Android-Based Inventory System and Near Field Communication for Asset Inventory at SMAN 8 Malang

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***Abstract*—SMAN 8 Malang currently employs manual methods and barcode/QR code technology, which are inefficient. The purpose of this study is to design and develop an Android application that integrates Near Field Communication (NFC) with NTAG213 chips as unique asset identifiers, and Optical Character Recognition (OCR) supported by machine learning from Firebase for data entry automation. The system also establishes cloud-based data storage using Firebase to ensure data accessibility and security. Through the Research and Development (R&D) method with the Waterfall model, testing was conducted by measuring NFC data transfer speed and OCR accuracy. Results indicate improved efficiency and accuracy in asset data collection, with an average NFC transfer rate of 81.6 kbps and 100% OCR accuracy. In conclusion, integrating NFC and OCR in an Android application is a promising solution to enhance inventory management in educational environments, contributing to the development of more modern, efficient, and accurate inventory systems, and has the potential to be implemented in various educational institutions.**

***Keywords*— Android, Firebase, Inventory Management System, Machine Learning, NFC, NTAG213, OCR**

I. INTRODUCTION

In this digital era, information has become an increasingly crucial asset in various sectors, including education [1]. Schools, such as SMAN 8 Malang, need to adapt by utilizing the latest technologies to optimize the efficiency of their inventory management. Currently, SMAN 8 Malang still relies on a combination of manual methods, QR Codes, and barcodes, which have proven to be less than optimal in terms of accuracy and speed [2]. Similar challenges are faced globally, where traditional inventory methods are being phased out in favor of more modern, tech-based approaches [3]-[5].

This research focuses on developing an Android-based inventory system integrated with Near Field Communication (NFC) technology using the NTAG213 chip, as well as Optical Character Recognition (OCR). NFC technology has been increasingly adopted for its ability to facilitate secure, contactless data exchange, which is particularly useful in inventory management [6]-[8]. Furthermore, integrating OCR technology with machine learning via cloud-based platforms enhances the accuracy and efficiency of scanning essential information on school assets, such as ID, name, category, condition, and quantity [9] [10]. OCR has demonstrated high accuracy rates in various fields, reducing manual input errors and increasing overall efficiency [11]-[13].

Through an Android application, inventory officers can quickly and accurately scan school assets. Scanning accuracy, bolstered by machine learning algorithms, is claimed to reach 80-100% depending on the quality of the input data and environmental conditions [14]-[16]. Once scanned, the data can be directly stored and accessed through NFC tags attached to each asset, allowing for easy retrieval and updating [17]. The use of NFC tags for data storage offers a secure and efficient solution for managing large inventories, particularly in educational settings [18]-[20].

The combination of NFC, OCR, and machine learning presents a powerful tool for modernizing inventory management systems in schools and other educational institutions [21]. Studies have shown that such technological integrations can significantly improve both the accuracy and efficiency of inventory management [22][23]. As educational institutions evolve, embracing these advanced technologies will be crucial for maintaining competitive and effective resource management [24]-[26].

II. METHOD

This research employs the Ground Truth and Levenshtein distance methods to measure the accuracy of OCR (Optical Character Recognition) in recognizing text on inventory asset labels. Ground truth serves as the correct and accurate reference data, while the Levenshtein distance quantifies the difference between the text produced by OCR and the ground truth. The smaller the Levenshtein distance, the higher the OCR accuracy level [12] [21].

In parallel, the speed of NFC data transfer is measured by recording the start and end times of the process of writing and reading data on the NFC tag. The recorded time is then used to

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calculate the data transfer speed (throughput) in kilobits per second (kbps) [22] [23].

The research also follows the Research and Development (R&D) Model using the Waterfall methodology, which involves systematic stages: requirement analysis, system design, implementation, testing, deployment, and maintenance. This model was chosen due to its structured approach, which is well-suited for developing complex systems like the Android-based inventory system proposed in this study [24] [25].

By employing these methods, this research aims to evaluate the performance of the developed system, focusing on OCR's text recognition accuracy and NFC's data transfer speed. The results of this evaluation will provide a comprehensive understanding of the system's effectiveness and efficiency, forming a basis for further improvements and development [26].

