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Development of a Self-Service Bookshelf System for Public Spaces Using RFID Technology integrates with Mobile Apps

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***Abstract*— Reading culture is an indicator of a country's public interest in knowledge, creativity, and critical thinking skills. Based on research by the Program for International Student Assessment (PISA), Indonesia is ranked at the bottom of the 80 participating countries. Furthermore, Indonesia's limited book production and relatively high book prices, especially for the lower-middle class, are also contributing factors. Many solutions have been proposed to improve literacy in Indonesia, including the digitization of libraries. This research aims to develop a self-service bookshelf for public spaces, such as waiting rooms, train stations, bus stops, offices, classrooms, and other public spaces. An RFID-based system will be used to read and write data. For security, a system will be implemented that grants access only to registered users. Furthermore, the system will be equipped with a mobile application to provide users with real-time information regarding book borrowing and returns. This system uses the RFID Reader CT-1808 to read RFID tags attached to books as book identifiers. Based on testing, it was found that, despite having anti-collision, this reader still requires a distance between tags, not being able to be close to each other, namely the optimal 5 cm. In addition, this reader has a blind spot that needs to be considered, so the placement of books (tags) is very important. In general, this bookshelf can be accessed by visitors via a QR Code obtained during registration using the mobile app. Visitors can now borrow and return books independently, and their history can be accessed in the mobile app.**

***Keywords*— Self-Service Bookshelf; RFID Reader; Mobile Apps; QR Code.**

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I. Introduction

Reading culture is one indicator of a country's public interest in knowledge, creativity, and critical thinking skills. According to the Program for International Student Assessment (PISA), Indonesia's reading interest decreased significantly in 2018.[1] This placed Indonesia in 74th place out of 80 participating countries.[2]

The low reading interest in Indonesia is due to several factors. These include the lack of an early-childhood reading culture, both in elementary schools and in families, and the inadequate number and quality of educational facilities. Furthermore, Indonesia's limited book production [3] and relatively high book prices, especially for the lower-middle class,[4] are also contributing factors.

Many solutions have been proposed to improve literacy in Indonesia, including the digitalization of libraries. While this digitalization has had a significant impact in increasing public interest in reading, it has not been sufficient to bring about meaningful advances in human resource development in Indonesia from an international perspective, such as an increase in Indonesia's ranking in international literacy assessments. One study supporting this is [5], which showed that, in that year, the average library in Indonesia had adopted digitalization. This study showed that student interest in reading and library visits remained relatively low, as evidenced by students' statements that they preferred to search for information online rather than through books.

Another existing solution to improve this problem is the use of e-books, or electronic books. E-books provide readers with easier access to books, can be read at any time, and are not damaged because they are digital. Many methods have been developed to reduce eye fatigue when reading digital books. However, most e-books are still relatively expensive compared to physical books. Even when we compare only the price of physical books, they are already expensive for lower-middle-class people [6], and some groups experience a different sensation when reading e-books and prefer reading physical books [7].

This research aims to develop a self-service bookshelf for public spaces, such as waiting rooms, train stations, bus stops, offices, classrooms, and other public spaces. An RFID-based system will be used to read and write data. For security, a system will be implemented that grants access only to registered users. Furthermore, the system will be equipped with a mobile application to provide users with real-time information regarding book borrowing and returns. The system aims to stimulate reading interest rather than replace libraries. Providing convenient access to physical books in public spaces serves as a gateway to cultivating reading habits, potentially encouraging subsequent library visits to explore broader collections.

II. METHOD

The system comprises three main components: hardware modules, a mobile application that is connected to the database. Figure 1 illustrates the overall system architecture, integrating a microcontroller as the central processing unit, an RFID reader for book detection, a QR code scanner for user authentication, servo motors and solenoid locks for door control, Firebase as a real-time database, and a mobile application for the user interface.

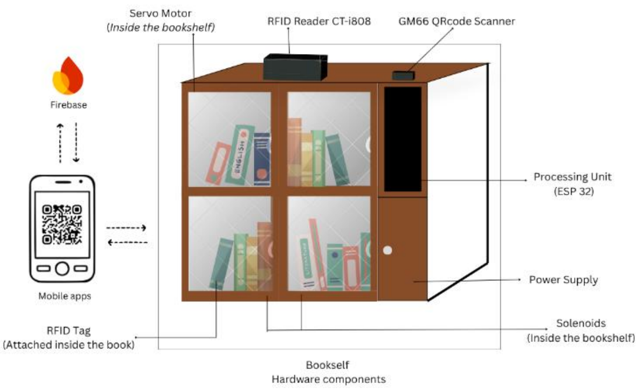


Figure 1. Architecture of the self-service bookshelf system

The system begins with users registering via the mobile app to obtain a unique QR code for access. To borrow and return books, registered users must scan the QR code. If the QR code is valid, the system will open the bookshelf door using servo motors and solenoid locks.

