IoT-Based Helmet Storage Cabinet with Solar Panel

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Abstract. The IoT-based Helmet Storage Cabinet was created to address the issue of helmet loss in parking areas that lack storage facilities. This tool is intended for motorcycle users who need helmet storage. This helmet storage has several storage spaces that can be accessed independently by users registered with the application. users are required to download an application by scanning the QR code located on the side of the cabinet and then registering an account within the application. The way this tool works is by opening the storage locker automatically via QR code. Storage test results show that the average speed of the control system is 494 milliseconds. To make this tool portable and can be used outdoors without access to electricity, this tool is equipped with a solar panel as an energy source. The energy obtained from the solar panels is stored in the battery in the device. The battery performance test results show that the battery can be used for up to 102 hours without a solar panel. As feedback after using this tool, a questionnaire was distributed to students who had used this helmet storage. The response given shows that 91% of users agree that this tool can prevent helmet loss in the parking area.

Keywords: IoT Based, Storage Cabinet, QR Code

1 Introduction

Crime, particularly theft, frequently occurs in society and has become a problem without an effective solution. One example of a theft crime is helmet theft in parking areas, especially in places that lack helmet storage cabinets. As a preventive measure, conventional helmet storage with human attendants is in place, but it comes with several issues for users. One common problem faced by users of conventional helmet storage cabinets is the limited operating hours. In some places where the helmet storage operates 24 hours, users encounter difficulties when retrieving their helmets during the late hours when attendants or owners are asleep, requiring users to wake them up. To minimize such issues, there is a need for secure helmet storage cabinets that can be accessed 24/7.

Several methods can be used to create an automatic helmet storage cabinet, including using RFID cards and QR codes. The Radio Frequency Identification (RFID) method is a technology that uses Auto-ID or Automatic Identification [1], which is used as an automatic control tool in a chain of activities [2]. On the other hand, QR-Code is a two-dimensional barcode consisting of black squares within a larger white square [3]. The use of the QR-Code

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method tends to be more flexible and user-friendly compared to the RFID method. Although the RFID method allows for accurate and fast scanning of RFID cards [4], users are required to purchase and register RFID cards with the owner, which may reduce flexibility in usage. The use of the QR Code method in the research of automatic helmet storage cabinets would be more suitable for the research's objective of solving existing problems and making it easier for the public to use.

The development of an IoT-based helmet storage cabinet with solar panels is necessary to address the issue of helmet loss in unattended parking areas. The problems to be addressed in this development include the creation of mechanical components, control systems, and an Android application as access to the automatic helmet storage cabinet. In the upcoming development, it is essential to consider regulations, taking into account civil law articles 1694, 1699, and 1708 concerning regulations and responsibilities for entrusted goods.

The operation of the storage cabinet system requires a database to store data, replacing the conventional system which relies on document files [5] needed for storing and retrieving helmets from the cabinet. A database is a systematic collection of information stored in a computer [6]. In this research, the database uses the MySQL database server. SQL Server is one of the relational database management systems (RDBMS) developed by Microsoft [7]. It is open-source and can be used freely and customized as needed [8].

The electrical energy source used in the device will harness sunlight, converting it into electrical energy through the photovoltaic effect using solar cells [9]. Indonesia, on average, has excellent solar energy potential, making it suitable for implementing Solar Photovoltaic (PLTS) as an alternative energy source [10]. The electrical energy generated will be stored in batteries that utilize chemical devices to store solar energy [11].

The technologies used in this research include Rest API, Arduino Mega WiFi with built-in capabilities, solenoid locks, and QR codes. In this development, Rest API serves as the communication protocol between the Android application, the server, and the Arduino Mega WiFi with built-in capabilities. Rest API is a communication standard in web applications that uses the JSON format [12]. The cabinet lock utilizes Solenoid door lock technology, which operates with a 12-volt voltage to unlock the latch and will lock the door in the normal position or when no voltage is applied [13]. QR-Code is used to store data in the form of an image [14] and as a quick way to retrieve information about the identity of each door. QR codes were initially developed to track products in the automotive industry [15].

2 Methods and Testing

The process of making an IoT-based Helmet Storage Locker with a Solar Panel consists of several stages that need to be carried out. It begins with creating a flowchart of the IoT-based helmet storage locker and solar panel system, followed by mechanical design, control system design, and user interface design for the Android application. Next, you gather the components, fabricate the locker, and create the front and back ends of the Android application. The next steps involve assembling the control system, which is then mounted on the locker, and programming the control system. This includes software such as a database, Arduino IDE programs, and the Android application. Once the hardware, which includes the control system, and the mechanical components like the locker for storing helmets, are complete, several tests are conducted to ensure that the IoT-based helmet storage locker with a solar panel works perfectly. Data is collected during testing and subsequently analyzed.

