Server: For robust and structured data storage.
- Responsive Web Frontend: Built using HTML, CSS, Bootstrap, and JavaScript for easy accessibility.
- QR Code Generation: For book details display and fast identification.
- Soft & Hard Copy Purchase Option: Online payment integration for different formats.
- Return Due Calendar and Notifications: To enhance book tracking and reminders.
- Dark Mode UI Toggle: For improved accessibility and customization.

3.3 Design Constraints

While designing the system, several real-world constraints were considered:

- Economic Constraints: Budget limitations restricted the choice of hardware (Arduino UNO over advanced boards) and influenced the decision to use open-source frontend tools.
- Technical Constraints: Compatibility between RFID hardware and microcontroller, serial communication delays, and backend integration challenges.
- Environmental Constraints: Ensuring that RFID signals are not disrupted by interference or metal shelves.
- Safety Constraints: Power isolation for Arduino and RFID circuits to prevent

hardware damage.

- User Constraints: The interface had to be intuitive for non-technical students and admins.
- Data Privacy & Security: User and book data had to be securely stored and transmitted over HTTPS.

3.4 Feature Finalization

Based on user feedback and practical feasibility, the final features of the system included:

- RFID scan for book issue/return
- Role-based login system
- Student dashboard with:
  - Search and filter books
  - Borrowing history
  - Book purchase (soft/hard copy)
  - Return due calendar
- Admin dashboard with:
  - Book inventory management
  - Student record management
  - Transaction logs
- QR code for every book
- Theme toggle (dark/light)
- Auto-suggestions in search
- Chat/Help section

3.5 Design Flow (Alternative Designs)

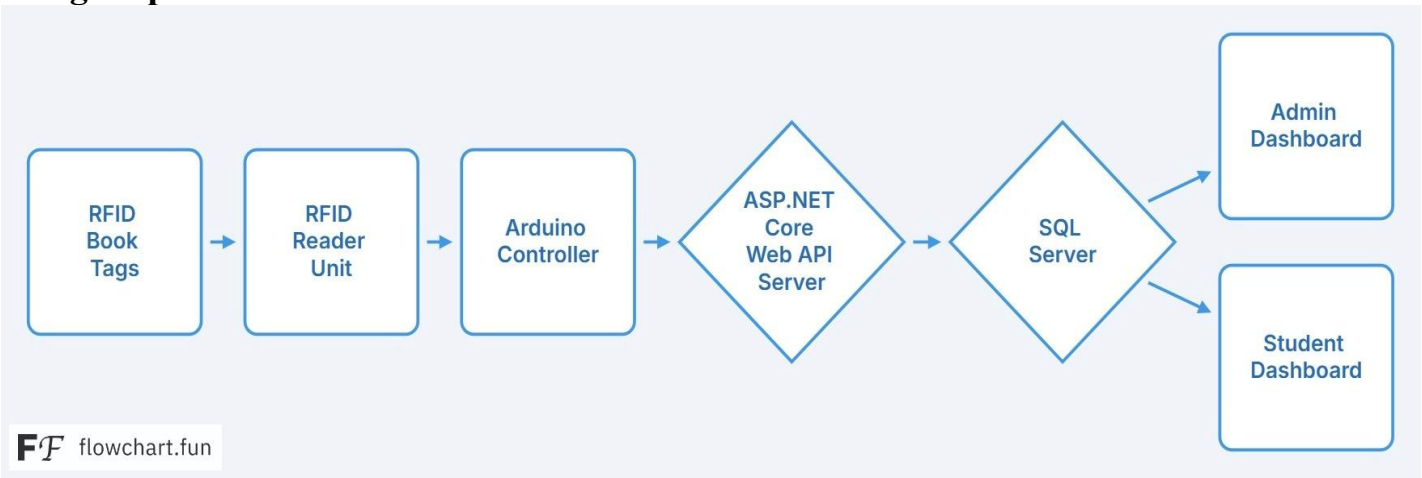
Design Option 1:

- RFID + Arduino UNO
- Backend with local ASP.NET Core API
- SQL Server running on local machine
- HTML/CSS dashboard with minimal JavaScript

Pros: Low-cost, easy to prototype

Cons: Limited scalability, requires manual deployment

Design Option 2:



- RFID + ESP32 (Wi-Fi enabled)
- Backend hosted on cloud (Azure/Heroku)
- SQL Server or cloud-hosted DB
- React-based frontend (or Bootstrap-enhanced UI)

Pros: Scalable, supports real-time sync, cloud backup
Cons: Higher complexity, more setup/configuration required

3.6 Best Design Selection

After comparison, Design Option 1 was selected for implementation due to:

- Cost-effectiveness for student-level project
- Simpler integration with offline or LAN environments
- Easier debugging and development workflow
- Suitable for small to medium-scale libraries

Despite the advantages of Option 2, cloud dependency and higher initial effort made it less suitable under the project's timeline and scope.

3.7 Implementation Plan (Flowchart / Algorithm)

Implementation Steps:

1. RFID tag is attached to each book
2. RFID reader scans student ID and book
3. Arduino processes and sends data to server
4. Server validates user and book
5. Database updates issue/return record
6. Dashboard reflects updated transaction
7. QR code is generated/displayed
8. Student/Admin can interact via respective dashboards

CHAPTER – 4 RESULTS ANALYSIS AND VALIDATION

4.1 Modern Engineering Tools

To ensure precision, reliability, and efficiency in both hardware and software development, a variety of modern engineering tools were used during the course of the project. The **Arduino IDE** was used to write, compile, and upload embedded code to the Arduino UNO for managing RFID interactions. For backend development, **ASP.NET Core** within **Visual Studio 2022** enabled the creation of scalable RESTful APIs that connected the hardware with the database and frontend.

The system's data was stored and managed using **Microsoft SQL Server**, with **SQL Server Management Studio (SSMS)** supporting database creation, table design, and query execution. To test API responses and ensure proper client-server communication, **Postman** was extensively used. Early UI design and prototyping were done using **Figma**, which helped lay out the dashboards for both students and administrators.

