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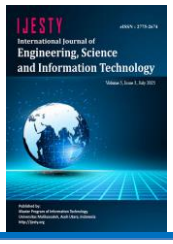

The Radio Frequency Identification Implementation Design for INLISLite Library Management System

Majidah[1*], Widiyanto[1], Aji Purwinarko[2], Kasinyo Harto[3], Fridiyanto Fridiyanto[4], Amirul Mukminin[5]

[1]Library and Information Science, Universitas Terbuka, Indonesia
[2]Department of Informatics, Universitas Negeri Semarang, Indonesia
[3]Universitas Islam Negeri Raden Fatah, Palembang, Indonesia
[4]UIN Sulthan Thaha Saifuddin Jambi, Indonesia
[5]Graduate School, Universitas Jambi, Indonesia

**Corresponding author Email: majidah@ecampus.ut.ac.id*

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Abstract

A challenge with self-borrowing services is the investment cost for both software and hardware. A software license is required to connect INLIS [Integrated Library System] Lite with Radio Frequency Identification [RFID], which results in a high cost, especially when the software is only compatible with specific RFID devices. This study aims to look at the INLISLite Library Information System, focusing on implementing a self-borrowing service using microcontrollers and RFID technology. In this research, system development uses the prototyping method. This study developed a self-borrowing module for INLISLite without the need for licensed connector software. Additionally, the module is compatible with various microcontrollers and RFID devices that are readily available. The research proposes a novel model that utilizes RFID technology and NodeMCU ESP8266 for the INLISLite Library Information System. RFID sensors read book data from tags, while the NodeMCU microcontroller facilitates communication between the RFID system and the server, allowing automatic transmission of book data to the INLISLite database. This setup enables seamless self-service borrowing, which was tested successfully, supporting processes such as logging in, scanning book data, and updating loan status in the database.

Keywords: *Library Self-Service, Self-Bowrowing System, NodeMCU ESP8266, Library Management System.*

1. Introduction

The evolving development of science and information technology significantly impacts information seekers' behavior and information services provision [36][37], such as libraries [1][2]. Library services have undergone fundamental transformation through technological advancements across multiple dimensions of library administration, including online catalogs, enduring preservation, linked open data, digital resources, and automated self-service systems [3]. While traditional services like book borrowing remain essential [4], implementing Industry 4.0 principles has reshaped nearly all work sectors within modern libraries [5][35][36][38].

Information technology plays a crucial role in library development, enabling the invention of digital libraries and automation systems [6]. This technological integration has streamlined library management processes from acquisition to service delivery, enhancing overall efficiency and simplifying librarians' tasks. The positive impact of technology on service quality is widely recognized [7][34]. However, limitations remain, especially in traditional library management practices, resulting in operational inefficiencies and reduced user engagement in some cases [8]. Consequently, libraries with resource constraints may need help implementing new technology services [9].

Library computerization, a critical application of ICT in the Industry 4.0 era [10][11], has become essential for libraries adapting to Society 5.0, where both technological advancements and human resources are critical driving components [12]. Ideal library automation systems integrate and coordinate all processes from procurement to circulation, incorporating features like barcode technology and web-based mechanisms. The limitation inborn in barcode technology has provoked the search for alternative arrangements, including RFID.

RFID technology offers numerous advantages over traditional barcode systems, including non-contact data transfer, minimal error rates, and the capability to store and modify information [13][14][15]. Its capacity to read multiple items simultaneously without line-of-sight requirements and its extended read range makes it particularly suitable for library use [16][17]. Studies consistently show that RFID technology improves the effectiveness and efficiency of library management, especially in self-service borrowing and returning materials [18][19][20][21][22].

