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Barcode Scanning Conveyor Automation System for Expedition Goods

Eko Sulistyo*, Muhamad Ilham, Dhea Prameswari, Yudhi
Department of Electrical Engineering and Informatics – Bangka Belitung State Manufacturing Polytechnic
Bangka, Indonesia
*sulistyo.eko@gmail.com

Abstract – *The development of expeditionary goods separation system technology is currently increasingly leading to automation systems. Including shipping expedition goods. However, currently the process of separating goods during shipping expeditions is still mostly done manually. Therefore, research is needed to create an automatic control system tool that can separate and record expedition goods so that it becomes more effective and efficient. The methodology used is 3 GM66 Barcode Readers to read Barcodes on expedition goods from the top, left and right positions. The reading results are sent to the Arduino Mega R3 and processed to move the servo motor and separate the expedition goods into 3 different sortings according to the destination area and 1 sorting for rejected goods. Reading data from the Barcode is also sent to the WiFi module and processed to be sent to the expedition's goods database. The expedition goods database then displays the data on the IoT control system. As a result, the Barcode reading by the Barcode Reader from the top, left and right positions was read well with an error percentage of 0%. Then separate the expedition goods from the reading results separately according to the destination with an error percentage of 0%. And reading the expedition goods input data through reading the Barcode is stored in the expedition goods database and can be read again based on the Barcode, recipient's name, recipient's address, and No. Recipient's cellphone.*

Keywords – *Expedition goods; Barcode scanning; Automation system; IoT control system; Arduino Mega R3.*

I. Introduction

AUTOMATION systems are a form of technological advancement realization. Industrial technology is no exception, where industrial advancements are increasingly leaning toward automation systems. Automation itself refers to the creation and application of technology to monitor and control the production and delivery of products and services [1].

The use of control systems, such as computers to manage industrial machines and replace human labor, is becoming increasingly widespread. This trend also extends to the freight forwarding industry, where sorting goods in expeditions is still predominantly done manually using human labor, resulting in inefficiencies and less effective operations [2].

Referring to previous research titled *"Design of a Prototype Sorting Machine Based on 1D Barcode on Products in the Production Area"* by Dean Anggara Putra and Gian Villany Golwa in 2021 [2], the study proposed a system that utilizes a microcontroller as the main controller. It reads barcodes via a barcode reader and sends characteristic signals to a Programmable Logic Controller (PLC) to instruct pneumatic actuators to direct products to designated gates. However, the study lacked integration with the Internet of Things (IoT) and utilized an excessive number of components, which should be minimized while still covering all desired operational principles.

Similarly, another study titled *"Design of a Goods Sorting Tool Using Microcontroller-Based Barcode"* by Perdian Pramana and Riki Mukhaiyar in 2022 [1], proposed a system utilizing an Arduino Uno as the primary controller. This system reads barcodes and then commands a servo motor to move according to the barcode's characteristics. Once the servo motor places the item in the designated location, an infrared sensor detects and counts the items. However, this study only used a single barcode scanner, which may lead to undetected barcodes since expedition goods can have barcodes placed in different positions, such as the top, left, or right. Additionally, the counting of sorted goods was managed by an infrared sensor, whereas it would be more efficient to implement an automated system program for real-time counting.

Given the aforementioned challenges and existing

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technological solutions, it is necessary to develop a `Barcode Scanning Conveyor Automation System` for expedition goods. This research aims to:

1. Develop an automated control system to facilitate the sorting and counting of expedition goods into three different categories based on regional destinations, including one category for rejected goods.
2. Enable barcode detection from multiple positions, including the top, left, and right, ensuring accuracy regardless of placement.
3. Integrate IoT technology to improve monitoring and data collection of expedition goods.

The expected outcome is a more effective and efficient sorting process, particularly when handling large quantities of goods, ensuring accuracy and improved logistics operations.

II. Research Methods

The methods and steps used in conducting this research are illustrated in the following figure.

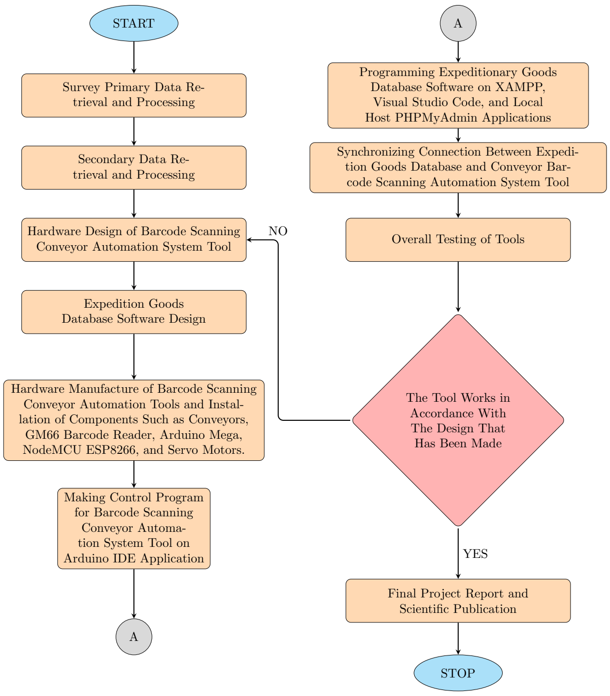

Figure 1: Flowchart of Implementation.