The web interface was developed using **HTML, CSS, JavaScript**, and **Bootstrap** inside **Visual Studio Code**, allowing for responsive and structured frontend design. For version control and collaboration, **Git and GitHub** were utilized to manage source code history and team contributions. Finally, tools like the **Serial Monitor** and **PuTTY** helped debug communication between Arduino and the server, ensuring accurate data transfer during RFID scans.

These tools were not only chosen for their individual capabilities but also for their interoperability, which allowed smooth integration across development layers. For example, Visual Studio's integrated terminal and Git support improved version tracking while enabling developers to push changes directly to GitHub without switching tools. Similarly, using Postman alongside the live server simplified endpoint testing without needing full UI deployment.

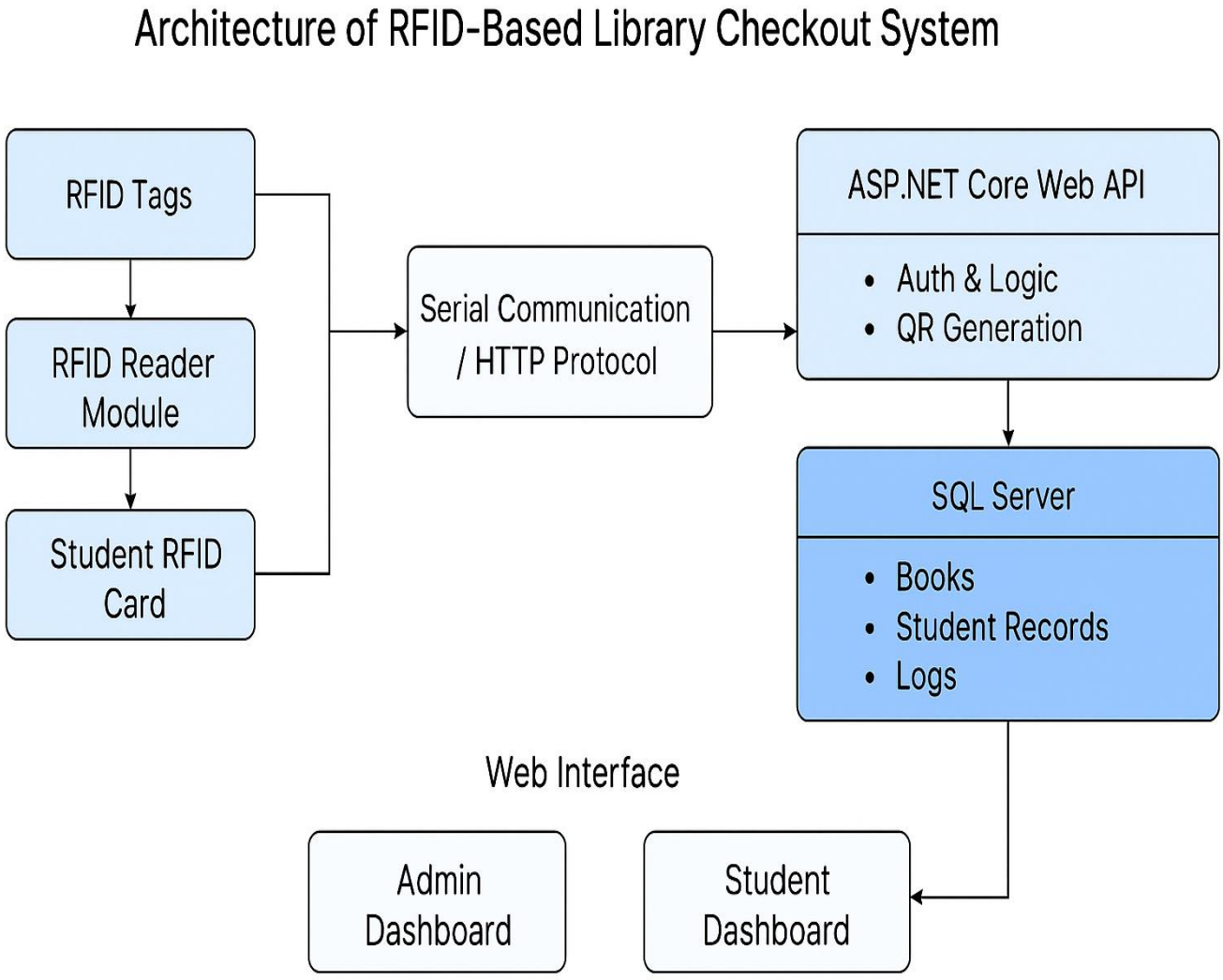
Overall, the careful selection and consistent use of modern tools ensured that the project maintained a high standard of code quality, traceability, and modular design. Each phase of development—from hardware prototyping to backend logic and frontend interface—was made significantly more efficient, manageable, and reliable through the use of these technologies.

4.2 Design Drawings / Interface Pages

The following design drawings and interface screenshots demonstrate the functionality and workflow:

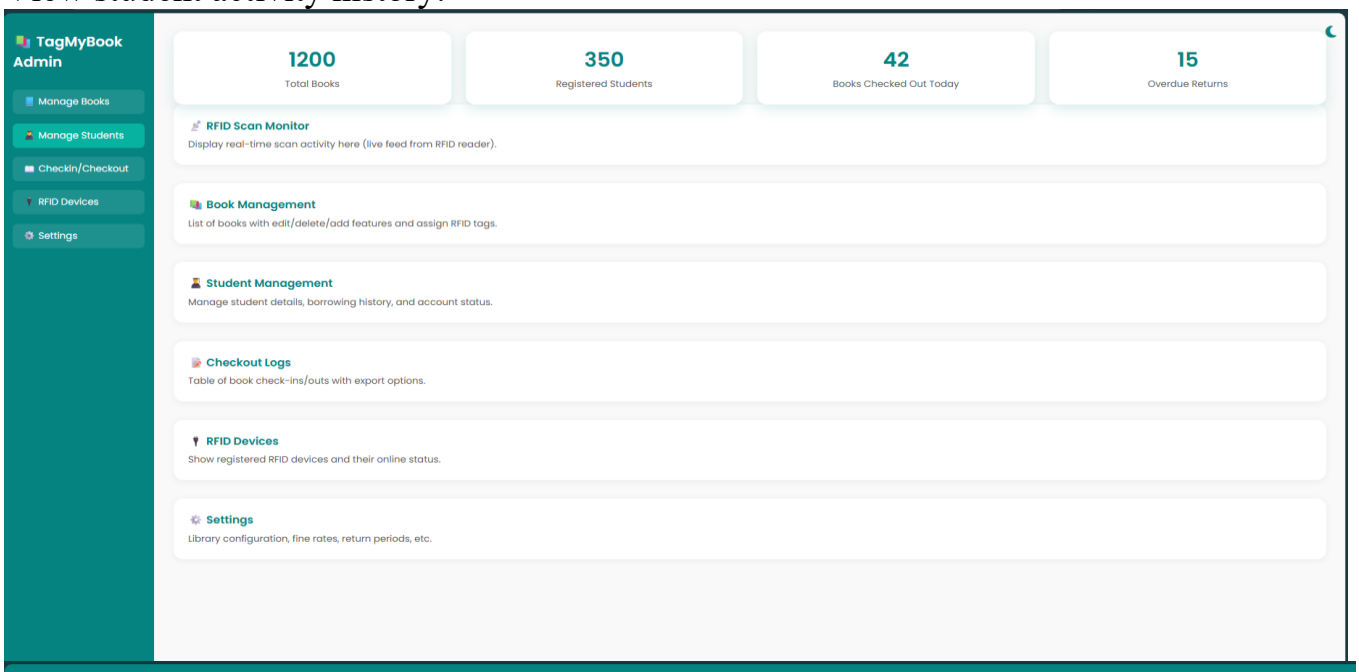
1. System Architecture Diagram

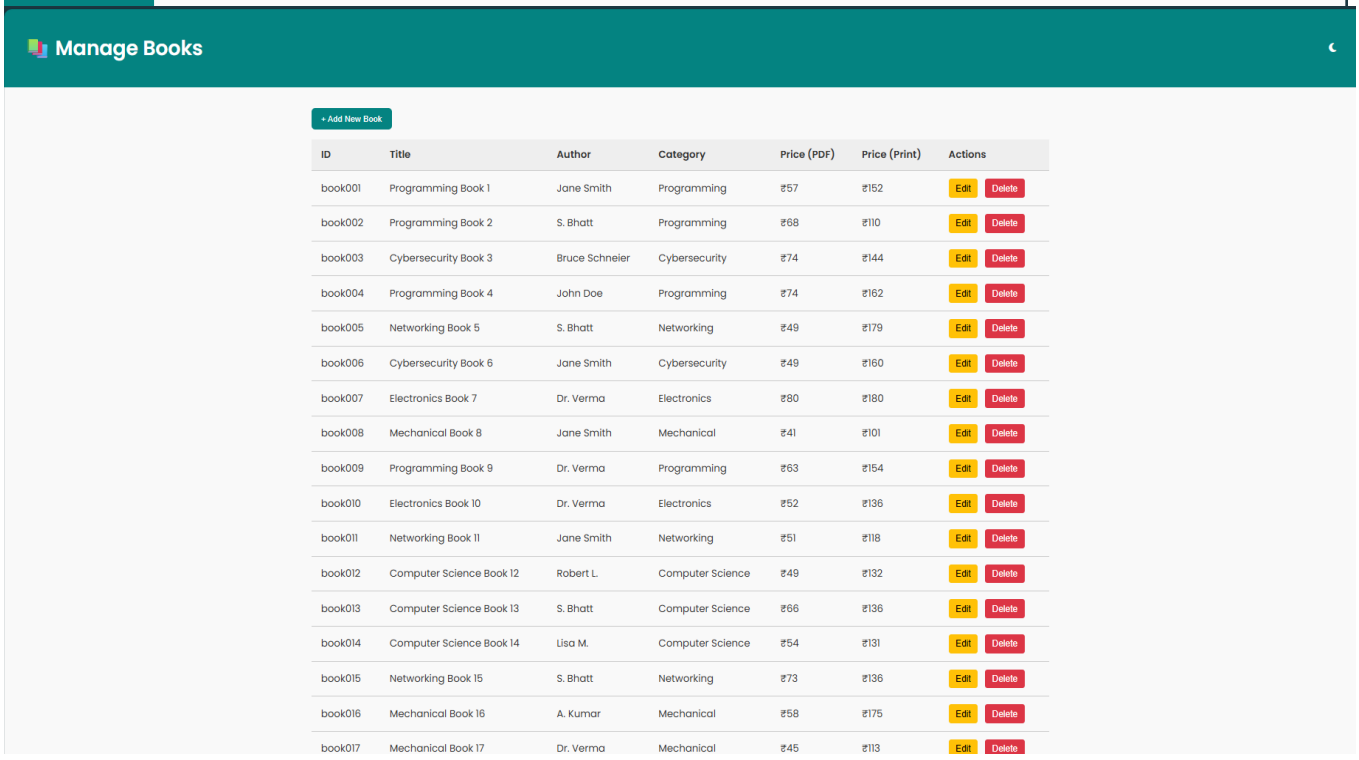
- Showcases the integration between RFID reader, Arduino, ASP.NET Core backend, SQL Server, and the web dashboard.