Procedures improve security and enhance patron satisfaction [23]. Its implementation in libraries has demonstrated significant potential in reducing theft and strengthening security [24]. Since its introduction in libraries in the late 1990s, RFID has proven effective in managing large-scale collections, providing real-time access, facilitating high-speed operations, and enabling self-service functionalities.
Consequently, scholarly inquiry into deploying and enhancing RFID and other cutting-edge technologies within library systems is crucial. It addresses essential requirements for modernizing library functions, improving user experiences, and effectively administrating informational resources in the current digital age [23][39].
Therefore, this study is particularly relevant to addressing the challenges of hardware and software compatibility and the high costs, which remain the primary barriers to the development of self-service systems in RFID-based libraries, particularly in the INLISLite Library Management System.
The main challenges of using barcodes in library automation are security and service efficiency. Barcodes can only be read by close-range scanners and must be accurately aligned with the reader, making them ineffective for securing books. Additionally, barcodes are prone to damage or becoming unreadable, slowing the scanning process.
RFID technology offers significant advantages as it can be read at several meters or contactless faster than barcodes. The contactless reading capability also makes it effective for securing books. However, a key challenge in implementing self-service systems in open-source library management information systems is the lack of a self-checkout module that supports RFID. Some library management information systems only support specific device brands and must also use protocols that match the device, often with closed-source code. Additionally, an RFID system locked to certain brands necessitates using tags from the same brand, leading to higher costs for implementing RFID-based self-service systems in libraries.
Many libraries have tried integrating RFID into their management systems, but this implementation often presents challenges, particularly due to the high costs associated with RFID devices and maintenance [25]. These expenses are primarily driven by many RFID systems being locked to specific tags and relying on closed-source software, restricting development to a few select companies. If the software were open source, more libraries could adopt it, and more parties could develop the system more freely. In Indonesia, tags and RFID devices are only provided by some vendors. Thus, the tags can only be used exclusively for those devices. This limited availability not only lengthens the procurement process but also increases costs. Some RFID tags also go undetected by security gates due to tag damage.
RFID could support the identification of library book reshelving, book borrowing, and book returns with self-service, which is expected to provide more accurate information and improve future library services in addition to supporting security aspects [26]. One of the initiatives to incorporate IoT-driven RFID technology within the library framework involves the utilization of the NodeMCU ESP8266 module. NodeMCU is a versatile wifi module with GPIO, ADC, UART, and PWM [27].
Despite various research efforts, there has been no significant development of RFID technology specifically for INLISLite. The library management system is widely used in public and regional libraries across Indonesia. INLISLite, developed by the Indonesian National Library, is designed for specific branded RFID devices that are not readily available in the market. This limitation hinders broader adoption and customization of RFID for INLISLite libraries. The Indonesian government actively promotes library automation using INLISLite [28]. It is shown that RFID implementation in libraries can enhance efficiency and security.
However, unresolved questions remain about integrating RFID with existing open-source library management systems. These challenges are mainly due to the limited availability of compatible devices and the high costs associated with implementation. An option to overcome these difficulties is developing RFID systems compatible with open-market devices and integrated with INLISLite [28]. Such an approach would facilitate the advancement of library self-service functions, reduce costs, and improve system accessibility. Therefore, it is both timely and appropriate to conduct a study on developing an RFID system for INLISLite that seamlessly integrates with commercially available RFID devices.
RFID has been tested in various libraries, including the Defense Science Library in India, and implemented in the Libsys library management information system. The RFID operates at a frequency of 13.56 MHz with an operating read range of 20 to 30 mm. This improves the quality and speed of services and enhances user satisfaction. However, the limited operating range is less effective in detecting books that have not been adequately checked out from the circulation area [22]. In Pakistan, UHF-RFID has been implemented in academic libraries, integrated with the Insignia ILS and SIP II compliance, operating at a frequency of 2,920 MHz, with a reading range of up to 1 foot. RFID still depends on SIP II in this implementation, so it can only be used with hardware that supports SIP II [29]. Also, Vadlakonda developed a prototype for self-service book borrowing using an ATmega328P microprocessor and an RC522 RFID Reader. This prototype's integration with the library management system has not yet been achieved. Additionally, the tags used are still in the form of cards that cannot be attached to books [22].
In Pratiwi's study at Brawijaya University Library, RFID is implemented only for attendance purposes rather than managing library services [30]. Similarly, Hardiansyah's research on the implementation of RFID at the State Library UPT of Malang has not discussed the design of RFID and automation used, only the effectiveness and weaknesses of RFID usage. The design of a user security module (check-in) in the circulation of Riau University Library has implemented RFID technology within SLiMS. However, RFID is only used for user attendance tracking and not self-checkout purposes [31]. From various studies, there has yet to be any research discussing self-service functionalities in libraries utilizing RFID, particularly within library automation systems such as INLISLite.
This research aims to design a high-compatibility RFID device for book borrowing for an open-source library management system, utilizing readily available tags and RFID readers. This approach is expected to reduce implementation and development expenses while simplifying maintenance, thus addressing the current challenges in RFID implementation in Indonesian libraries. This study focuses on implementing RFID for open-source library management systems to enable self-service systems in libraries. RFID tags are more durable and offer faster reading than barcode readers, enhancing self-service capabilities and improving library services' efficiency and effectiveness. The RFID implementation utilizes open-source software and readily available devices, providing a viable solution to the high costs of developing self-service library systems.