Once the door is opened, users can borrow books by selecting the desired book directly. An RFID tag is attached to the inside of each book as an identifier. After the door has been open for 2 minutes, it will begin to close automatically. However, if the user is not finished accessing the bookshelf, they can manually delay the door closing through the mobile app. After the door is closed, the system will scan the RFID tag. If the tag is no longer readable, it is considered a borrowed book, recorded in the database and appearing in the user's app account.

The mechanism for returning books is similar to the one for borrowing. The difference is that users return the borrowed book to the bookshelf. Once the door is closed, the RFID reader will scan all the books. If a book is added from a previous list, it is detected as a return, recorded, and displayed in the user's account.

All transaction data, including book status, user ID, transaction time, and activity history, is stored in Firebase and synced in real time with the mobile app. For borrowed books, the app also displays a 7-day return deadline.

A. Hardware Module

This system uses an ESP32 as the processing device due to its Wi-Fi feature. A GM66 scanner is a device that can scan 1D and 2D QR codes, including QR codes [8]. In this system, a QR code is first generated by the mobile app as the user's identity, and the scanner then scans it to access the bookshelf. To detect books, a Ultra High Frequency (UHF)-based RFID module i.e. CT-i808. The tags used are UHF tags operating at 902–928 MHz, in line with the characteristics of the CT-i808 module. UHF tags have antennas designed to support readings at distances of several meters, enable multi-tag reading, and are less sensitive to orientation than HF tags.

For the door opening and closing actuators, two servo motors, two solenoids and two TIP122 transistors are used. The TIP122 is an NPN Darlington transistor capable of handling relatively large currents [9], used as a controller for a solenoid. It has high current amplification, making it suitable for use as an electronic switch for inductive loads such as door solenoids. The TIP122 provides more stable switching, faster response, and lower power consumption compared to relays

B. Mobile Apps

Visual Studio Code is used as the primary development environment for mobile application development, serving as the user interface to the system. Application development is carried out using the React Native framework and Expo, a third-party toolchain that supports application compilation, testing, and distribution. The programming language used is JavaScript with an emphasis on TypeScript to ensure more structured data types, reduce the potential for errors during development, and facilitate long-term code maintenance. For interface display settings, the application uses Tailwind CSS, a utility-first styling framework that enables a more consistent, efficient, and easily adaptable design process during development. The mobile application on the system is named BookNook, as in Figure 2.

Figure 2 presents the user interface of each page in the BookNook application. A detailed description of each page is provided below:

- **Sign In**: as an authentication interface for registered users. This page also provides navigation to the account creation process for new users..
- **Sign Up**: as the registration interface for new users. On this page, users enter initial data such as email address, password, username, and phone number. Newly created accounts cannot be used immediately as they require administrator approval.
- **Home**: as the main application page that displays information about books available in the database. Once a user successfully logs in, all book data is displayed as a card list with the title, author, cover image, and availability status.
- **History**: presents a summary of the user's book borrowing and returning activities in two separate categories