i. Primary Data Collection and Processing Survey

In the implementation of this research, the initial stage involves collecting primary data. Primary data collection is obtained through surveys conducted at expeditionary goods delivery companies in Sungailiat, Bangka Regency. Data is gathered from major logistics service providers such as `JNE Express` and `TIKI`.

(a) JNE Express

(b) TIKI

Figure 2: The process of sorting and inputting expedited goods data.

Based on surveys and interviews conducted, it was found that the process of sending expeditionary goods at JNE Express and TIKI companies in Sungailiat, Bangka Regency still heavily relies on manual methods. Human labor is used to sort and count the number of incoming expedition goods. Consequently, the sorting and counting results are not systematically recorded, leading to inefficiencies and potential inaccuracies.

The primary data analysis highlights the necessity of developing an automated system to facilitate the sorting of expeditionary goods. This system aims to enhance automation in the calculation and recording of incoming expedition goods, ensuring improved efficiency and accuracy in logistics operations.

ii. Secondary Data Retrieval and Processing

In addition to collecting data through surveys, secondary data collection was also conducted by reviewing reference data from previous research journals. These references provide supporting data essential for the implementation of this research.

After conducting several literature searches, notable references were obtained, including research titled `"Design of a Prototype Sorting Machine Based on 1D Barcode on Products in the Production Area"` by Dean Anggara Putra and Gian Villany Golwa in 2021 [2], as well as research titled `"Design of a Goods Sorting Tool`

`Using a Microcontroller-Based Barcode"` by Perdian Pramana and Riki Mukhaiyar in 2022 [1].

The secondary data collected was processed to support the primary data findings. This was crucial for determining the system and components required for the implementation of this research. Additionally, to ensure system efficiency, data was collected on several key components to optimize performance.

The research by Dean Anggara Putra and Gian Villany Golwa [2] highlighted the need for an Internet of Things (IoT) system to facilitate real-time monitoring and data collection of sorted goods. This aligns with advancements in Industry 4.0 technologies. The study also suggested minimizing the number of components while maintaining full functionality, leading to the use of a more integrated control system such as the `Arduino Mega Microcontroller` and `NodeMCU`.

Similarly, the study by Perdian Pramana and Riki Mukhaiyar [1] suggested that an additional barcode scanner should be implemented to detect barcodes from multiple angles. Furthermore, the study used infrared sensors to count goods, but this process could be optimized using an automated system for more accurate calculations. Based on the analysis of secondary data, the following components were selected for this research:

1. **One mini conveyor**
   Conveyor is one type of tool that has a function to move or transport goods in the industrial world, both solid and box [2].
2. **Three pieces of GM66 Barcode Reader**
   Barcode is a bar code consisting of a collection of optical data that can be read by machines [3]. And at this time, most of the industrial world uses 1-dimensional barcodes.
   Then, to read a Barcode code, a tool is needed, namely a Barcode Scanner. Barcode Scanner is a tool that can be used to read codes in the form of vertical lines or called Barcodes which can usually be found on most products in the form of goods [4]. There are several types of Barcode Scanners on the market, one of which is the GM66 Barcode Reader. GM66 Barcode Reader is a high-performance barcode scanner, which can read 1D barcodes easily and read 2D barcodes at high speed [5]. Inside this Barcode Reader there is a Universal Asynchronous Receiver-Transmitter (UART) system that can be used for communication between devices with short transmission distances and low transmission speeds. The process is carried out in each bit per unit time [6].
   In the UART system itself, there are two main pins used in this research, namely the Transmitter (Tx) pin and the Receiver (Rx) pin [7]. In addition, the UART system also has its own reading system [8].
3. **One Arduino Mega R3 AT2560**
   Microcontroller control system is a computer system that can process commands and has input pins and output pins that can be programmed according to the needs that are centralized into one physical form, namely IC [9]. One of the types of microcontrollers is the Arduino Mega R3 AT2560. This microcontroller is a microprocessor board based on the Atmega2560 IC chip [10].
   This microprocessor has a total of 54 digital input/output pins, consisting of 15 pins that can be used as PWM (Pulse Width Modulation) outputs, 16 analog input pins, and 14 pins as UART [11]. Then, to create a program on Arduino, a software is needed that can create the control system program needed in this research. The software is the Arduino IDE. Integrated Development Environment (IDE) is an integrated environment used to perform a development on the program to perform functions that are immersed in the programming syntax [12].
4. **One NodeMcu ESP8266 CH340**
   NodeMcu is a development of ESP8266 made by Expessif System which is equipped with Firmware and is also based on the e-Lua Scripting programming language which is more or less the same as the JavaScript language [13]. NodeMcu has combined ESP8266 into a compact board with various functions such as Microcontroller coupled with its ability to access WiFi and has a USB to serial communication chip so that to program it only requires a micro USB data cable [14].
   NodeMcu is also easy to program and has sufficient input/output pins and can be accessed with an internet network to send and retrieve data via a WiFi connection [15].
5. **Three Tower Pro SG90 Servo Motors**
   Servo motor is one of the devices that functions as a motor (rotary actuator) which is designed with a servo feedback control system (closed loop) [16]. Basically, servo motors have a working principle based on PWM (Pulse Width Modulation) signals using control cables [17]. Pulse Width Modulation (PWM) in general is one way to manipulate the width of a signal which is usually expressed in the form of a pulse with a period [18]. In the Tower Pro SG90 servo motor used in this study, to control it needs to be done by sending a control pulse and a frequency of 50 Hz and a period of 20 ms and a different duty cycle. Where to move this servo motor which has a 180° rotation, a pulse width of 2.5 ms is required [19].