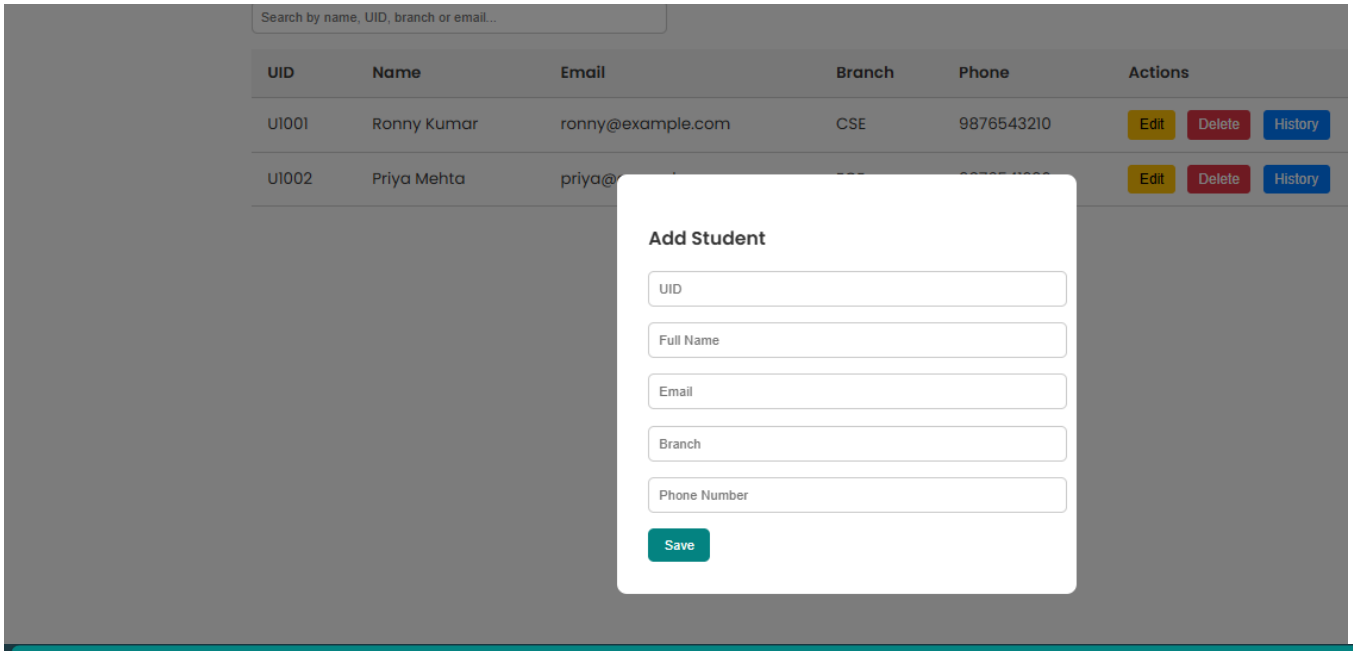


2. Admin Dashboard Page

- View, add, and manage book records.
- Monitor check-in/check-out logs.
- View student activity history.