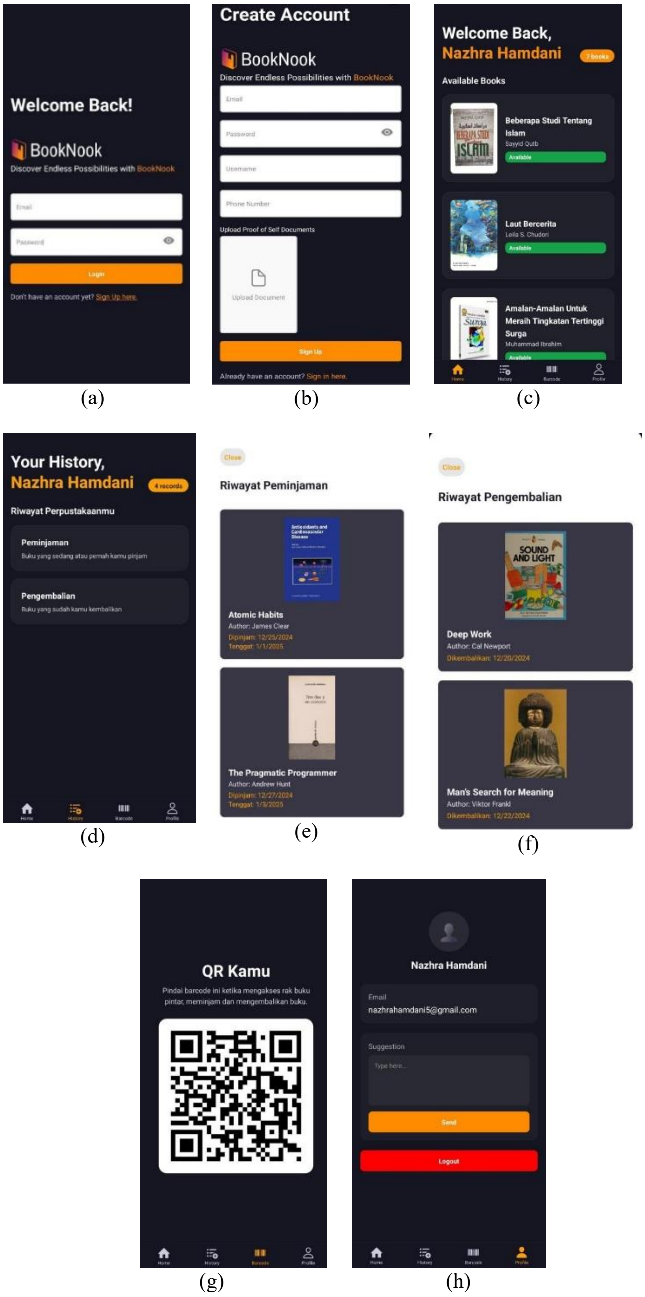


Figure 2. User interface of the BookNow mobile application :(a) Login; (b) Register; (c) Home; (d),(e), and (f) History; (g) Qrcode; (h) Profile

- **QRCode**: Displays the user's identification code in QR code format for borrowing and returning books. The QR code is displayed in the main area of the page with white padding and a white background to facilitate scanning by external devices.
- **Profile**: The user information management center displays the user's name, email address, and profile photo. Users can update their profile photo by uploading an image from their device's storage. Additionally, this page provides a suggestion field that allows users to submit feedback directly to the database, where each entry is recorded along with a timestamp and the sender's identity. This page also includes a logout function that exits the current session and redirects users to the login page.

C. Database

The database system for this bookshelf is implemented using Firebase. This platform stores user data, book data, and system operational status, such as shelf door conditions, borrowing activity, and book returns. Firebase Firestore is used as a non-relational data storage medium that supports document and collection structures [10], thus simplifying the grouping of user data, book data, and system status. In addition, Firebase Authentication [11] is used for user identity validation based on the registered QR code. By using Firebase, all system activities, from access validation to book status updates, can occur in an integrated, synchronous manner between the hardware and the user application. In Firestore, data is stored in collections. This system consists of 5 Collections shown in Table I.

III. Result and Discussion

All previously described components are integrated into a single system. All components are connected and configured to work synchronously, enabling the system to perform access validation, open and close the door, and automatically read and record changes in book data to the database. Meanwhile, the resulting mobile apps are the same as the design results, in Figure 3.

Figure 3. The implementation of self-service bookshelf

TABLE I
THE STRUCTURE OF DATABASE

Collection	Description	Field	Description
Users	Stores user account information and authentication data.	QRCode	A unique QR code used as the user's access identifier.
		Username	The username used to identify the user's account within the system.
		Email	The user's email address used for communication and authentication.
		PhoneNumber	The user's phone number used as contact information.
		UID	A unique identifier generated by Firebase Authentication to ensure that each user has a distinct identity within the system.
		IsAdminApproved	A Boolean value indicating whether the user has been approved by the administrator to access the system.
		DocumentUrl	The URL of the supporting document uploaded to Firebase Storage for user verification.
		Fine	Stores information about the user's outstanding fines or penalties resulting from borrowing violations.
Door	Stores information related to the bookshelf door status.	DoorStatus	The current door status, such as *Open* or *Closed*.
		LastUpdate	Records the timestamp of the most recent door status update.
		UID	The unique identifier of the user who performed the door opening or closing operation.
		Username	The username associated with the door status update.
Books	Stores information about all books available in the smart bookshelf.	TagUid	The unique RFID tag identifier attached to the book.
		Title	The title of the book displayed in the mobile application and administration system.
		Author	The name of the book's author.
		ISBN	The International Standard Book Number (ISBN) of the book. A symbolic value may be used if an ISBN is unavailable.
		Description	A brief description or summary of the book.
		ImageUrl	The URL of the book cover image stored in Firebase Storage or another image source.
		Available	A Boolean value indicating the availability of the book. **True** indicates the book is available on the shelf, while **False** indicates that it is currently borrowed.
		BorrowedBy	The UID of the user currently borrowing the book.
History	Stores the borrowing and returning history of books for each user.	TagUid	The RFID tag identifier of the first book involved in the borrowing or returning activity.
		TagUid2	The RFID tag identifier of the second book when multiple books are processed within the same session.
		StatusBook	The status of the first book, such as *Borrowed* or *Returned*.
		StatusBook2	The status of the second book, such as *Borrowed* or *Returned*.
		BorrowedTime	The timestamp of the borrowing or returning activity for the first book.
		BorrowedTime2	The timestamp of the borrowing or returning activity for the second book.
Suggestions	Stores user feedback, complaints, and suggestions for system improvement.	UserId	The UID of the user who submitted the feedback or suggestion.
		Suggestion	The content of the user's suggestion, complaint, or feedback regarding the system.
		CreatedAt	The timestamp indicating when the suggestion was submitted. This field is used to organize and analyze user feedback over time.