The selected components ensure efficient sorting, barcode detection, and real-time monitoring, which are critical for the successful implementation of the proposed system. To control the servo motor, a PWM signal is generated based on the required duty cycle. The equation governing PWM is shown in Equation (1) [20].

$$PWM_{\text{value}} = \frac{\text{pulse width}}{\text{period}} \times 100\% \quad (1)$$

Equation (1) defines the relationship between pulse width and duty cycle, which is crucial for precise servo motor operation. The block diagram illustrating the system architecture is shown in Figure 3.

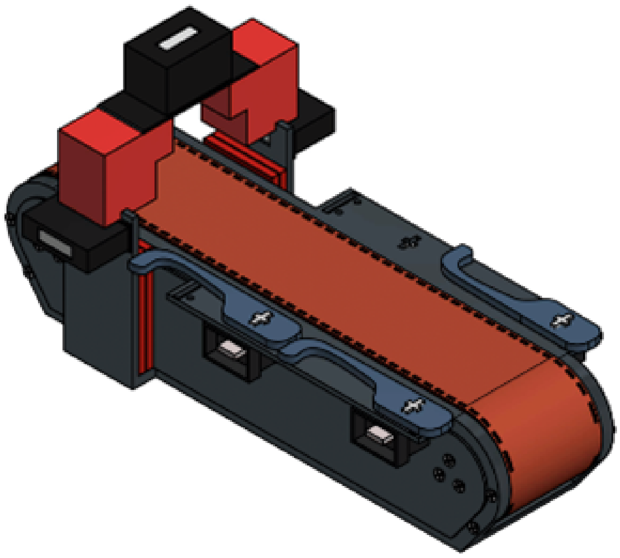

Figure 3: Overall design of Barcode Scanning Conveyor.

As seen in Figure 3, the system integrates barcode scanners, a microcontroller, and a conveyor belt to automate the sorting process. To manage the database and implement control functions, several software tools are required. These include:

1. XAMPP Control Panel Application
2. PHPMyAdmin Web Interface
3. Visual Studio Code Development Environment

These software tools will facilitate data collection, processing, and system monitoring.

At the hardware design stage of this tool, a mechanical construction design is first developed. This design is created using the `AutoDesk Inventor` application, where the `Barcode Scanning Conveyor` is modeled with its main component, a `mini conveyor`. The overall design appearance of the tool is shown in Figure 4.

After finalizing the mechanical design, the next step involves designing the `electrical control circuit` for component integration. The circuit is

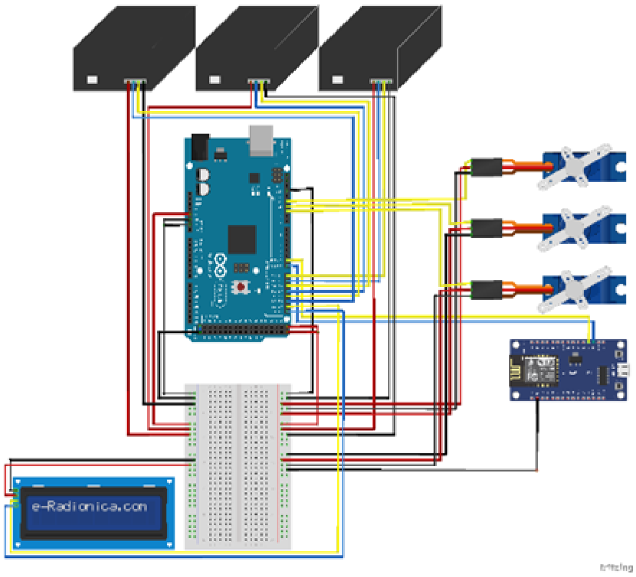

Figure 4: Electrical design (control circuit).

created using the `Fritzing application`, ensuring proper connectivity and functionality of the `Barcode Scanning Conveyor`. The electrical design diagram is illustrated in Figure 5.