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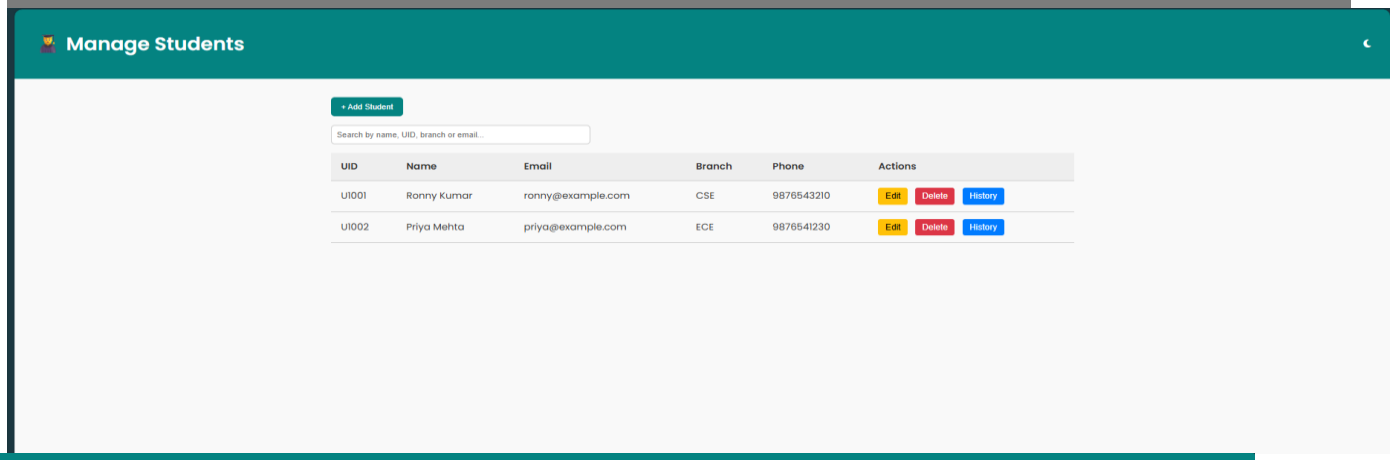
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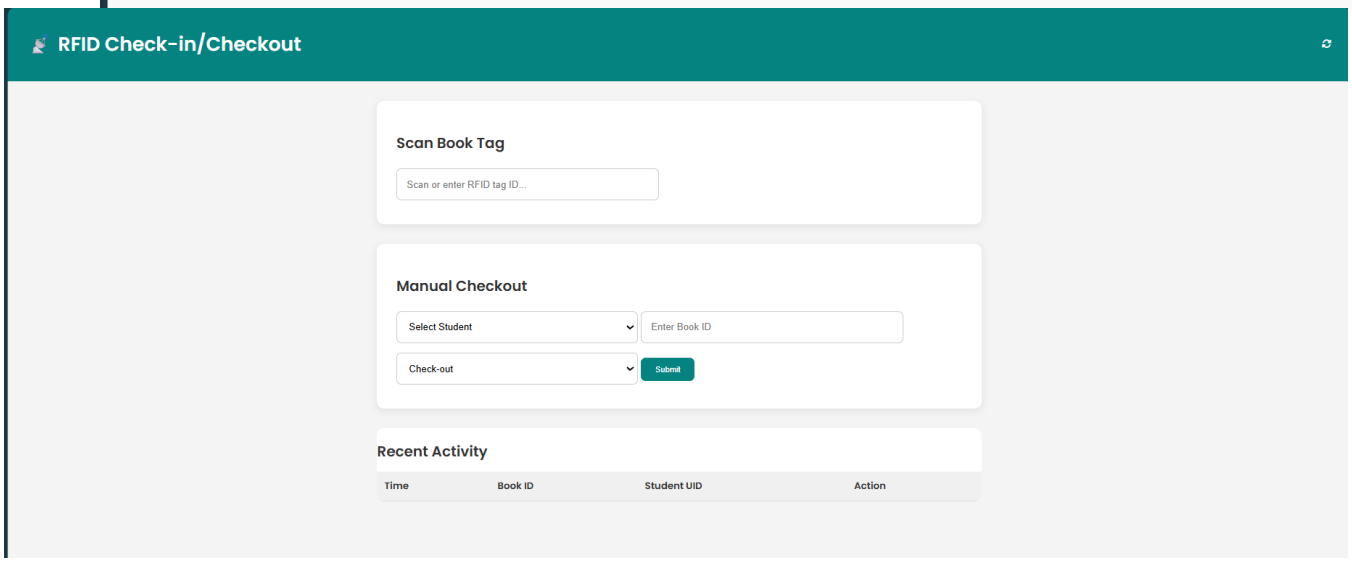
RFID Check-in/Checkout
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Select Student
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Submit
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Student UID