A. Block Diagram

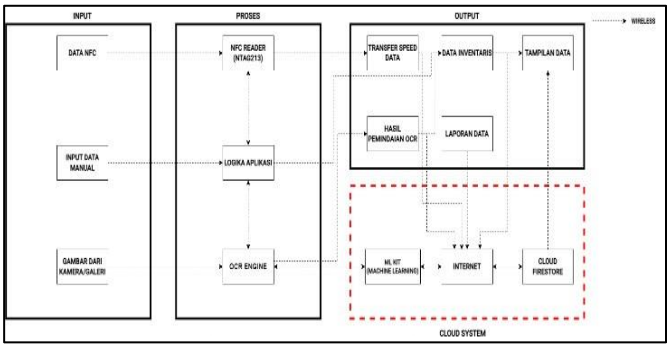


Figure 1. Block Diagram

Figure 1 is diagram block on planning system which done for prepare apps and the firebase database. The process begins with the input section, which includes three main sources: NFC data, manual data input, and images from a camera or gallery. The NFC data is read by the NFC reader (NTAG213) in the process section, while the manual data and images are processed by the application logic and the OCR engine respectively. The processed data is then transferred to the output section, where it undergoes various transformations.

In the output section, the data is categorized into three main outputs: transfer speed data, OCR result data, and data reports. The transfer speed data represents the efficiency of data transmission, while the OCR result data provides the outcome of the image recognition process. The data reports compile all processed information for further use. Additionally, the system has a cloud system component that includes ML Kit for machine learning, internet connectivity, and Cloud Firestore for secure and structured data storage. This cloud system facilitates the transfer and storage of data, ensuring real-time access and reliability. The final output is the display of data, which presents the processed information in a user-friendly format for monitoring and analysis.

B. Research Method

This research uses the Research and Development (R&D) Method with the Waterfall Model. This method is very influential in the research stages of preparing the flow and implementation of tools, this method really shows its effectiveness for this research, as shown in Fig 2.

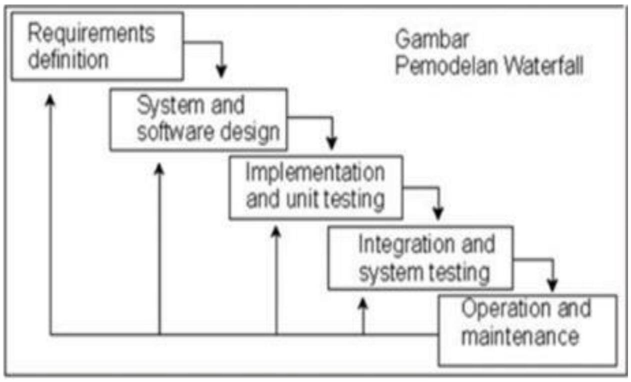


Figure 2. R&D Model Waterfall

C. Use Case Diagram

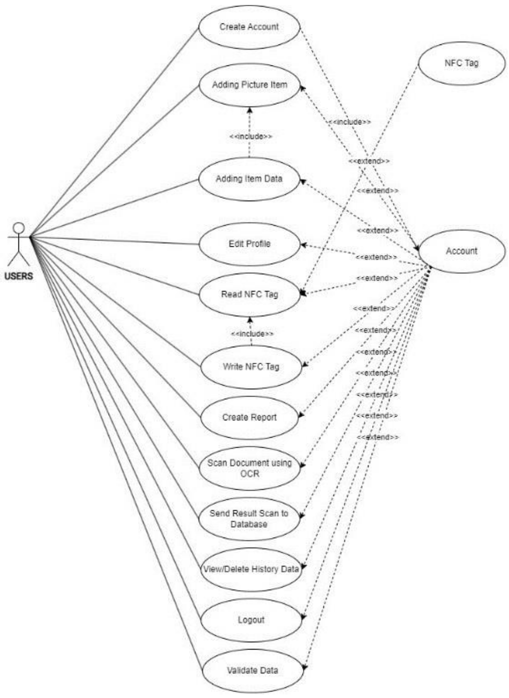


Figure 3. Use Case Diagram

Figure 3 depicts the interactions between users and various features of an inventory management system. Users start by creating an account, enabling access to functionalities such as adding inventory data manually or through NFC tags, which includes reading from and writing to the tags. Users can edit their profiles, generate reports, and use OCR to scan and add images, with the resulting data sent to Firestore for secure storage. The system allows viewing and managing data history, logging out securely, and validating data to ensure accuracy and integrity. Each function is interconnected, relying on the user account and NFC capabilities to provide a comprehensive inventory management solution.