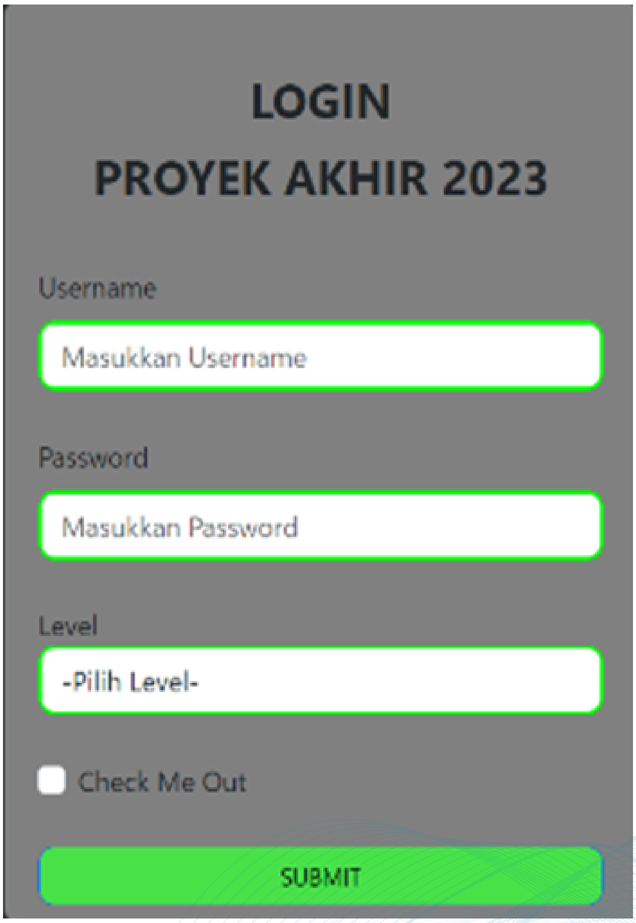

Figure 5: Login menu interface design.

iii. Design of Expedition Goods Database Software

In this design, an `application interface` is developed for implementation on a laptop screen. The system is built using an `Internet of Things (IoT)` control system to facilitate the management of the expedition goods database.

To enhance usability, the `IoT-based control system` is designed with a database that can be accessed not only via a laptop but also through a mobile phone. The graphical interface for this system is illustrated in Figure 6 and Figure 7.

Figure 6: Main Page menu interface design.

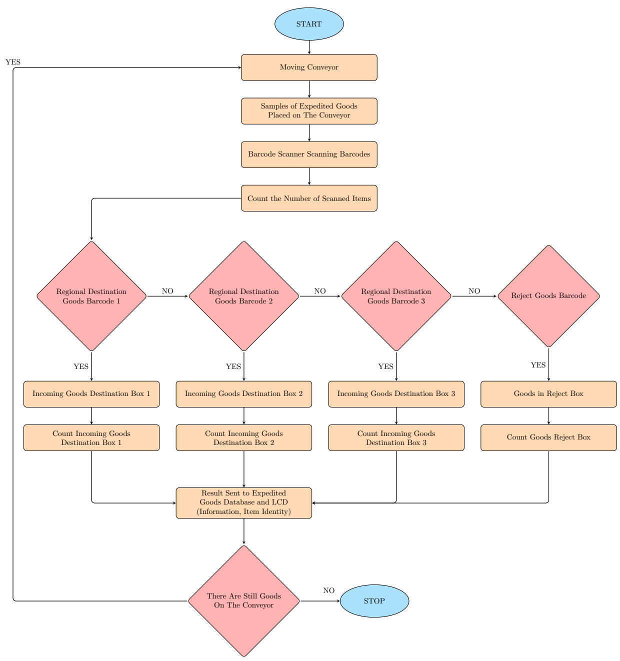

Figure 7: Flowchart of the overall working system.

As illustrated in Figures 6 and 7, the interface consists of two main menus: the `login menu` and the `main page menu`. These serve as references for developing the final `IoT system interface` in this study.