A. RFID Reader CT-1808 Testing

Testing on this device includes anti-collision capabilities, blind-spot areas that the reader cannot detect, and the effect of tag spacing placement:

1) Anti-collision testing: The CT-i808 RFID reader has an anti-collision mechanism that allows the device to read multiple tags simultaneously without signal collisions. To evaluate the performance of the anti-collision mechanism on the CT-i808 RFID reader, 6 test scenarios were conducted with varying numbers of books, as shown in Table II and Figure 4. Each test was repeated five times to ensure the consistency of the results. The reading result categories were divided into three: “always detected”, “inconsistent”, and “always undetected”.

TABLE II
ANTI-COLLISION TEST SCENARIOS

Scenario	Number of books	Description
1	30	All books were placed on the four shelves of the cabinet, positioned directly under the reader, with no gaps between them (stacked tightly).
2	30	The books were arranged in a spread-out position with space between each book.
3	15	The 15 books that were consistently detected in the second test were used. Books with inconsistent reading results or not detected were not used. The positions of these fifteen books were kept the same as in the second test.
4	12	The 12 books consistently detected in the third test were used, while the three books with inconsistent reading results or not detected were not. The positions of these twelve books were kept the same as in the third test.
5	14	Two more books were added from scenario 4, bringing the total number of books tested in this experiment to 14. These additional books were placed on the bottom and top shelves of the cabinet.
6	16	The two more books from scenario 6 were added, bringing the total number of books tested to 16

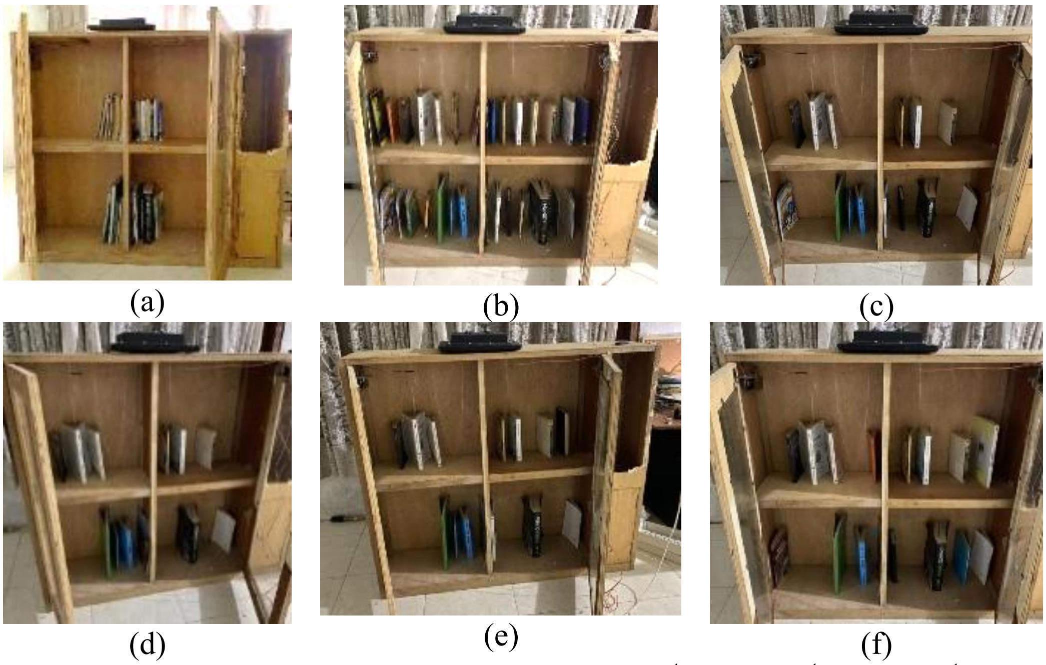


Figure 4. Experimental Setup for Anti-Collision testing: (a) 1st scenario; (b) 2nd scenario; (c) 3rd scenario; (d) 4th scenario; (e) 5th scenario; (f) 6th scenario

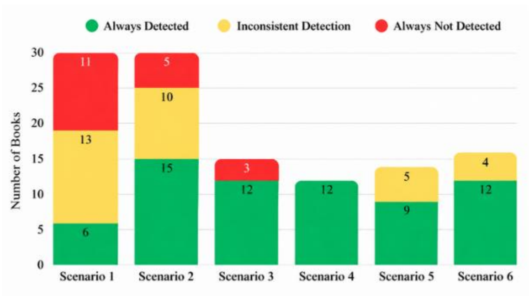


Figure 5. Book Detection Results Across the Six Anti-Collision Test Scenarios

Based on Figure 5, in scenarios 1 and 2, with the same number of books but different positions, there was a difference in the consistency of RFID tag readings. Scenario 2, with books spaced apart, showed greater consistency in RFID tag readings. Based on this, the arrangement of books in scenario 2 was used as a reference for subsequent tests.