2. Methods

This study examined the open-source library information system, focusing on implementing a self-borrowing service using microcontrollers and RFID technology to enhance library service quality. This research developed a self-loan feature in an open-source library management system using a NodeMCU ESP8266 microcontroller and an MFRC-522 RFID reader. System development uses a prototyping methodology.
This study follows a systematic approach comprising several vital stages: a literature review, needs analysis, system design, testing, conclusions, and suggestions. This research began with a literature review, followed by an analysis of the requirements from the perspectives

of users, hardware, and software. Once the system requirements were identified, the system design was carried out. After the system was designed, testing was conducted. If any failures occurred, redesigning would be done until the system could operate optimally. The system testing results could serve as material for further system development.

The development of this self-loan feature enables library users to borrow books independently. In the self-loan procedure, users must log in to the system. After successfully logging in, the user inputs the data of the book to be borrowed by placing the book on the RFID reader. If the book data are available, the book can be borrowed; however, if the book data are invalid or already checked out, the book cannot be borrowed. The self-loan procedure can be seen in Figure 1.

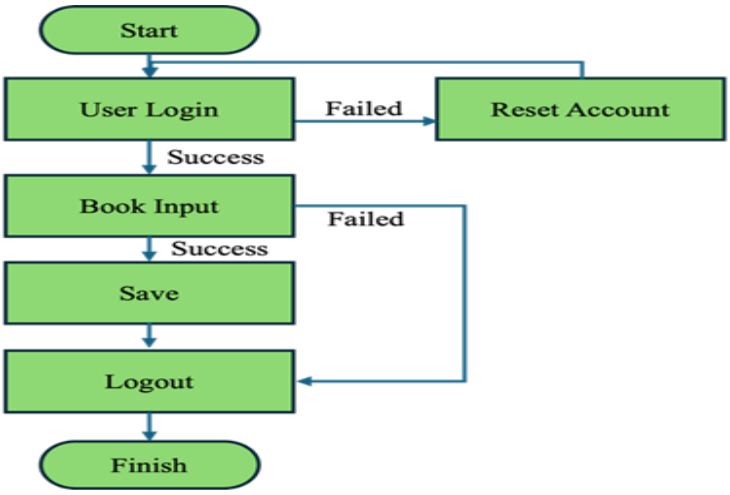

Fig 1. The self-loan procedure

The role of RFID in self-service book borrowing lies in the process of inputting book data. Book data will appear on the user's screen when the book is placed on the RFID reader. In the borrowing process, low-range RFID is used because it needs to read the tags of books carried by the user. If middle- or long-range RFID were used, it would read books from a considerable distance.

3. Results and Discussion

3.1. Requirements analysis

The initial phase involved an extensive literature review to determine the hardware and software specifications required for implementing RFID-based self-service facilities in libraries using the INLISLite system. This stage aimed to identify suitable microcontrollers, RFID readers, and tag specifications.

A comprehensive needs analysis was conducted, emphasizing the development of independent lending applications. The hardware requirements identified included a personal computer, MFRC-522 type RFID reader operating at 13.56 MHz (Fig. 2, a), NodeMCU ESP8266 microcontroller (Fig. 2, b), NFC NTag213 Paper Label Circle 25 mm tags.

a *b*

Fig 2. Hardware: a – MFRC-522 Module; b NodeMCU ESP8266 microcontroller

MFRC-522 is a high-integration read-write card chip used in 13.56 MHz contactless communication, offering ease of use and low cost. It is particularly suitable for advanced application users, such as device developers, card reader developers, and those who need to design or manufacture RF card terminals. This module can be directly integrated into various reader prototypes. The module operates at 3.3V and can be directly connected to the CPU motherboard. NodeMCU is an open-source IoT platform that features the ESP8266 System on Chip. This NodeMCU device includes 10 GPIO ports from D0 to D10, PWM, I2C, SPI interfaces, one wire, and ADC. MFRC-522 is compatible with NodeMCU. The data read by the MFRC-522 is sent to the server by the NodeMCU ESP8266 via a wifi network.