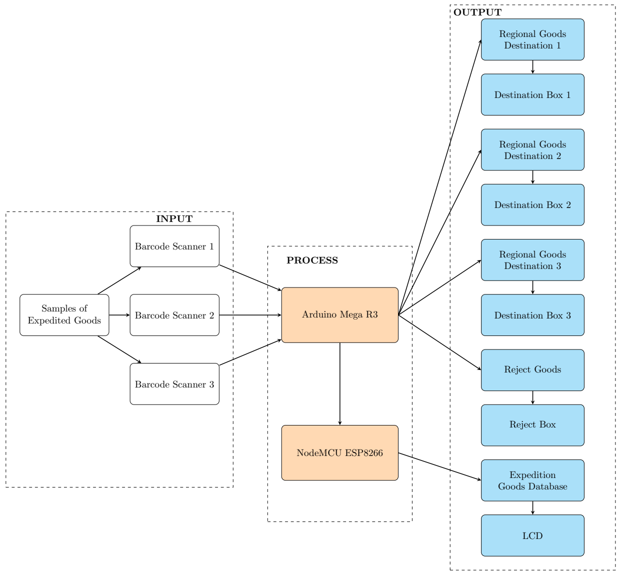

Figure 8: Block diagram of the overall working system.

After completing the `hardware design`, which includes both `mechanical construction` and `electrical control circuits`, the next phase involves the physical assembly of the hardware. The manufacturing of the hardware is conducted at two locations: the `Bangka Belitung State Manufacturing Polytechnic` and the `maker's workshop`.

The hardware is constructed based on the designed `Barcode Scanning Conveyor` framework. Additionally, the installation of components follows the pre-designed `electrical control circuit`. After completing the construction and installation, the tool control program is developed using the `Arduino IDE` application. This program governs the `automation system` to ensure its proper functionality in this research.

iv. Programming of Expeditionary Goods Database

After constructing the `hardware tool` and installing its components, the next step involves developing the `expedition goods database software`. This software is built based on the previously designed `Internet of Things (IoT)` control system interface. The development of this software takes place at the same locations as the `hardware manufacturing` previously described.

v. Overall Testing of the Tool

The next stage involves testing the entire system. The testing process ensures that the designed tool functions correctly. The key aspects of this testing are as follows:

1. The tool is tested in accordance with the designed `automation system`. The first step is to verify the `barcode reading position` for each sample of `expedition goods`. The barcode scanner is positioned to detect barcode codes placed on the `top, left, and right` sides of the goods. The purpose of this test is to evaluate whether the tool reliably scans barcodes in all positions and to check its effectiveness when barcode labels are `damaged`.
2. Once the barcode reading test is successful, the next step is testing the sorting mechanism. This involves verifying that the `barcode scanner` correctly sorts goods into `destination boxes 1, 2, 3, and the reject box`. The goal is to determine whether the control system successfully sorts goods based on barcode information and detects items with `damaged or unreadable barcodes`.
3. After confirming the accuracy of barcode sorting, the third test evaluates the synchronization `and data entry` into the `expedition goods database software`. This ensures that the `IoT-based interface` correctly synchronizes and displays barcode data, maintaining consistency in recorded inventory.

vi. Final Report and Scientific Publication

After completing the system testing phase, the next step is to `analyze and evaluate` the performance of the system. If the tool does not function as designed, necessary `modifications and improvements` will be made. Once the tool meets the required specifications, the research will proceed to the `final report preparation` and `scientific publication` of the findings.

III. Results and Discussion

Before discussing the research results, it is essential to understand the `working system` of the entire tool. To illustrate this, a `flowchart` and `block diagram` are provided, which offer a structured view of the `Barcode Scanning Conveyor Automation System`. Figures 9 and 10 depict the system's working flow.

Based on Figures 9 and 10, the `working process` of the system operates as follows:

1. The conveyor is turned on by connecting the `power supply cable` to the power source, allowing the conveyor to start moving.
2. The sample of the `expedited goods` is placed on the moving conveyor.

Figure 9: Hardware results of the Barcode Scanning Conveyor Automation system tool.

Figure 10: Interface on the login menu.

3. As the goods move along the conveyor, they pass through three `barcode scanners` positioned to scan barcode labels attached to the `top, left, and right` sides of the goods.
4. The scanned barcode data is then processed to count the total number of items that have been sorted.
5. The barcode data is further processed by the `Arduino Mega R3` microcontroller to sort the goods into four different `sorting destinations: destination box 1, destination box 2, destination box 3,` and the `reject box`.
6. The sorted expedition goods data is transmitted to the `NodeMCU ESP8266` microcontroller for processing before being sent to the `expedition goods database` and displayed on an `LCD screen`. The LCD provides real-time updates on the number of incoming goods and their designated sorting location.
7. The system continues to operate automatically, processing additional `expedition goods` as long as there are items present on the conveyor.

i. Results of Hardware Manufacture

The hardware tool in this study was built based on the previously designed mechanical and electrical construction designs (control circuits). The final result of the hardware manufacturing process is shown in Figure 11.