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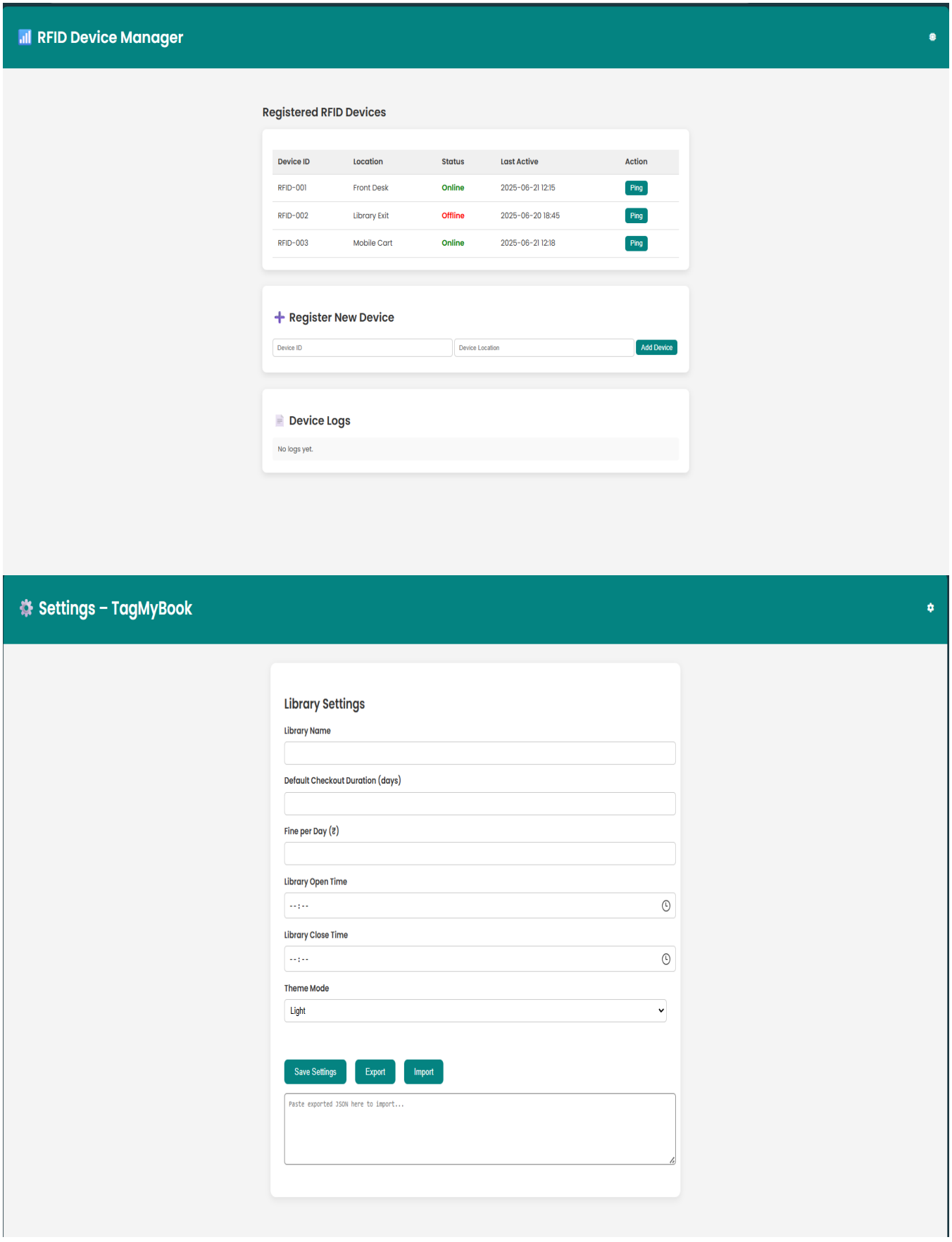
RFID Device Manager
Registered RFID Devices
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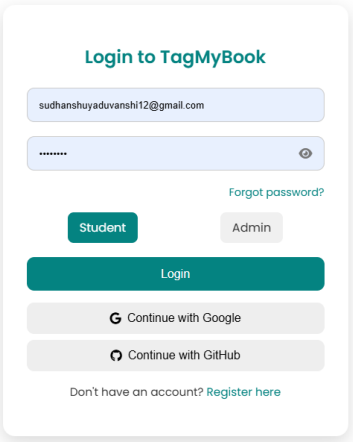
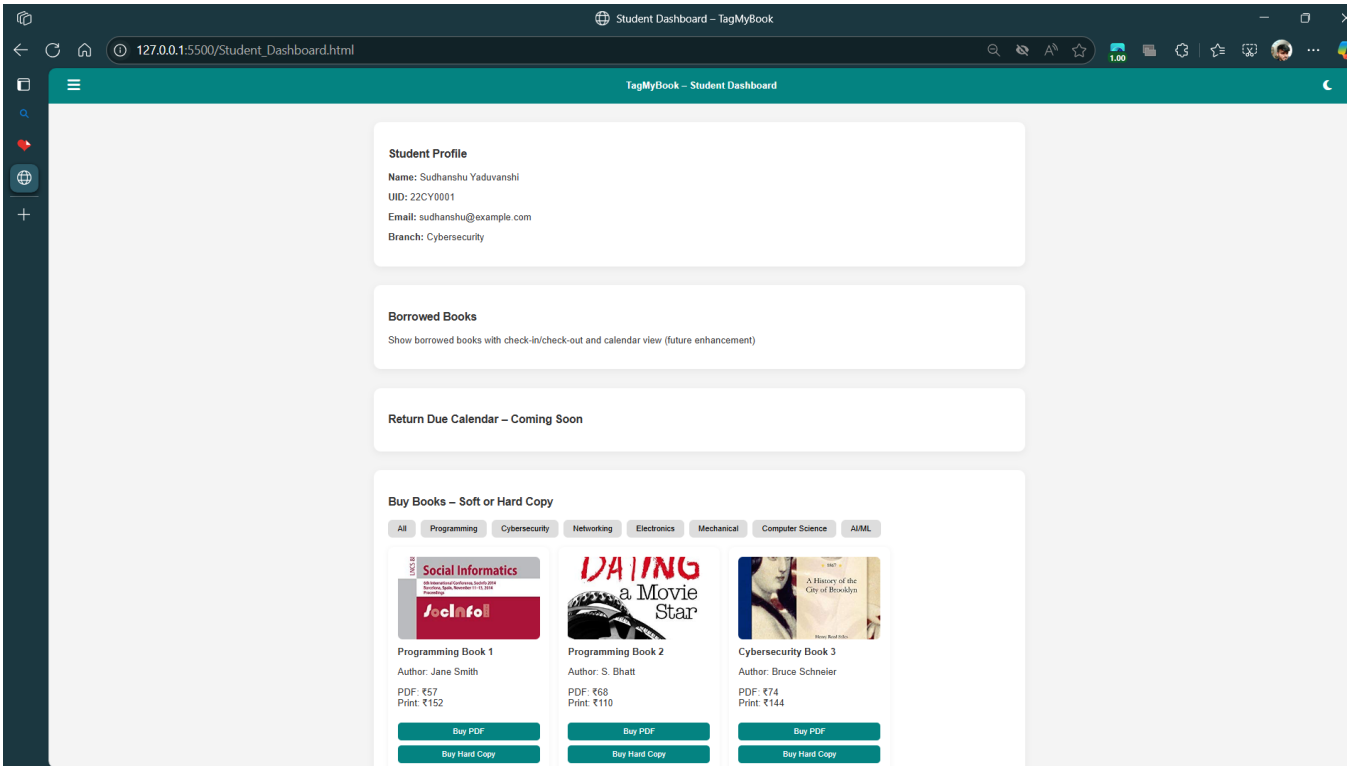
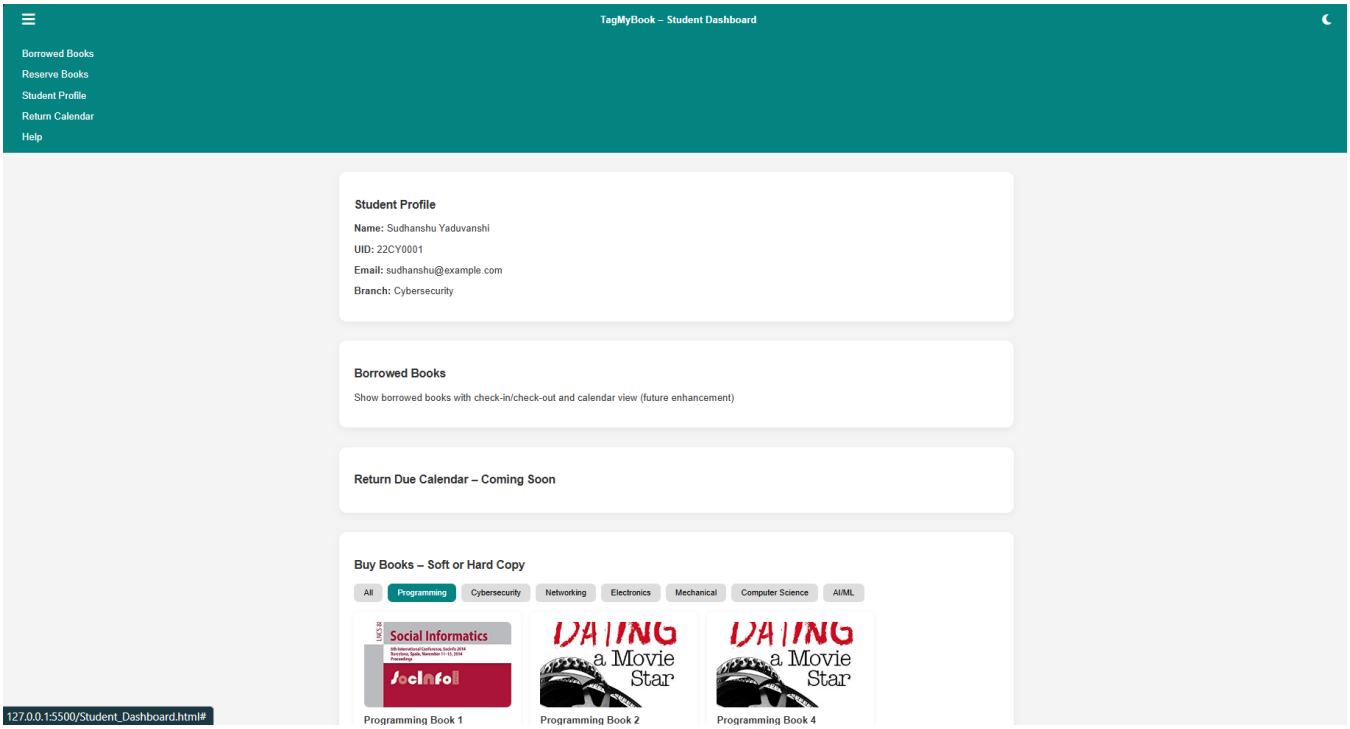
3. Student Dashboard Page