Based on differences in the number of books, scenarios 3 to 6 show that the fewer the books, the more consistent the results tend to be. Especially at the smallest number of books, 12, all books can be read consistently through the RFID tag. This shows that, even equipped with anti-collision, RFID tags placed close together (close together) tend to have poor performance. Therefore, for this RFID tag, the distance between tags is still required for consistent reading.

2) Blind-spot testing: This test aims to identify weak points in the RFID reader's readings that will later affect book placement. Based on the test in scenario 2 (30 books positioned apart), 5 books could not be read at all (always undetected). The five books were located in the outer corner of the shelf, shown in Figure 6. The same pattern is also evident in the fifth scenario (book 14, positioned apart), indicating that the corner area still affects the reader's reading consistency. In this scenario, although no books were always undetected, several tags in some books still showed fluctuating reading results when placed in the corner of the shelf.

(a)

(b)

(c)

(d)

Figure 6. Experimental Setup for Blind-spot testing: (a) 2nd scenario; (b)5th scenario; (c) 7th scenario; (d) 8th scenario

To further understand the blind spot area in RFID tag reading, scenario 7 was carried out (12 in total: 3 books per shelf, placed on the left and right sides of each shelf, and 1 in the middle, as shown in Figure 7). There were still books that went undetected due to the weak signal in that area. After the books were moved so they were not too close to the corner of the shelf in scenario 8, the results remained the same: there were still books at the very end that were not detected.

Based on the analysis of the series of tests conducted, a more detailed picture of the RFID reader's blind spots was obtained. The findings indicate that when the reader is placed on the top shelf of a cabinet, the signal is attenuated in two main areas: the far left and far right sides of the cabinet, approximately 20 cm in length. These areas can be categorized as blind spots, meaning they lack optimal signal coverage, making the tags within them difficult to detect consistently.

This finding is important because it indicates that while the reader's signal generally reaches most of the cabinet, its distribution is not uniform. Therefore, identifying blind spots can serve as a basis for determining book layout, tag placement, and antenna positioning to optimize reading performance. A visualization of the results of this analysis is shown in the following image. The total length of the cabinet used for book placement is approximately 96 cm. After subtracting the length of the blind spots on the left and right sides, each of which is approximately 20 cm, it can be assumed that the effective range of the reader signal is approximately 55 cm in the center of the cabinet.

Figure 7. Blind-spot area

3) Evaluation of the Effect of Distance Between Books/Tags: The distance between RFID tags is an important factor affecting the reader's reading performance. Based on anti-collision testing, if tags are placed too close together, the likelihood of signal collisions increases, resulting in inconsistent or even failed readings. Conversely, by providing a certain distance between tags, the chance of interference can be reduced. To determine the optimal distance for each book (RFID tag), tests were conducted with scenarios 9, 10, and 11, as shown in the Table III and Figure 8.

TABLE III
DISTANCE TEST SCENARIOS

Scenario	Number of Books	Description
9	10	All books are placed on the two top shelves of the cupboard (5 books on the left shelf and 5 on the right shelf), with a distance of 7 cm between shelves.
10	9	The number of books was reduced by 1 compared with scenario 9. This reduction was made because all the books used in the ninth scenario were concentrated on one top shelf of the cupboard. Adjusting to using one shelf required reducing the number of books and setting the distance between books to 5 cm.
11	8	The number of books in scenario 10 was reduced by 1, specifically the book on the outer edge of the shelf, to avoid blind spots. The placement of the books remained the same as in the tenth test, with the distance between books also maintained at 5 cm.


(9)


(10)


(11)

Figure 8. Experimental Setup for distance testing: (a) 9th scenario; (b) 10th scenario; (c) 11th

The test results in scenario 9 showed two books with inconsistent readings and no books that were not detected at all. The test results in scenario 10 showed a significant improvement, with eight books consistently detected and only one book showing inconsistent readings. These findings indicate that, in addition to the number of books, using areas with stronger reader signals and properly spacing books can yield more stable reading results.