2.1 Flowchart of The Helmet Storage And Retrieval System Operation

To create an IoT-based helmet storage cabinet with a solar panel, a flowchart is needed as a visual representation used to depict the operation of a complex system or process presented in a simplified form with blocks to make it easier for readers to understand and comprehend the working system of a product or device. The flowchart for helmet rental and retrieval is depicted in Figure 1 and Figure 2. The user needs to be connected to the internet and then scan the QR code located on the side of the locker. Upon scanning, the user will be directed to Google Drive and can download and install the ROMEKA application to use the IoT-based helmet storage cabinet.

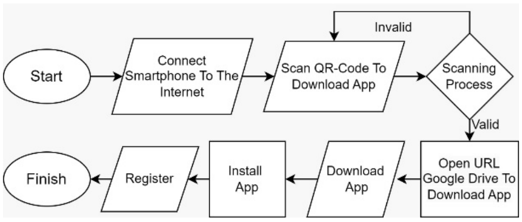

Figure 1. Flowchart of Helmet Storage

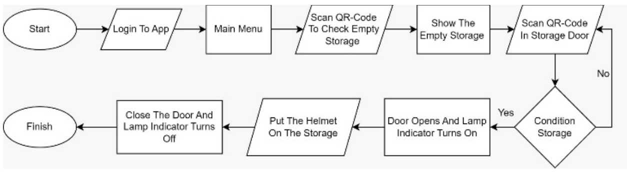

Figure 2. Flowchart of Helmet Retrieval

2.2 Helmet Storage Cabinet

The IoT-based helmet storage cabinet with solar panels is made using iron plates and is equipped with a roof. It has solar panels on top to serve as a power source. This cabinet features 8 doors that users can use to store their helmets. Each door has a QR code attached to it as an identifier. Additionally, there is a QR code located beside the cabinet that serves as a link for downloading the application and another QR code for identifying the cabinet's location. An image of the IoT-based helmet storage cabinet with solar panels can be viewed in Figure 3.

The control system of the IoT-based helmet storage cabinet with solar panels utilizes an Arduino Mega Wi-Fi built-in, which serves as the controller for pilot lamps, magnetic sensors, solenoid door locks, and a buzzer on the door system connected to the internet. This control system is powered by a battery with energy sourced from solar panels. It connects to a web server via the internet using the Rest API protocol. To operate the control system, a smartphone is required to scan the QR code on the cabinet door to open and close the cabinet door when storing or retrieving helmets. The design of the control system for the IoT-based helmet storage cabinet with solar panels is illustrated in Figure 4.