- Search/filter books.
- View borrowing history.
- Online booking/purchase option.
- Return due reminders.

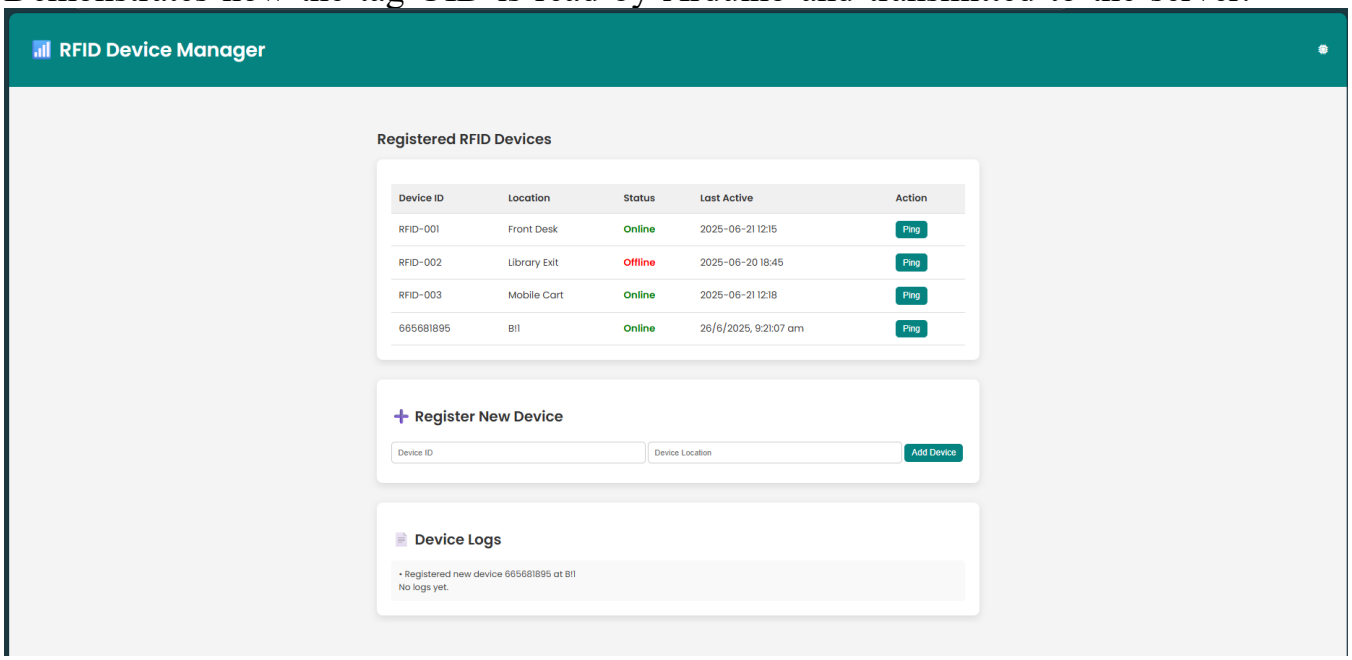






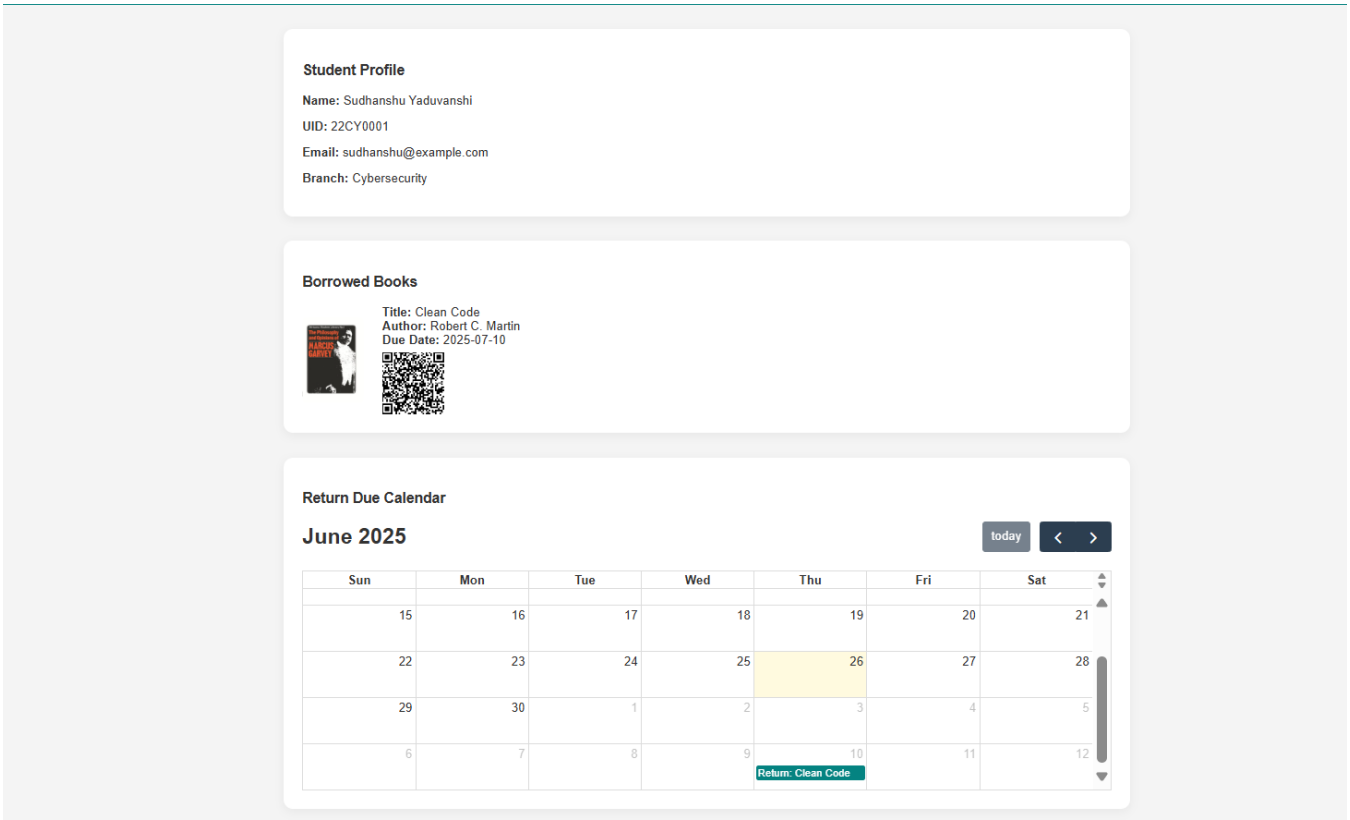
4. RFID Scan Simulation

- Demonstrates how the tag UID is read by Arduino and transmitted to the server.