The test in scenario 10 specifically considered blind spot factors. Throughout the experiment, inconsistent readings were still found in each test. This inconsistency was no longer primarily due to the distance between books, but rather to the relatively dense number of tags on one shelf. This "crowded" condition increases the potential for interference between tags, thus reducing reading consistency.

These findings were reinforced by the eleventh test, which used only 6 books with a 5 cm spacing between them. The test results showed that all books could be read consistently across repetitions, confirming that tag density is an important factor in addition to distance.

Therefore, the conclusion regarding the spacing between books is that varying the spacing can still produce good readings as long as it is within the 5 cm to 10 cm range. However, reading accuracy is highly dependent on two additional conditions: the books must be placed in an area with strong reader signal distribution, and the number of tags on a single shelf must not be too dense. These findings provide a practical guideline for designing storage shelf layouts to ensure RFID systems operate more consistently and efficiently

B. GM66 Scanner Testing

Testing of the GM66 scanner was performed to assess its performance in reading codes under various environmental conditions: lux, smartphone LCD brightness level, and distance of smartphone to scanner. Each test was conducted five times.

1) Lux: The lighting range used was 10–2000 lux, as this range is considered representative of real-world conditions in public areas where the smart bookshelf will be placed. At 10–50 lux, these conditions correspond to very low lighting, such as hallways or dimly lit rooms. The 50–200 lux range represents environments with low light intensity, such as libraries or cafes. The normal lighting range, 200–500 lux, was chosen because it aligns with the lighting standards for workspaces or study spaces, often found in train stations or bus stops during the day on cloudy days. Meanwhile, the 500–2000 lux range was used to simulate bright conditions, such as public areas with large light openings or with fairly intense artificial lighting. The lower limit of 10 lux was not considered because it is too dark for normal use, while values above 2000 lux generally occur only in outdoor areas exposed to direct sunlight. This is not relevant to the implementation of smart cabinets, as the devices are designed to be installed in enclosed areas or indoors. In this test, it is grouped into 4 categories: very low (10-50 lux), low (50-200 lux), normal (200-500 lux), and bright (500-2000 lux), based on international scientific standard references for various activities.

The test results are shown in Figure 8. In very low-light conditions (10–50 lux), the scanner still performed with a fairly high success rate, although the failure rate was also relatively close to it. This phenomenon was most frequently observed in tests at a distance of 5 cm. In low-to-normal lighting (50–500 lux), scanner performance was more stable and consistent, with results not significantly different from those in tests at 10–50 lux. These conditions are considered optimal because the ambient lighting is sufficient to facilitate the reading process without causing excessive glare. Furthermore, these conditions align with the practical requirements of smart cabinet placement in everyday use.

Conversely, in bright conditions (500–2000 lux), the success rate decreased because the scanner sensor experienced glare (overexposure), making the QR code pattern difficult to recognize. A visualization of the effect of lighting on QR code reading results is shown in Figure 9.

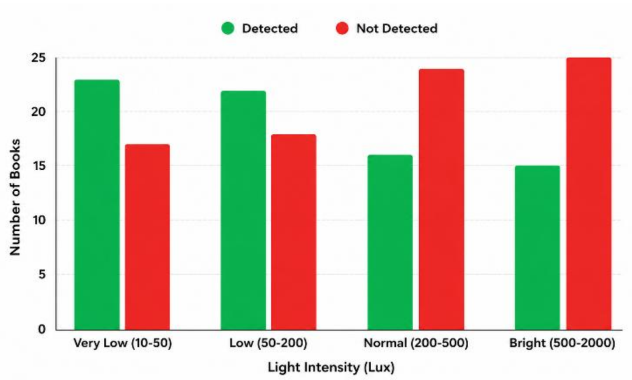


Figure 9. GM66 Scanner testing: lux condition

2) Brightness Level: The brightness levels used were 25% and 50%, as these two conditions are considered representative of actual phone user habits. Brightness levels below 25% are rarely used, as the screen would be too dim and difficult to read, especially in public areas. Meanwhile, 50% was chosen as the standard level most commonly used in everyday activities.

Brightness levels above 50% (75–100%) were not used as testing parameters, as they logically facilitate QR code reading by the scanner. In other words, if reading results at 50% are already good, increasing brightness will only make the results clearer without providing significant additional information.

Furthermore, using high brightness is less representative, as most users avoid it due to increased battery consumption and eye discomfort.