D. Activity Diagram

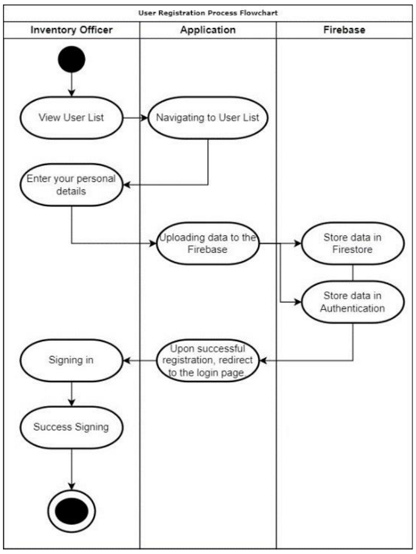


Figure 4. Activity Diagram New User List

Figure 4 depicts the flow of activities in the process of registering a new user in an application that is integrated with Firebase. Starting from the inventory officer selecting the user registration option, then the application displays the registration page. After the inventory officer enters personal data, the application sends the data to Firebase to be stored in Firestore and Authentication. After successful registration, the inventory officer is automatically directed back to the login page to enter the system.

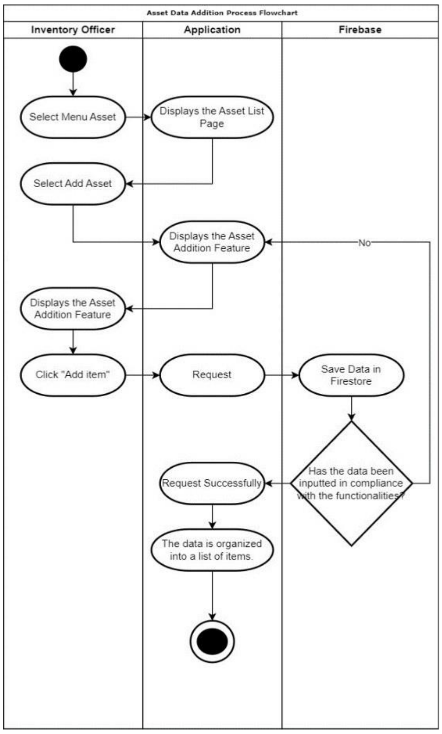


Figure 5. Activity Diagram Add Asset Data

Figure 5 illustrates the workflow of the process of adding new assets to the inventory application. The inventory clerk starts by selecting the "Assets" menu and then selecting the "Add Asset" option. The application will display an asset addition form, where officers can fill in asset details such as name, category, condition and quantity, either manually or by scanning the NFC tag. Once the data is filled in, the inventory clerk clicks the "Add Item" button to send the data to Firebase. Firebase will save the new asset data into Firestore and send a "Request Successful" response to the app. The application then validates the data, and if valid, the new asset is displayed in the asset list. If it is invalid, the inventory clerk will be asked to correct the entered data.

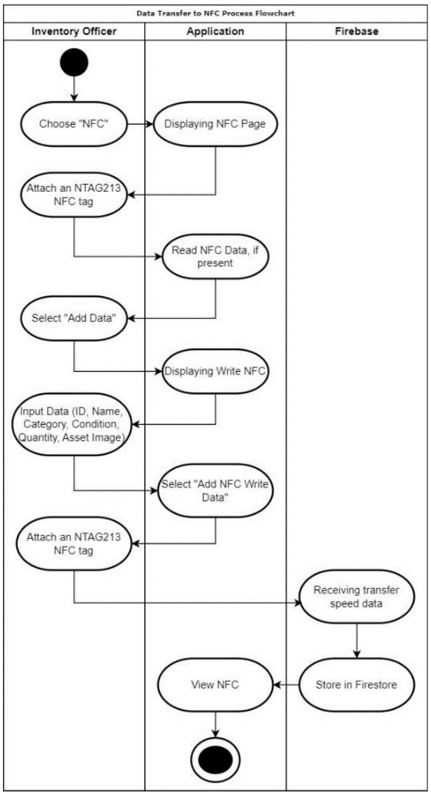


Figure 6. Activity Diagram Data Addition via NFC

Figure 6 illustrates the flow of adding data to an NFC tag. The inventory clerk starts by selecting the "NFC" menu in the application, then attaching the NTAG213 NFC tag. The application will read the data on the NFC tag if any. Then, the inventory clerk selects the "Add Data" option and the application displays a form for entering data (ID, Name, Category, Condition, Quantity). After the data is entered, the inventory clerk selects "Add Write Data to NFC" and reattaches the NTAG213 NFC tag. The app then writes data to the NFC tag, receives transfer speed information, and saves the data to Firestore.