5. QR Code Generation

- Automatically generated on book selection to allow mobile scanning.



4.3 Report Preparation and Project Management

The preparation of this report was carried out systematically alongside the technical development of the RFID-Based Library Checkout System. From the outset, a clear outline of chapters, sub-sections, and milestones was created to ensure that the documentation would reflect not only the final product but the entire development journey. Each section of the report was designed to align with the project's objectives, technical components, and implementation strategies, ensuring completeness and clarity.

The report preparation involved multiple phases, including regular collection of system data (such as design changes, screenshots, test results), recording development challenges, and maintaining versioned drafts. Tools such as **Microsoft Word** and **Google Docs** were used for collaborative writing, formatting, and proofreading. Diagrams like system architecture and flowcharts were developed using **draw.io** and **Figma**, while tabular data and Gantt charts were created in **Microsoft Excel**.

In terms of project management, the overall development process followed a **modular and iterative approach**. Major phases included requirement analysis, design planning, hardware prototyping, API development, interface design, integration testing, and final validation. Each phase had its own set of tasks, expected outcomes, and review checkpoints. Simple Kanban boards (via tools like Trello) and checklists were used to

track progress and ensure timely completion of deliverables.
Periodic review meetings and self-assessments ensured alignment with the project timeline. Risks and challenges, such as hardware connectivity issues or backend integration delays, were documented and addressed iteratively. Overall, the structured planning and documentation process helped maintain focus, improved team coordination, and resulted in a detailed, comprehensive report that accurately represents the technical and developmental aspects of the project.

4.1. Testing and Characterization

Testing was carried out to ensure that all system components—both hardware and software—performed as expected. Unit testing was done for individual modules such as RFID reading, API response handling, and database connectivity. Integration testing verified end-to-end flow from RFID scanning to transaction logging and UI updates.

The RFID reader was tested with various tags to ensure consistent detection range and speed. API endpoints were validated using Postman to check for correct data retrieval, error handling, and response times. On the frontend, form validations, user login sessions, and dashboard functionalities were tested across multiple browsers.

The system successfully passed all key functionality tests, including real-time book issuance, return, and dashboard synchronization. Minor adjustments were made to improve scan accuracy and UI responsivene

The system underwent multiple levels of testing to ensure reliable performance and accurate integration between hardware and software components. Initial **unit testing** was conducted for individual modules such as the RFID tag scanner, Arduino serial communication, backend API responses, and database operations. Each module was tested in isolation to confirm that inputs produced the expected outputs. RFID scanning was tested for range and tag consistency, while API requests were validated using **Postman** to check response codes, data handling, and latency

4.5. Data Validation and Interpretation

Data validation was a critical step in ensuring the system's accuracy, consistency, and reliability. During each book transaction—whether issue or return—the data transmitted from the RFID hardware was verified against existing entries in the database to confirm the book's availability and the student's borrowing status. This real-time cross-check helped avoid duplicate transactions, unauthorized access, or incorrect record updates. SQL constraints and backend validations were implemented to enforce rules such as maximum borrow limits, unique student entries, and correct date logging.

Interpretation of the test results confirmed that the system consistently maintained correct book status updates and user activity logs. Transactions recorded in the database were accurately reflected in the student and admin dashboards, with no data loss or corruption observed during high-volume testing. The return due calendar, QR code data, and live search suggestions also functioned based on dynamically fetched, validated records. Overall, the system demonstrated high reliability and correctness in handling user data and library records.

CHAPTER 5 - CONCLUSION AND FUTURE WORK

5.1 Conclusion

The RFID-Based Library Checkout System successfully integrates hardware components like RFID tags, readers, and microcontrollers with a robust software stack consisting of ASP.NET Core, SQL Server, and a user-friendly web interface. The system automates book issue and return processes, reduces manual effort, and improves overall efficiency in library operations. Testing showed that the system performs reliably, handles data accurately, and delivers a seamless experience for both students and administrators. The project met its key objectives and demonstrated how modern embedded and web technologies can transform traditional library workflows.

5.2 Deviation from Expected Results

While the core functionality was implemented effectively, a few minor deviations were encountered. For example, real-time data sync over Wi-Fi using the ESP32 was initially planned but replaced with a USB-based Arduino setup due to hardware limitations. Additionally, online payment integration for book purchases was scoped but not fully implemented due to time constraints. These limitations, however, did not affect the primary functionality of the system.

5.3 Future Work and Way Ahead

The system can be further improved by integrating a cloud-based database to enable cross-campus access and backups. A mobile app version of the dashboard can also be developed for ease of access. Additional features like NFC support, voice search, AI-based book recommendations, and fine management automation could enhance the system's usefulness. Expanding the system to support inter-library book exchanges or blockchain-based transaction records could also add future value**.**

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User Manual

1. Student Login

Open the Student Dashboard webpage.

Enter credentials to log in.

View borrowed books, due dates, and profile.

2. Book Checkout

Place the book near the RFID reader.

Tap the student RFID card.

Book details and confirmation appear on the dashboard.

3. Book Return

Tap the RFID card again and scan the book.

Dashboard updates the return status.

Return calendar reflects the change.

4. Search & Purchase

Use the search bar with live suggestions.

Click on a book to view details.

Choose "Soft Copy" (PDF) or "Hard Copy" to purchase.

Confirm order (payment integration under development).

5. Admin Access

Admin logs into the Admin Dashboard.

Can add/edit/delete books or student records.

Views borrowing history and system logs.

Achievements

- Successfully implemented a hybrid hardware-software library system.
- Designed and deployed role-based dashboards for students and administrators.
- Integrated RFID scanning with real-time transaction logging.
- Built features like QR code generation, due date alerts, and online book booking interface.
- Achieved functional prototype within the timeline and demonstrated in a live academic setting.