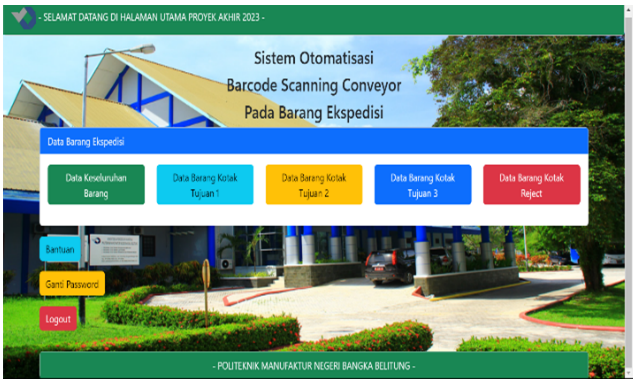

Figure 11: Interface on the main page menu.

ii. Results of Expedition Goods Database Software Development

The expedition goods database software was developed using the Internet of Things (IoT) control system. This system was implemented based on the previously designed IoT system interface. As a result, the software consists of two primary menus.

The first menu is the login menu. This is the initial interface that users encounter when accessing the IoT system software. In this menu, users are required to enter credentials before proceeding to the main interface. The login menu is shown in Figure 12.

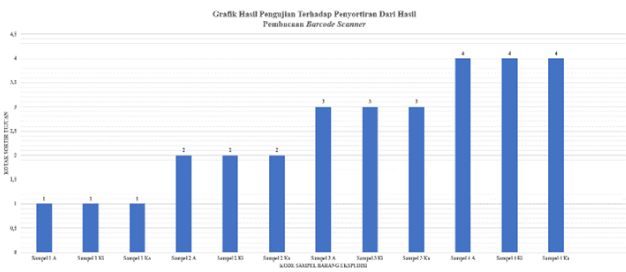

Figure 12: Enter credentials before proceeding in main interface

Once the user has entered all necessary credentials and pressed the submit button, they are automatically redirected to the main page menu. This interface serves as the second stage of interaction within the IoT system software. The main page menu interface is depicted in Figure 16.

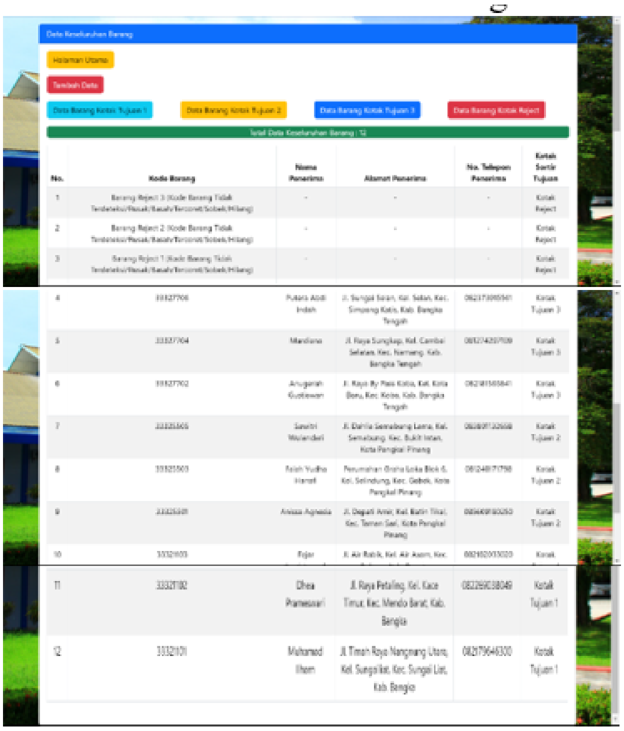

Figure 13: Main page menu interface

iii. Expedited Goods Sample

Before proceeding to the overall test results of the tool, it is necessary to examine the expedition goods samples used for testing. A total of 12 samples were tested in this study. Each sample contains a unique barcode code and specific data regarding its weight and dimensions. The details of each sample are presented in Table 1.

Table 1: Data of each sample expedited goods.

Sample	Barcode Code	Item Weight (gram)	Item Size	
			P (cm)	L (cm)
1 A	33321101	10	3.5	3.3
1 Ki	33321102	10	3.4	3.4
1 Ka	33321103	10	3.5	3.4
2 A	33325501	10	3.6	3.4
2 Ki	33325503	10	3.1	3.5
2 Ka	33325505	10	3.3	3.5
3 A	33327702	10	3.5	3.4
3 Ki	33327704	10	3.6	3.3
3 Ka	33327706	10	3.0	4.4
4 A	33321104	10	3.6	4.1
4 Ki	33325507	10	3.5	3.9
4 Ka	33327708	10	3.5	3.9

As observed in Table 1, each barcode code affixed to the samples is positioned differently. The notation:

1. A indicates the top position.
2. Ki indicates the left position.
3. Ka indicates the right position.

These different positions are necessary as the barcode scanners are installed in three distinct locations: top, left, and right.