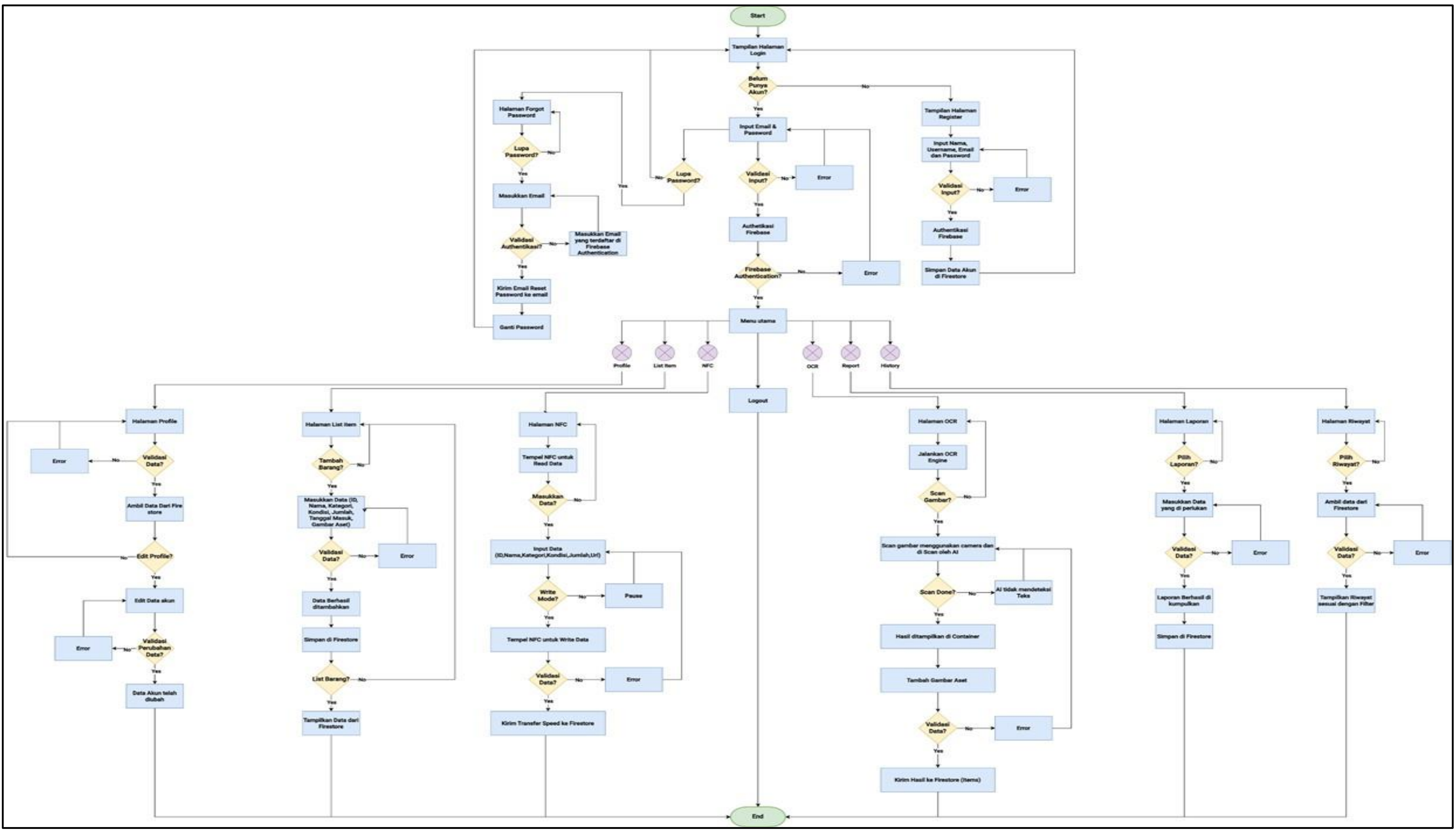


Figure 7 Application Flowchart

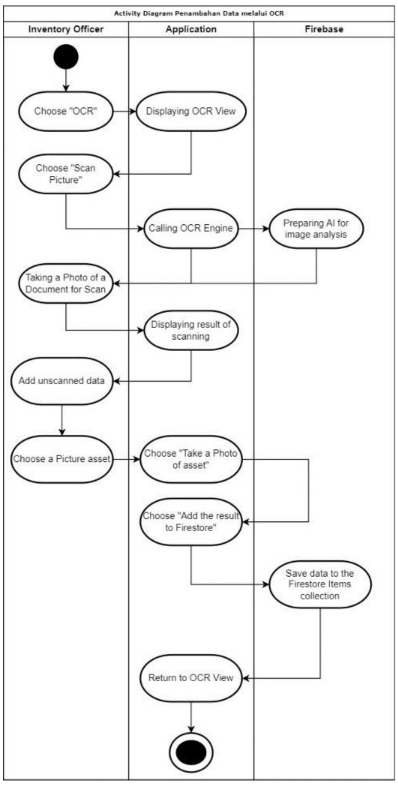


Figure 8 Activity Diagram Data Addition via OCR

Figure 7 depicts the flow of adding inventory data using OCR (Optical Character Recognition) technology in the application. Starting from the inventory clerk selecting the "OCR" option, then the application displays the OCR page. Officers can choose to scan images directly from the camera or take images from the gallery. After the image is selected, the application calls the OCR feature which has been prepared with the help of AI to recognize text in the image. The scan results are displayed to the inventory officer, and the officer can manually add data that has not been read by OCR. Once the data is complete, the officer selects "Add results to Firestore" and the inventory data will be stored in Firebase Firestore in the "Items" section.

E. Flowchart

Figure 8 depicts the flow of the login process into the inventory application. Users will be directed to the login page, then enter their email and password. The system will validate the input. If valid, the system will authenticate via Firebase. If successful, the user will enter the application's main menu. If it fails, an error message will appear. There is also an option to create a new account (register) if the user doesn't have an account, or to reset the password if you forget it. After successfully logging in, users can access various main application menus, such as Profile, List Item, NFC, OCR, Report and History. Finally, users can exit the application (logout).

F. App View

Figure 10. Splash Screen

Figure 9 the splash display opens the initial display of the application where it displays the logo and text.

Figure 11. Login Screen