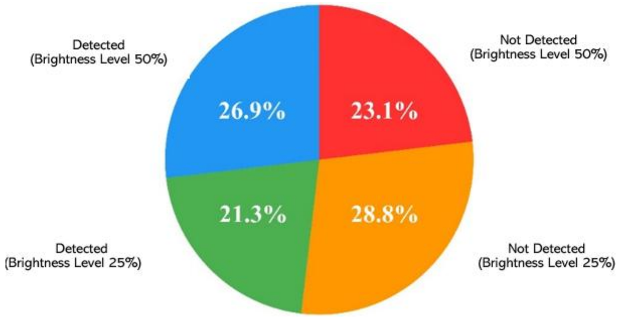


Figure 10. GM66 Scanner testing: brightness level

In tests with 25% screen brightness, the failure rate was relatively high as shown in Figure 10, especially when combined with bright ambient lighting. This indicates that the light from the phone screen is not strong enough to produce a clear reflection for the scanner. Conversely, at 50% brightness, reading results were more consistent and stable. Almost all parameter combinations at this brightness level yielded successful readings, especially at a distance of 10 cm. Therefore, a minimum brightness of 50% is considered the standard for reliable QR code reading.

3) Distance of smartphone to scanner: The distances used in the testing were set at 5 cm and 10 cm, as they were considered representative of the natural distances for user interaction with the device. Distances of less than 5 cm were not selected, as they were considered impractical—the user would have to hold the phone too close, which could reduce comfort and potentially cause the QR code to be incompletely read due to the scanner's capture area being cut off. Conversely, distances greater than 10 cm were also not considered due to the risk of reducing reading accuracy, given the scanner's limited optical focus range. Therefore, a range of 5–10 cm was considered realistic and appropriate for everyday usage patterns in the context of system implementation.

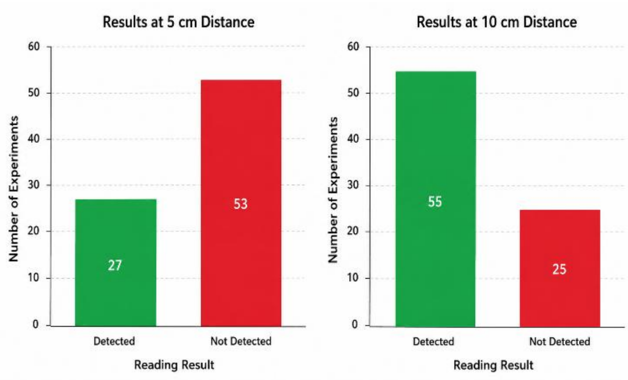


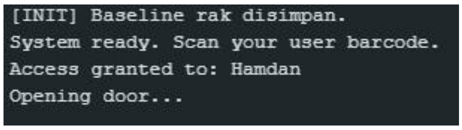
Figure 11. GM66 scanner testing: distance

At a distance of 5 cm, most of the experimental results were unreadable, with a success rate of 33.8% as in Figure 11. This could be due to the distance being too close or the QR code area being cut off during the reading process. Meanwhile, at a distance of 10 cm, reading results were much better, with a success rate of 68.8%. Therefore, a reading distance of 10 cm is sufficient for reading QR codes.

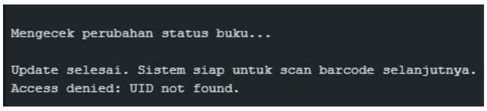
C. *Functional testing*

The system access process begins with scanning the user's QR code using a GM66 QR code scanner. If the scanned QR code is registered and valid, the system will verify the user's identity based on the UID stored in the database. Successful verification will trigger the automatic opening mechanism for the bookshelf door, allowing the user to borrow and/or return books.

The system is designed to distinguish each user based on their QR code. If the scanned QR code is not registered in the database, the system will identify it as invalid through integration between the database and the ESP32 microcontroller, preventing the door opening mechanism from operating. The Figure 12 shows the difference in system response to valid and unregistered QR codes. Figure 10 b shows an access denied message. If registered, the user is recognized and the system will open the door.



(a)



(b)

Figure 12. System response to registered and unregistered QR codes: (a) registered QR code; (b) unregistered QR code

The bookshelf door opens in real time after the user's QR code is validated. A servo motor controls the door opening and closing mechanism. Once the door is opened, the user is given a two-minute transaction session to borrow or return books. If this time is insufficient, the system displays a pop-up in the mobile app prompting the user to add 2 minutes to the transaction. If the user does not respond within the time limit, the system automatically closes the door by changing the doorStatus. The app also provides a "close door" button that users can use to close the door once the transaction is complete manually, as in Figure 13.