The software development process followed the Rapid Application Development (RAD) model, emphasizing short, iterative development cycles. The RAD process consisted of four main stages: Requirement Planning, User Design, Construction, and Cutover. This ap-

proach was chosen for its benefits in terms of user satisfaction, speed, and flexibility, particularly for projects requiring quick delivery and continuous adjustments.

The system was designed to enable users to perform self-service borrowing. Key components of the design include a user interface for logging in and inputting book data; – integration of the RFID reader with the NodeMCU ESP8266 microcontroller; communication between the RFID system and the INLISLite database server; a security gate mechanism to detect unauthorized book removal. The physical design incorporated a kiosk-style setup with a touchscreen interface, a barcode reader for membership cards, and an RFID reader under a 2 mm thick acrylic book holder.

Software testing was conducted using the Black Box Testing method. This approach tests the software's functionality without knowing its internal code structure [30]. A test scenario was developed to evaluate various aspects of the system, including RFID data input, member search functionality, and book borrowing process. The testing aimed to verify the system's ability to accurately read RFID tags, match data with the INLISLite database, and update book status accordingly. Following this methodology, the research develops and evaluates an RFID-based self-service borrowing system integrated with the INLISLite Library Information System.

3.2. The Radio Frequency Identification Implementation in the INLISLite Library Management System

The MFRC-522 is an RFID reader widely available at a very low cost. This device is highly compatible with various microcontrollers, such as NodeMCU ESP8266 or other types of Arduino. The use of NodeMCU is due to its ability to send RFID data via Wifi using the ESP8266 to the INLISLite server. An additional web service or REST API can connect the microcontroller with the library management system server. The API endpoint receives the UID from the RFID tag detected by the RFID reader and sent by the NodeMCU. After obtaining the UID of the RFID card, the server can verify whether the UID is registered in the INLISLite system and provide a response, such as details of book borrowing or access to library rooms.

The study integrated commercially available RFID components with the INLISLite database. The system uses: RFID Reader: MFRC-522 operating at 13.56 MHz; RFID Tag: NFC NTag213 Paper Label Circle 25 mm; Maximum reading distance: 2 cm; The integration process involves: – Reading the tag ID when a book is placed on the RFID reader; Forwarding the data to the NodeMCU ESP8266; Matching the data in the INLISLite database; Displaying book information if a match is found; Showing "Unlisted Book" message if data is not found in the database.

An additional web service or REST API connects the microcontroller with the library management system server. The API endpoint receives the UID from the RFID Tag read by the RFID reader, which NodeMCU sends. After receiving the RFID card's UID, the server can check if the UID is registered in the INLISLite system and provide a response, such as book loan details or access to the library room. The MFRC-522 is connected to the NodeMCU by attaching jumper wires to each PIN. Next, the MFRC522 Library (MFRC522.h) is installed using the Arduino IDE. The Wifi (ESP8266WiFi.h) and SPI (SPI.h) libraries are also installed to connect to the serial port.

Once the NodeMCU is powered on, it will connect to the pre-configured Wifi. The MFRC-522 will read the RFID Tag attached to a book. The RFID Tag's UID will be input into the library management system's database. The NodeMCU will send the UID read by the MFRC-522 via Wifi to the server. The UID is transmitted using the HTTP POST protocol, with the data formatted as URL-encoded. The data received by the server will be processed during the loan transaction.

3.3. Development of an Open-Source Self -Checkout Module for INLISLite

This research has successfully developed an interface for users to borrow self-service. The system allows users to borrow books independently without assistance from librarians or staff. Users can log into the system and input book data using an RFID reader. When book data is saved, the book's status in the database changes to "borrowed." The RFID tag reading process is illustrated in Fig. 3. The self-service borrowing process includes the following steps: The user logs in to the application; The user's name appears on the screen; The user places the book on the RFID reader; RFID reader reads the ID on the tag attached to the book; RFID data is sent from the microcontroller to the server; System displays book data corresponding to the read RFID; User confirms and saves the borrowing transaction.