Figure 10 Login Screen is the initial view users see. When entering the application, users are asked to enter their email address and password to enter the application. There is also the option "Forgot Password?" for users who have forgotten their password and the link "Register here!" for users who don't have an account.

Figure 12. Forgot Password

Figure 11 Forgot Password display functions for users who have forgotten their password to reset their password using the link from the email sent.

Figure 13. Register Screen

Figure 12 Register Screen is a display for users who want to create a new account. There is a form with an input field for entering username, name, email and password. There is a "Register" button to submit registration data and a "Login here!" to direct users who already have an account to the login page.

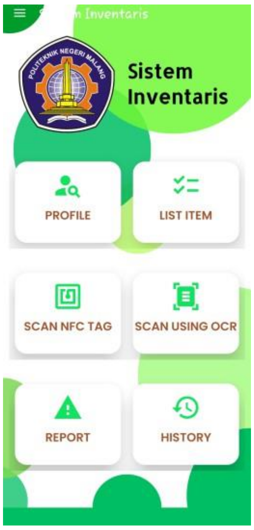
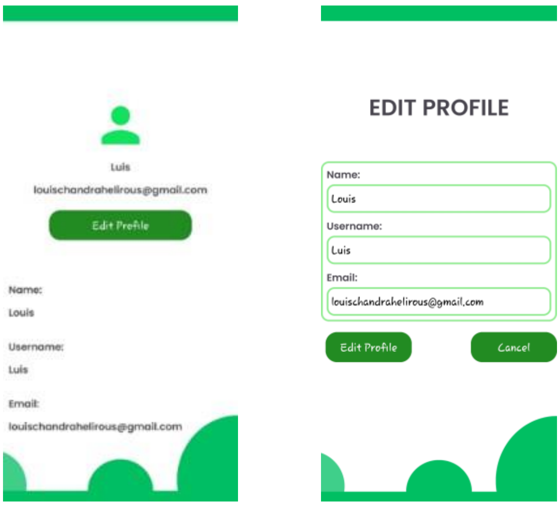


Figure 14. Main Menu

Figure 13 displays the main menu of the inventory system application, featuring six key functionalities. The "Profile" section allows users to view and edit their personal information. "List Item" provides a comprehensive list of all inventory items, facilitating easy access and management. The "Scan NFC Tag" function enables users to quickly input or retrieve data by scanning NFC tags attached to items. "Scan Using OCR" allows for the scanning of images to extract text information using Optical Character Recognition technology. The "Report" feature lets users generate detailed reports of the inventory data, ensuring organized record-keeping. Lastly, the "History" section provides access to the historical data and previous interactions, helping users track changes and maintain accurate records. This main menu serves as the central navigation hub for managing inventory efficiently and effectively.