Additionally, the first to third samples represent expedition goods with different regional destinations, while the fourth sample represents goods with damaged or rejected barcodes. This includes barcodes that are undetected due to damage, moisture exposure, being crossed out, torn, or missing.

iv. Test Results on the Position and Distance of Barcode Reading

The first test conducted was Barcode reading position and distance testing. This test aimed to determine whether the developed system has high reliability in reading barcode codes attached to expedition goods from different positions: top, left, and right. Additionally, it tested the system's ability to detect damaged barcode codes. The test results are summarized in Table 2.

Table 2: Results from testing the Barcode reading position. The checkmarks (✓) indicate successful barcode detection at each scanner position: 1(Ka) (right), 2(A) (top), and 3(Ki) (left).

Sample	Barcode Code	Barcode Scanner Active		
		1 (Ka)	2 (A)	3 (Ki)
1 A	33321101		✓	
1 Ki	33321102			✓
1 Ka	33321103	✓		
2 A	33325501		✓	
2 Ki	33325503			✓
2 Ka	33325505	✓		
3 A	33327702		✓	
3 Ki	33327704			✓
3 Ka	33327706	✓		
4 A	33321104		✓	
4 Ki	33325507			✓
4 Ka	33327708	✓		

As presented in Table 2, the system successfully detected barcode codes from all positions using the three barcode scanners. The placement of these scanners is defined as follows:

1. Scanner 1 (Ka) – Positioned on the right side.
2. Scanner 2 (A) – Positioned at the top.
3. Scanner 3 (Ki) – Positioned on the left side.

To further illustrate the test results, a graph representation is provided in Figure 17.

Based on Figure 17, the data confirms that:

Figure 14: Graph of test results on Barcode reading position.

1. Samples with code A were successfully read by Scanner 2 (top).
2. Samples with code Ki were successfully read by Scanner 3 (left).
3. Samples with code Ka were successfully read by Scanner 1 (right).

A total of 12 samples were tested, and all were successfully detected. The reliability percentage of the test is calculated using Equation 2:

$$\text{Error Rate} = \frac{\text{Failed Tests}}{\text{Total Tests}} \times 100\% \quad (2)$$

$$\text{Error Rate} = \frac{0}{12} \times 100\% = 0\%$$

Thus, the barcode reading test achieved a 100% reliability rate.

v. Sorting From Barcode Scanner Reading Results

The second test assessed the sorting accuracy of the system. This test aimed to determine whether the control system successfully sorted expedition goods based on their barcode codes. The goods were directed to destination sorting boxes 1, 2, 3, or the reject box if the barcode was unreadable. The results are summarized in Table 3.

Table 3 shows that all samples were sorted correctly. The servo motors controlling the sorting were configured as follows:

1. Servo 1 – Sorting goods to destination box 1.
2. Servo 2 – Sorting goods to destination box 2.
3. Servo 3 – Sorting goods to destination box 3.

To further illustrate the test results, a graphical representation is provided in Figure 18.

A total of 12 tests were conducted, all of which were successful. The success rate was calculated using Equation 3:

Table 3: Results from testing the sorting results of Barcode Scanner readings.

Sample	Barcode Code	Barcode Scanner Active			Description
		1 (Ka)	2 (A)	3 (Ki)	
1 A	33321101	✓			Box 1
1 Ki	33321102	✓			Box 1
1 Ka	33321103	✓			Box 1
2 A	33325501		✓		Box 2
2 Ki	33325503		✓		Box 2
2 Ka	33325505		✓		Box 2
3 A	33327702			✓	Box 3
3 Ki	33327704			✓	Box 3
3 Ka	33327706			✓	Box 3
4 A	33321104				Reject Box
4 Ki	33325507				Reject Box
4 Ka	33327708				Reject Box

Figure 15: Graph of test results on sorting from Barcode Scanner reading results.

$$\begin{aligned} \texttt{Success Rate} &= \frac{\texttt{Successful Tests}}{\texttt{Total Tests}} \times 100\% \\ &= \frac{12}{12} \times 100\% = 100\% \end{aligned} \tag{3}$$

Which means, in testing the position of reading this Barcode code there is an average error of 0%. Which means that reading the Barcode code that has been attached to the sample of expedition goods from all positions and when there are expedition goods whose Barcode code is damaged has a reliability level of 100%.

vi. Barcode Code Data on Expedition Goods

The third test conducted was `Barcode code data entry testing` in the `expedition goods database software`. The objective of this test was to evaluate whether the `Internet Of Things (IOT)`-based system ensures accurate `synchronization` and `data suitability` between the barcode codes and the database. The test results are presented in Figures 16 to 20.