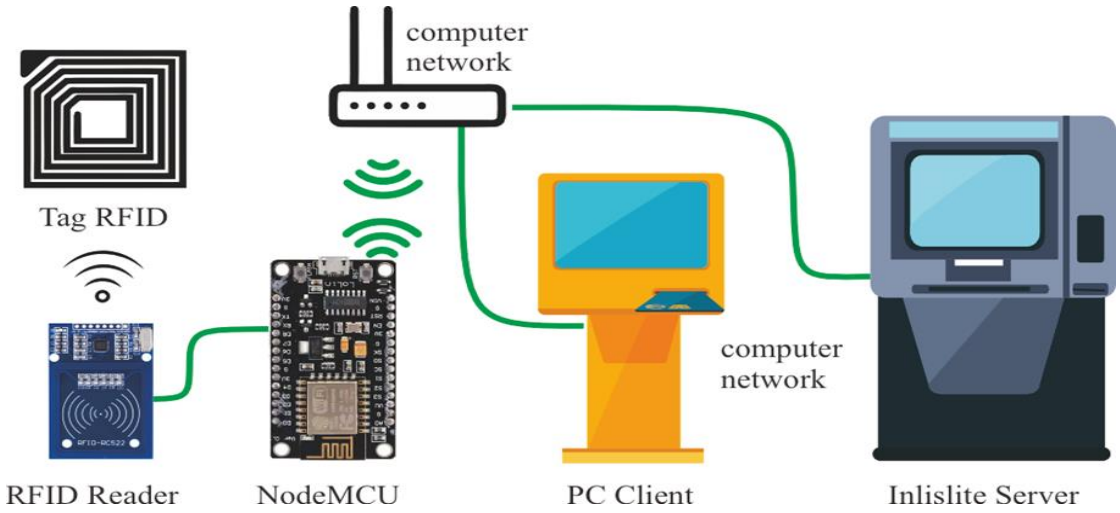

Fig 3. Radio Frequency Identification Reading Process

The RFID reader reads the data from the RFID tag attached to the book during the book-borrowing process. The data the NodeMCU receives is sent via Wifi to the server using the ESP8266. The INLISLite server will send feedback to the user through book data corresponding to the ID read from the RFID tag. The interface was developed for the self-service borrowing system. Key features include a touch screen for easy data input, a barcode reader for membership card scanning, an option for manual input of membership number, clear instructions for book placement and borrowing process, display of book data, and borrowing confirmation.