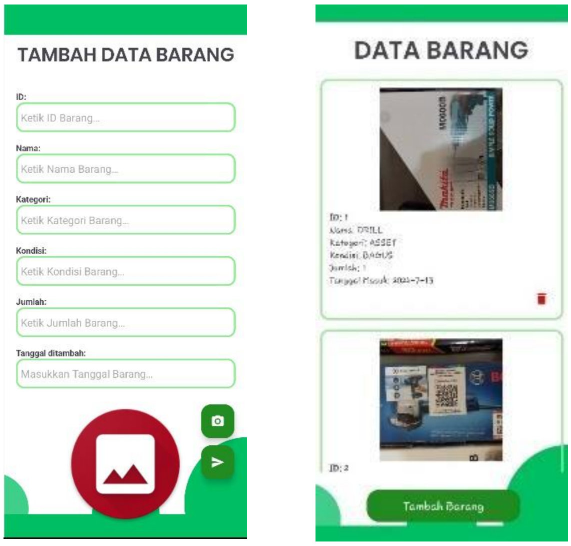


(a) (b)

Figure 15. Screen (a) Profile and (b) Edit Profile

Profile display (a) shows us our account data and there is also an "Edit Profile" button if you want to change the account data. The Edit Profile display (b) displays a place to edit our information data to change Name, Username and Email.

Figure 16. Item List Screen



(a) (b)

Figure 17. Screen (a) Add Item and (b) View List Item

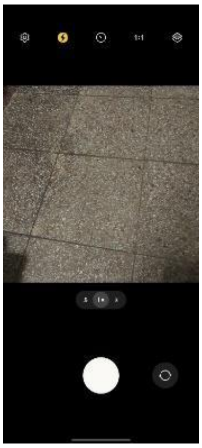
The display in the Item List (Figure 15) is a page for managing the list of items, featuring two main options. The "View Item List" option likely displays a list of items already in the inventory, as seen in picture (a). The "Add Item" option allows the user to add new items to the inventory, as shown in picture (b).

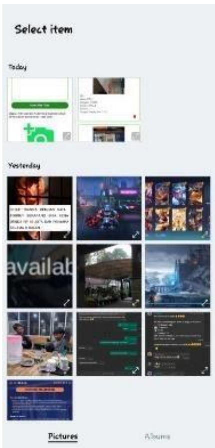
(a) (b)

Figure 18. Screen (a) NFC and (b) Write NFC

The NFC display (a) is a place to view data on the NFC Tag and write data to the NFC tag and also delete data on the NFC tag. The "Enter Data" display can be seen in (b). where users can enter data into the NFC tag.

Figure 19. OCR Screen





(a) (b)

Figure 20. Screen (a) Scan Picture and (b) Photo Asset from Gallery

The OCR display (Figure 18) is a place for OCR to scan documents where the user can see the OCR results which will be placed in the empty box area, Scanning Images to scan documents directly using the device camera, displaying the scanned camera image in (a), Saving OCR results to save OCR scan results into the application database, and take images from the gallery to be scanned by OCR. The view of taking a picture of asset on the gallery can be seen in (b).

Figure 21. Report Screen

Report Screen (Figure 20) is a place for users to report lost items, borrowed items, and changes to items.

Figure 22. History Screen

History Screen (Figure 21) is a place where users see the history of adding item data to the database and also reports.