As seen in Figure 16, the system successfully displays all data from the sorted expedition goods.

Based on Figures 16 to 20, the following key observations were made:

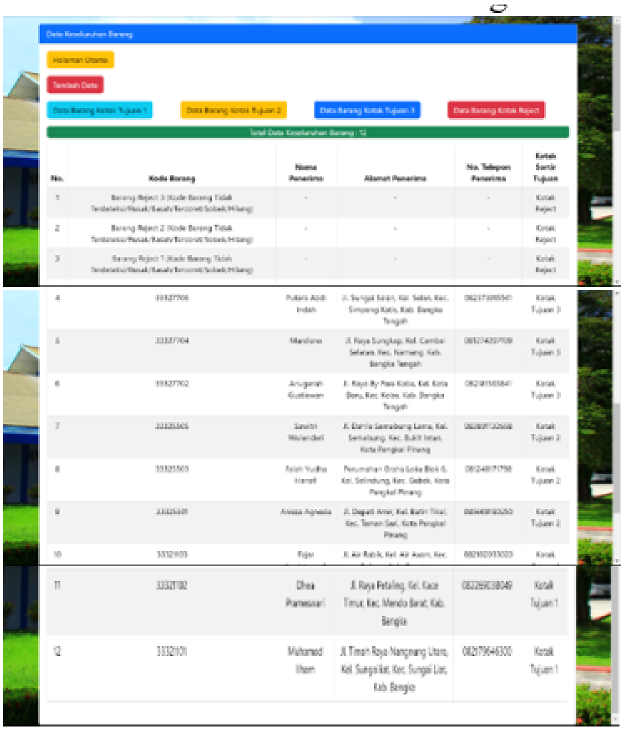

Figure 16: Overall item data in the database.

Figure 17: Destination box 1 item data.

Figure 18: Destination box 2 item data.

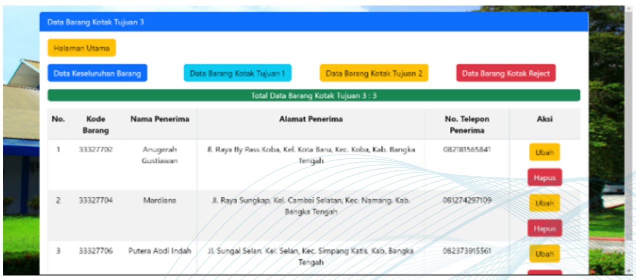

Figure 19: Destination box 3 item data.

Figure 20: Reject box item data.

1. The system includes four `interface menus` in the database:
   (a) `Overall item data`
   (b) `Destination box 1 item data`
   (c) `Destination box 2 item data`
   (d) `Destination box 3 item data`
   (e) `Reject box item data`
2. Each `interface` menu successfully displays:
   (a) `Item code`
   (b) `Recipient's name`
   (c) `Recipient's address`
   (d) `Recipient's phone number`
3. The system successfully maintains data `synchronization` between the barcode readings and the database entries.

Thus, the `barcode code data entry test` demonstrated a 100% `success rate`, ensuring accurate `monitoring and recording of expedition goods`.

IV. Conclusion

The results of this study demonstrate that the `Barcode Scanning Conveyor Automation System` effectively automates the sorting and tracking of expedition goods. The `Barcode Scanner sensor` successfully reads barcode codes placed on expedition goods from `top, left, and right` positions, achieving an `error rate of 0%`. The `sorting system` reliably directs goods into their respective `destination boxes` (1, 2, 3, and reject) with an `error percentage of 0%`, ensuring accurate categorization. Furthermore, the `expedition goods database software` effectively `stores and retrieves` data based on barcode codes, enabling seamless access to information such as `recipient's name, address, and phone number`. These findings highlight the potential of integrating automation and `Internet of Things (IoT)` technology to improve efficiency and reliability in logistics operations.

While the system performs with high accuracy, future improvements can focus on expanding detection capabilities to accommodate various package shapes, increasing sorting categories based on additional attributes such as `size, dimensions, and weight`, and further enhancing automation for application in large-scale industrial environments. Continuous advancements in barcode scanning technology and machine learning-based object recognition may also contribute to refining the overall functionality of the system.

Acknowledgment

This research was made possible through the support of the `Bangka Belitung State Manufacturing Polytechnic`, which provided the necessary resources and infrastructure for the system's development and testing. The contributions of individuals and organizations involved in data collection, technical discussions, and system implementation were instrumental in refining the research framework and ensuring the feasibility of the proposed automation system. The insights from previous studies and industrial references significantly enhanced the methodology, guiding the successful integration of barcode scanning and automated sorting technologies. The authors acknowledge these contributions, which played a vital role in achieving the research objectives.

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