Figure 3. Design of helmet storage cabinet

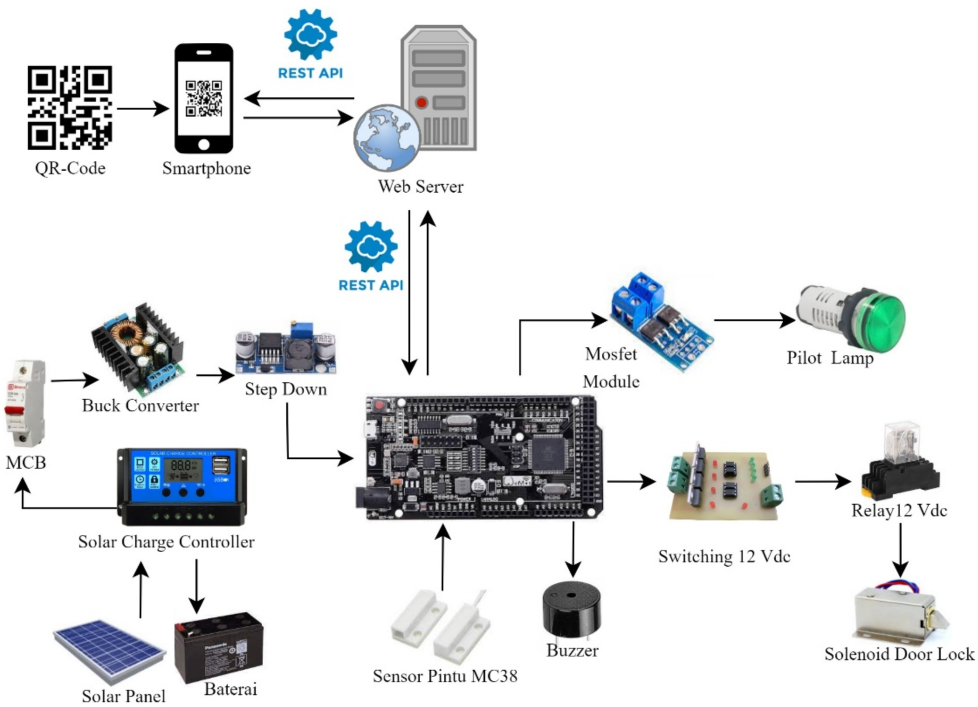

Figure 4. Design of the helmet storage cabinet system

The user interface design of the application is created using Figma software and is depicted in Figure 5. Based on the image, the application has three main functions: login, registration, and the main menu. In the login view, there is a registration button for users to sign up and create an account to use the helmet storage cabinet. In the registration view, there is an information button for users to access the terms and customer service agreement for using the IoT-based helmet storage cabinet with solar panels. In the main menu view, there are five functions available to users, including the Check Cabinet button for users to find empty cabinets, the Deposit button for users to store their helmets, the Deposit Information button for users to locate the cabinets they are using, the Feedback button for users to provide feedback and suggestions, and the Contact Person button for users to contact the cabinet provider in case of any issues with the IoT-based helmet storage cabinet with solar panels.

Figure 5. Design of user interface

Several tests were conducted on the IoT-based helmet storage cabinet with solar panels to ensure that the control system and Android application operated according to the established flowchart. The cabinet testing encompassed the evaluation of the application's ability to control the opening and closing of the cabinet doors and the assessment of the solar panel's power capacity to supply energy to the control system continuously for 24 hours.

These tests for the IoT-based helmet storage cabinet with solar panels spanned 7 days and were carried out at the Politeknik Negeri Batam (Polibatam) parking area. The testing involved members of the Polibatam as users to assess the cabinet's performance. Data collected during the testing included the speed of accessing the control system when users requested opening and closing access. This data was transmitted from the server to the Arduino Mega Wi-Fi built-in to execute the cabinet's control.

Additionally, the data collected encompassed the daily usage of the cabinet by users, the quota consumption required by the control system, power consumption by the control system's battery, and the recharging of the electrical power source for the battery. After users access the cabinet to open and close it, the usage history of the cabinet is stored on the server. This allows for analysis of the control system's working speed, the number of cabinet users in a day, and the amount of quota required by the control system. Furthermore, voltage values on the solar charge controller are monitored at 8:00 AM, 10:00 AM, 12:00 PM, 3:00 PM, and 5:00 PM (WIB) to assess the power usage of the control system and the charging of the solar panels to the battery over a day. Methods of data collection regarding power requirements and solar panel charging to the battery can be seen in Figure 7.

Figure 7. Solar charge control

3 Result and Discussion

The system that has been constructed is an IoT-based helmet storage cabinet with solar panels. This cabinet features 8 doors that users can utilize to store their helmets. It has a roof to protect against heavy rain and to accommodate the solar panels. The IoT-based helmet storage cabinet can be placed in outdoor locations. The IoT-based helmet storage cabinet with solar panels is portable, featuring wheels that make it easy to move. It is equipped with batteries to store the electrical energy generated by the solar panels. The panel box located on the left side of the cabinet is used to store the control system, while the right side is used to store the batteries. Placing the panel box on the lower side of the left and right sections is intended to facilitate maintenance and repairs.

The testing of the IoT-based helmet storage cabinet with solar panels has been carried out at the parking area of the Polibatam and has been used by the academic community of Polibatam. This testing was conducted to determine the speed of the control system when users utilize the cabinet and to assess the quota requirements used by the control system in a day. Based on the data on the server, 61 users have registered on the application, and 36 active users have used the IoT-based helmet storage cabinet product. Based on the user data on the server who have used this product, the response speed of the control system when requesting to open the cabinet door is shown in Table 1. According to the table, the IoT-based helmet storage cabinet product did not encounter any issues with the cabinet door's open and close control system.

Table 1
Response speed of the control system

Average Response (ms)	**Minimum Response (ms)**	**Maximum Response (ms)**
494	19	1742

From the results of the data analysis from the IoT-based helmet storage cabinet with solar panels, it can be concluded that the response speed of the control system when users access the cabinet's door during helmet borrowing and retrieval has an average response time of 494 milliseconds. The longest recorded response time was 1742 milliseconds, while the fastest response time was as quick as 19 milliseconds. Differences in the response times are influenced by the internet speed used by the users and the internet connection utilized by the control system.

The solar panel testing was carried out by monitoring the battery voltage in the morning, afternoon, and evening. This testing was conducted to assess the performance of the solar panels in charging the battery with electrical energy and the battery's use as an energy storage source required by the control system. The test results regarding the solar panel's power input to the battery are shown in Table 2.