G. Structure Menu and SubMenu

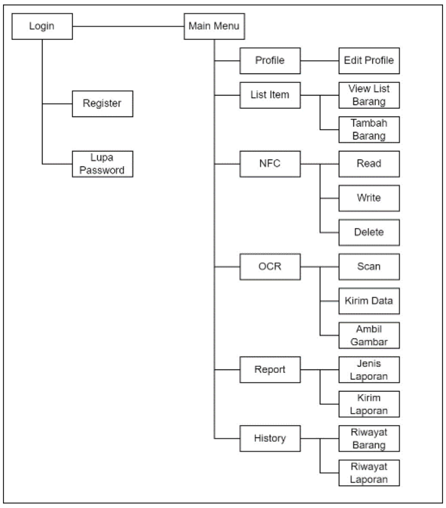


Figure 23. Application Menu and Submenu Structure

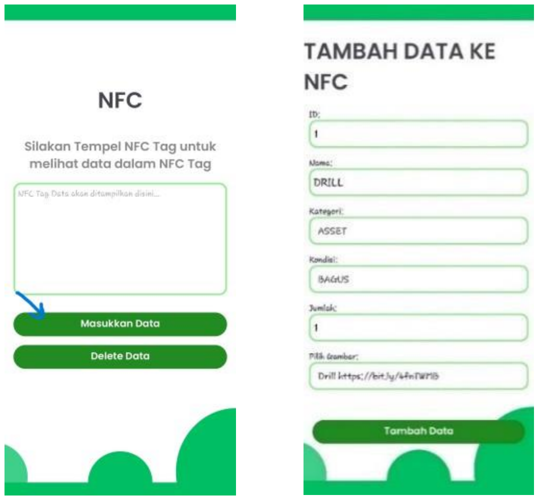
Figure 22 is a structure for the menu and submenu. At the top level, users can log in, register, or recover their password. Once logged in, they access the main menu, which branches into several primary options: Profile, List Item, NFC, OCR, Report, and History. Each of these primary options further subdivides into more specific functionalities. Under Profile, users can edit their profile. The List Item section allows viewing, adding, and managing items. The NFC section includes options to read, write, delete, and scan data, and to send data. The OCR section provides functions for scanning and sending data, including capturing images and specifying report types. The Report section allows users to send reports and view item and report histories. Finally, the History section is for viewing item and report histories.

III. RESULTS AND DISCUSSION

A. Retrieve NFC Data Transfer Speed

Here instruction to retrieve Data Transfer Speed as goes follow:

Figure 24 Goes to NFC display



(a) (b)

Figure 25 (a) Go to the Data Enter Display and (b) Enter data first then press add data to ready sent to NFC Tag

After user done login go to "Scan NFC Tag", then press the "Data Enter" and fill all data to label on the NFC tag when it's done press "Add data" and tap close to the NFC tag.

Figure 26 Check Data if already sent to the Tag

To make sure the data is already in the tag user can tap close to tag and the data will appear on the box.

When measuring NFC data transfer speed is focused on two main aspects:

Throughput (Data Transfer Rate): This is the amount of data successfully transferred per unit time, measured in kilobits per second (kbps). Throughput reflects the efficiency of NFC data transfer and can be affected by factors such as the NFC data rate used, the size of the data transferred, and environmental conditions.

In calculating Throughput we can use the formula below:

$$Throughput = \frac{(\text{Data Size}*8)}{\text{Transfer Time (ms)}} \quad (1)$$

For Data Size (bytes) where the size of the data entered in the NFC Tag is then multiplied by 8 because it is still bytes not kbytes then the results are divided by Transfer Time (ms) where the average of the data in the document is 10 ms making it easier for us to calculate.

The throughput data is displayed in the table below:

TABLE I
DATA TRANSFER NFC

NTAG213	Transfer Speed Data		Throughput	Average of Data
	Speed	Data Size		
1	10 ms	98 byte	78.4 kbps	
2	10 ms	102 byte	81.6 kbps	
3	10 ms	100 byte	80 kbps	
4	10 ms	112 byte	89.6 kbps	
5	10 ms	94 byte	75.2 kbps	
6	10 ms	102 byte	81.6 kbps	81.6 kbps
7	10 ms	114 byte	91.2 kbps	
8	10 ms	102 byte	81.6 kbps	
9	10 ms	94 byte	75.2 kbps	
10	10 ms	102 byte	81.6 kbps	

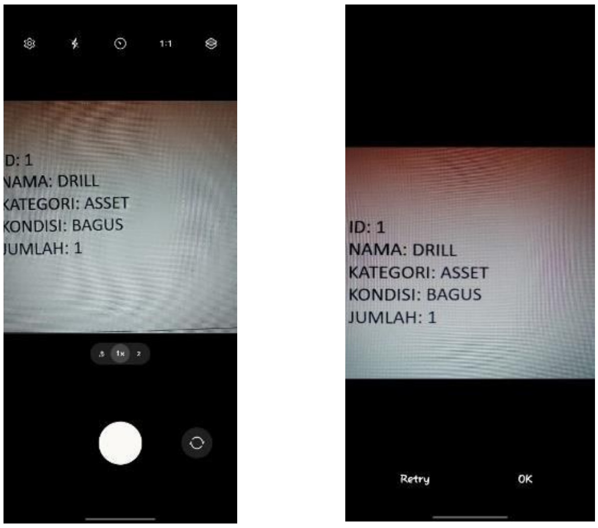
B. *Retrieve OCR Accuracy Data*

Here for the instruction to retrieve OCR Accuracy Data as goes follow:

Figure 27 Goes to OCR display

Figure 28 Follow Step provide on the screen

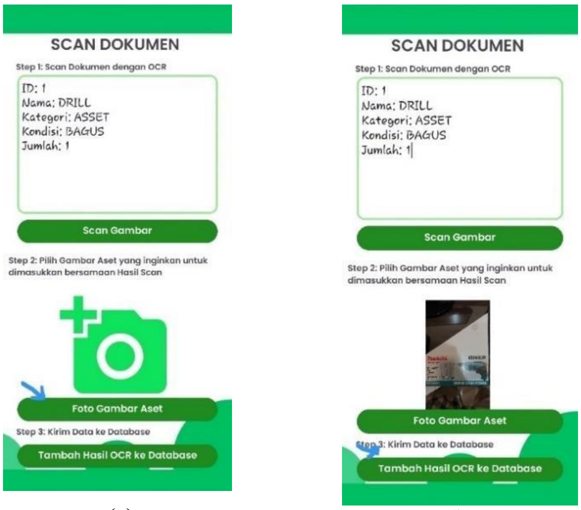
First, after user login go to "Scan Using OCR" and then follow the step-by-step that provide on the screen, start with scan picture.