Before self-service borrowing can be performed, RFID data must be inputted into the system. Book data already present in INLISLite will appear in the "Data Buku" (book data) menu. Subsequently, editing and updating can be done on the Edit RFID page.
To perform self-service borrowing, users first log in to the application. Upon successful authentication, the user's identifier will be displayed on the interface, allowing the individual to position the book on the RFID reader. The RFID reader will read the ID on the tag attached to the book. The RFID data will be read and sent from the microcontroller to the server. The system will display book data corresponding to the RFID reading. If the book is correct, the user can proceed to save it.
The process of inputting member data can be done by scanning the membership card containing a barcode using a barcode reader or manually typing the information. Upon successful login, the screen will display instructions on how to place the book on the book holder, which has an RFID reader underneath it. The tag ID will be read once the book is placed on the RFID reader. The data obtained from the tag will be forwarded to the NodeMCU ESP8266 into the application to match the data in the INLISLite database. The application will display the data if there is a match. Otherwise, it will display the "Unlisted Book" message if the data is not found in the database.
The system was successfully tested in a library setting. Self-service borrowing was successfully conducted through the developed system, and the system improved lending services by reducing queues. Challenges were identified, such as the need for precise book placement due to the RFID reader's low reading range. The cover on the RFID reader affected book reading, necessitating the use of non-metallic materials.
The design of the self-service book loan system in the library management system enables users to borrow books independently without librarian assistance. During testing, users were successfully logged into the system. Next, users placed the book to be borrowed on the RFID reader (MFRC-522). The test indicated that books registered in the system and not yet borrowed would appear on the loan page and could then be saved as borrowed books.
However, issues may arise in reading the book's UID if it is not correctly placed on the RFID Reader, requiring the book to be adjusted until it can be accurately read. The book's thickness may exceed the RFID optimal reading range, which has been demonstrated to be nearly limited to the MFRC-522. In tests with unregistered books, a warning message appeared on the page indicating that the book was invalid. This could also be due to the book's UID not being entered or not present in the library management system database. This aligns with the procedures for the self-service loan system; where incorrect or the book is already borrowed, it cannot be loaned out.
This research provides a solution to the issues in the self-service features of open-source library management systems that do not yet fully support RFID. Open-source software and easily accessible hardware can offer a cost-effective solution for implementing library self-service. The successful operation of this system is expected to enhance the implementation of self-service features in libraries using open-source library management systems. This self-service feature is expected to improve the quality and speed of services while reducing the workload of librarians in handling book circulation services in the library.
This study has successfully developed an RFID-based self-service borrowing module integrated with the INLISLite Library Management System. The results demonstrate the system's effectiveness in enabling autonomous book borrowing, as evidenced by successful trial implementations.
The uniqueness of this approach lies in its integration with INLISLite using an ESP32 microcontroller, which has yet to be attempted in previous studies. Previous studies reached the prototype stage; none have successfully integrated with a Library Management System [22]. Other studies have only implemented RFID for attendance tracking [30]. Additionally, RFID integration in libraries in Pakistan still uses SIP II with UHF tags on Insignia ILS, limiting its use to devices that support the SIP II protocol [29]. Notably, none of these studies have developed an integration for INLISLite.
The system designed for the RFID implementation does not rely on third-party software and is open source, allowing greater flexibility in system development. This approach can help reduce costs in implementing RFID for library automation, as high costs are a significant issue in RFID implementation. Additionally, there are concerns regarding the dependency on hardware and software compatibility.
Unlike earlier research that focused on prototypes or limited RFID use for attendance tracking, this system provides a comprehensive solution for library automation. It also offers advantages over implementations like those in Pakistan libraries, which rely on proprietary protocols like SIP II, by utilizing open-source technology for greater flexibility and cost-effectiveness.
However, the study revealed certain limitations regarding the RFID reading range. The MFRC-522 RFID reader has a short reading distance of approximately 2 cm [33], necessitating precise book placement for successful tag reading. This constraint is influenced by the type of RFID tag employed and the current state of affordable RFID technology. In comparison, some commercial library RFID systems can achieve reading ranges of up to 1 foot (30.48 cm). The RFID reader collects data at the tag level and then subsequently forwards the data to the top sensor level, which is connected to the base station
A key disadvantage identified is the system's sensitivity to the protective casing material used for the RFID reader. Metallic materials can interfere with reader performance, requiring careful selection of non-metallic casing materials. This issue could be addressed in future iterations by exploring alternative casing materials or RFID reader designs that are less susceptible to interference.
Future development of this system could focus on expanding the RFID reading range and improving tag detection reliability. This may involve exploring higher-frequency RFID technologies or more advanced reader designs, such as those operating in the UHF range. However, such developments may incur increased costs and potential compatibility issues with existing library infrastructure.
Moreover, subsequent investigations could explore the potential for integrating this system with other widely utilized library management software to enhance its relevance and applicability. Additional features like automated inventory management and security gates could also be incorporated to create a more comprehensive RFID-based library management solution.

4. Conclusion

The system integrates the MFRC-522 RFID reader (13.56 MHz) and NFC NTag213 Paper Label Circle 25 mm tags, demonstrating compatibility with readily available hardware. This integration enables cost-effective implementation compared to proprietary solutions. The microcontroller effectively facilitates data transfer between the RFID system and the INLISLite server, enabling real-time updates of book status in the database. This approach provides some existing systems a flexible, open-source alternative to SIP II protocols. The system allows users to independently borrow books without librarian assistance, reducing queues and improving service efficiency. User testing demonstrated successful completion of borrowing transactions through the new interface. While the system successfully demonstrates RFID's potential to streamline library operations, limitations were identified. The 2 cm maximum reading distance necessitates precise book placement, a constraint explained by the low-cost RFID reader selected. Additionally, the impact of the reader's protective cover on performance highlights the need for careful material selection in future iterations. The touchscreen input and barcode scanning capabilities for membership cards contribute to an intuitive user experience, as evidenced by successful user trials of the self-service

process. These results showcase the feasibility of integrating RFID technology with INLISLite, thereby addressing the research aim of developing a cost-effective, open-source solution for library automation. The identified limitations provide clear directions for future research, particularly in enhancing RFID reading capabilities and optimizing hardware design for improved performance.

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