Table 2. Monitoring Battery Voltage

No	Voltage (V) on the Solar Charge Control Display				
	08.00	***10.00***	***12.00***	***15.00***	***17.00***
1	13.3	13.4	13.3	13.4	13.3
2	12.8	14.2	13.3	14.0	13.1
3	14.0	13.4	13.4	13.3	13.2
4	13.1	13.4	13.3	13.8	13.4
5	13.3	13.3	13.8	13.3	14.3
6	13.0	13.4	13.2	13.7	13.5
7	13.2	13.3	13.5	13.8	13.4

Based on the test results in Table 2, the smallest recorded battery voltage during the observations was 12.8 V, while the highest recorded voltage was 14.3 V. The battery used in this product has a minimum specification of 10.8 volts and a maximum specification of 14.3 volts. Based on the voltage analysis and the battery specifications, the solar panel can supply electrical energy to the battery, and the battery can serve as the energy source required by the IoT-based helmet storage cabinet's control system when the solar panel cannot supply the battery due to the absence of sunlight.

Battery endurance testing was conducted to determine the battery's ability to store electrical energy required by the control system when the solar panel is not operational. This testing involved monitoring the voltage drop over each hour of use. The test results are shown in Table 3.

Table 3. Battery Endurance Test

Hours	Battery Voltage in Standby Condition (without any user accessing the door)	Battery Voltage Condition (full access)
1	12.8 V	12.6 V
2	12.8 V	12.6 V
3	12.8 V	12.6 V
4	12.8 V	12.5 V
5	12.7 V	12.5 V
6	12.7 V	12.5 V
7	12.8 V	12.6 V

Following of the Table 3, the average battery voltage dropped by 0.1V over a 4-hour standby period. Similarly, the average battery voltage dropped by 0.1V over 3 hours when accessed for helmet borrowing and retrieval by users. The battery used in the IoT-based helmet storage cabinet with solar panels has a specification of 12V with a capacity of 35Ah. The maximum battery voltage is 14.3V, and the minimum is 10.8V. Therefore, the calculation of battery endurance and battery electrical capacity is as follows:

Battery usage in 3 hours = 0,1 V
Battery usage in 1 day = 0,8 V
Maximum Battery = 14,2 V
Minimum Battery = 10,8 V
Battery endurance: (14,2 –10,8)/ 0,8 = 4,25 days = 102 hours

Based on the calculations above, the battery used in the IoT-based helmet storage cabinet can last for 102 hours with full access conditions.

There are 61 users registered in the application and willing to provide feedback via Google Form link. Questionnaires were distributed to students from 4 departments in Polibatam. There were 23 respondents who provided feedback after using the helmet storage cabinet product. 6 people said they had lost their helmets in the parking area before using this product. After using this product, their response showed that this product could reduce helmet loss in the parking lot with 91% agreeing.

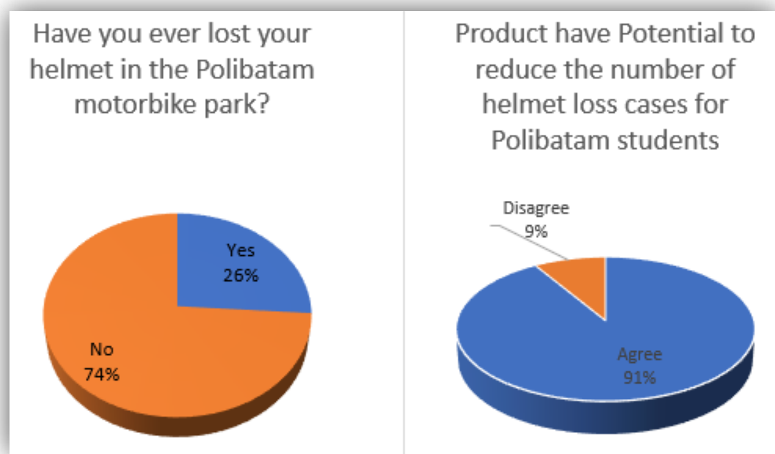

Figure 8. Questionnaire results of Polibatam users

4 Conclusion

The solar panels used as the electrical energy source, stored in the batteries, work very stably, with voltage values ranging from a minimum of 12.8 volts to a maximum of 14.3 volts (Table 1). These voltage fluctuations are influenced by factors such as sunlight intensity and the electrical energy consumption of the control system throughout the day. Battery endurance when the solar panels are unable to generate electrical energy has been calculated. With full access to helmet borrowing and retrieval per day, the batteries are ready to use for 102 hours. This product has a positive response from the user with a result 91% of users agreeing that this product has the potential to reduce helmet loss cases for Polibatam studies.

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