(a) (b)

Figure 29 (a) Taking picture to scan and (b) Result after taking picture user able to retake or done

The user will be directly directed to use the camera to take a picture, then after finishing taking the picture the user can choose to take it again or continue.



(a) (b)

Figure 30 (a) Second step is to take asset item picture and (b) Last step is send the data to the database.

For this OCR test, the accuracy of Optical Character Recognition (OCR) is measured using the ground truth method and Levenshtein distance**.** Ground truth is a true and accurate data reference, which is used as a comparison to measure how accurate the OCR scan results are. Levensthein distance is a metric that calculates the distance between two text strings, that is, the minimum number of edit operations (insertion, deletion, or replacement of characters) required to convert one string into another.

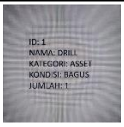
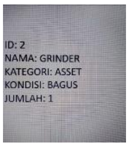
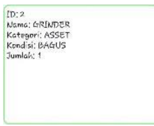
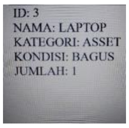
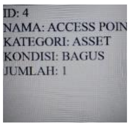
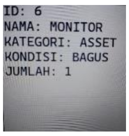
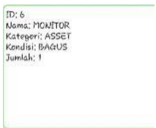
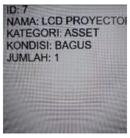
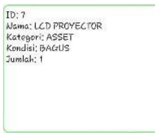
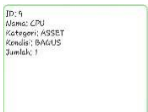
a) Ground Truth Setup: Ground truth data is prepared in the form of a *GroundTruthItem* object, which contains correct information about inventory assets, such as ID, name, category, condition, and quantity.
b) OCR scanning: The Android application is used to scan labels or asset documents, and the OCR scanning results are saved in text form.
c) Calculation of Levenshtein Distance: For each data field (ID, name, category, condition, amount), the Levenshtein distance between the OCR result text and the corresponding ground truth value is calculated using the levenshteinDistance() function.
d) Accuracy Calculation: OCR accuracy for each field is calculated using the following formula:

$$Accuracy = 1 - \frac{(Levenshtein\ \ Distance)}{(Ground\ Truth\ String\ Lenght)} \quad (2)$$

e) Normalization: Accuracy results are normalized by multiplying them by 100 to get the accuracy percentage.
f) Average Overall Accuracy: The average accuracy of all fields is calculated to obtain the overall OCR accuracy.

In this test, a scale factor of 5 is used in calculating accuracy. This scaling factor was chosen to adjust the resulting range of accuracy values, so that 100% accuracy indicates perfect agreement between the OCR results and ground truth, while 0% accuracy indicates complete discrepancy. This scaling factor value can be adjusted according to the needs and characteristics of the data used and also includes the resolution scale used, namely 1:1.

TABLE II
SCAN ACCURACY DATA

No	Test Result		Font Type	Accuracy %	Average Percentages %
	Scanned Picture	Result of Scan			
1			Calibri	100%	100%
2			Calibri	100%	
3			Times New Roman	100%	
4			Times New Roman	100%	
5			Cascadia Mono	100%	
6			Cascadia Mono	100%	
7			Arial	100%	
8			Arial	100%	
9			OCR A Extended	100%	
10			OCR A Extended	100%	

IV. CONCLUSION

This research indicates that the design of the inventory system, which includes data entry, reporting, item labeling using NFC, and data retrieval using OCR within the application, is highly satisfactory. A comparison of data input speed between manual entry and the application shows that the application is significantly faster, taking only 3-4 seconds compared to 6-30 seconds manually. The implementation of OCR in the application demonstrates excellent accuracy at 100% in recognizing asset information from images, while NFC enables fast and reliable data transfer with an average speed of 81.6 kbps. The utilization of the Firebase platform is also very helpful in securely storing inventory data and asset images, with Firestore Firebase being used for structured and flexible data storage, Firebase Storage for storing asset images, ML Kit Firebase for OCR, and Firebase Authentication for user creation and data storage.

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