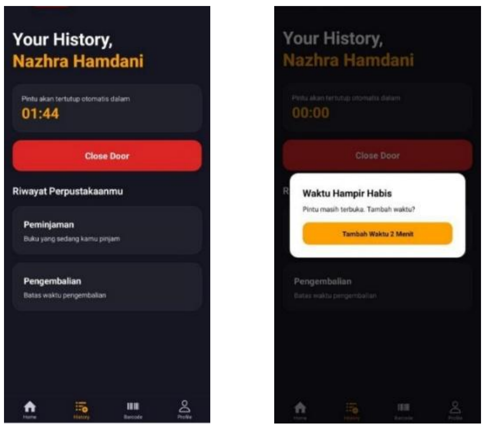
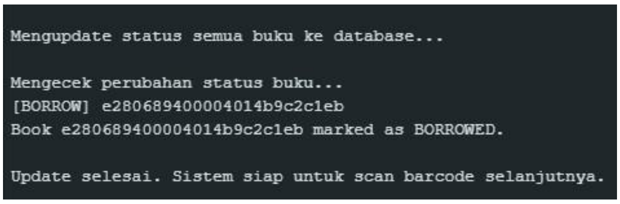


Figure 13. User interface of the BookNook mobile application: (a) bookshelf door open status; (b) transaction time extension pop-up while the bookshelf door is open.

In this test, 6 books were placed on one shelf. After the door closes, the system will perform an RFID scan of the books remaining on the shelves. In this test, the book being borrowed was titled "The Psychology of Money" with UID e280689400004014b9c2c1eb. The scan results showed that the system identified all remaining books on the shelves and classified "The Psychology of Money" as unlisted, indicating the user had borrowed it. The system scanned all remaining books and categorized "The Psychology of Money" (UID e280689400004014b9c2c1eb) as unlisted. Figure 14 shows that there are 5 books left. The image xx shows that there are 5 books left.

(a)



(b)

Figure 14. Results of the book scanning process: (a) detected and undetected books following a borrowing transaction; (b) the status of the undetected book updated to "Borrowed"."

Once the scanning process was complete, the system automatically updated the transaction data and saved the book borrowing information to the database. The borrowing data for "The Psychology of Money" is displayed in the database, as shown in Figure 15. Book borrowing information is also displayed in the user's mobile app, including the title of the borrowed book and a 7-day return deadline from the loan date.

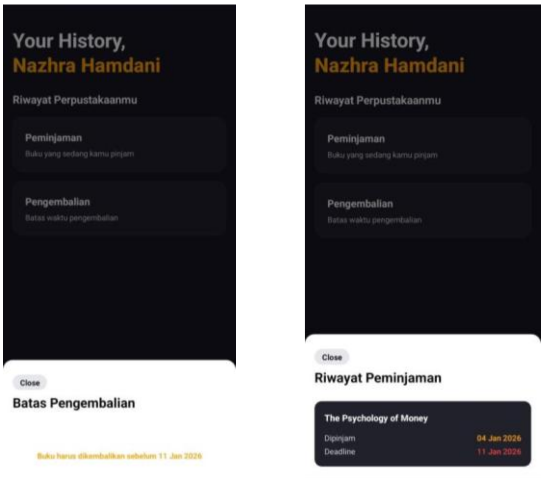


Figure 15. User interface of the BookNook mobile application displaying book borrowing details.

The book return process is carried out by the user re-accessing the smart bookshelf using their QR code. The user places the book back on the shelf and closes the door. Once the door is closed, the RFID system will re-scan and detect that "The Psychology of Money" has been returned to the shelf, as in Figure 16.

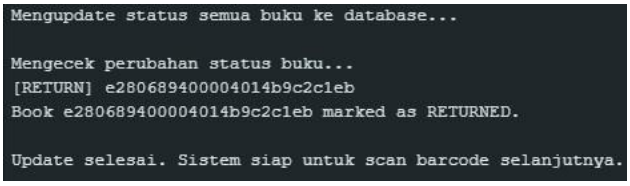


Figure 16. Updated book status after the return process.

IV. Conclusions

Based on testing, the bookshelf can optimally detect six books without collision, provided the appropriate distance between books (the distance between RFID tags) is provided. Although the RFID reader has anti-collision, spacing between RFID tags is still required to ensure consistent reader readability, with a distance of 5-10 cm between tags. Furthermore, the reader also has blind spots. The total length of the cabinet used for book placement is approximately 96 cm. After subtracting the length of the blind spots on the left and right sides, each of which is approximately 20 cm, it can be assumed that the effective range of the reader signal is approximately 55 cm in the center of the cabinet.

The bookshelf opening and closing system has been successfully implemented, using a QR code scan to recognize the user. Once the system recognizes the user, it can automatically open the door and close it again using a timer or manually via the user's smartphone. The user has two minutes to access the shelf. If there is no user intervention, the door will close after two minutes. However, the user can also add two minutes via smartphone. Next, for the borrowing and returning mechanism, the system can detect borrowed and returned books by scanning their RFID tags.

For future development, it is recommended to use a more robust RFID system with multi-network support to enable tag detection across a larger number of books and cabinets. Furthermore, an automatic user-detection mechanism can be installed near the door while still maintaining the security of books and data

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