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RESEARCH ARTICLE

Magazine Identification on SS1-V1 Assault Rifle using Web-based HX711 Load Cell Sensor

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Abstract: The SS1-V1 is an assault rifle model that is equipped with a magazine as one of its primary components. The magazine plays a crucial role in the storage and loading of ammunition. However, magazines can be stored separately from weapons, as the integrated storage of the latter can pose a substantial hazard to a country's security. Therefore, it was proposed that a web-based system be capable of identifying the presence of magazines in weapons in real time. The development of such a system is not just a technical advancement, but a crucial step in enhancing national security. The system was constructed using the prototype method and is supported by several hardware components, including a load cell sensor, HX711 sensor module, Arduino UNO R3, and an Ethernet shield for network connectivity. Furthermore, an Application Programming Interface (API) is employed for data management, and stored in a database. The research findings indicate that the average response time for each rack within a cabinet is between 2.7 and 3.3 seconds, while for racks serving as slaves, it ranges from 14.16 to 15.01 seconds. The weight-based weapon identification testing yielded results indicating a weight difference of 0.1 to 0.2 kilograms. The results demonstrate that the web system was able to successfully identify all tests in accordance with the specified weapon conditions on the rack.

Keywords: HX711, load cell, prototype, riffle magazine, SS1-V1, web-based

1 Introduction

For military operations and defense, ammunition is a crucial component, requiring significant investment to arm military forces adequately. However, environmental conditions can reduce the quality of ammunition, causing defects or even explosions [1]. The importance of storing ammunition in optimal conditions, such as in a dry and closed room, will prolong the quality of the ammunition and reduce the possibility of harm.

The SS1-V1 rifle, produced by Indonesia's state-owned arms company, was introduced in 1991. It is the preferred firearm for Indonesian security forces. The SS1-V1 rifle has an empty magazine weight of 4.02 kg and a full magazine (30 rounds) weight of 4.38 kg. The SS1-V1 is capable of firing with great precision up to 400 meters using NATO-standard 5.56 x 45 mm ammunition with a barrel length of 449 mm [2]. Historically, this rifle has also been exported on a limited basis to several other countries.

In Indonesia, military regulations stipulate that weapons must be stored on weapon racks without magazines attached, following Indonesian National Police Regulation Number 8 of 2012 concerning the Supervision and Control of Firearms [3]. However, a potential vulnerability exists in the return of firearms to the rack. Situations in the field often necessitate a prompt response from military personnel, which may not allow sufficient time to ensure that the weapon is not attached to the magazine when stored on the rack. This could lead to accidental discharge or unauthorized use of the weapon, posing a significant risk to personnel and mission success.

To resolve this matter, a proposed system designed to improve the security of weapon storage through the use of sensors to detect the presence of magazines in SS1-V1 assault rifles. A force sensor is a device for converting applied mechanical forces, such as tensile and compressive forces, into signals that can be interpreted [4]. The types of force sensors include strain gauges [5], force sensing resistors [6], optical force sensors [7], ultrasonic force sensors, and load cells [8].

The utilization of load cell sensor technology, capable of discerning an item's weight, provides precise data regarding the presence or status of the item [9]. The HX711 module stands as a 24-bit analog-to-digital converter designed explicitly for use in scales [10] [10]. The implementation of load cell sensors represents a viable solution for identifying magazines on firearms.

As web-based technology continues to evolve, this system is poised to transform into a hardware interface, facilitating real-time data collection and analysis, remote control functionalities, and seamless hardware-software interaction to support a wide array of applications. The integration of HX711 load cell sensor technology with a web-based magazine identification system will help in improving weapon safety. The sensor can determine whether a weapon, such as the SS1-V1 assault rifle, is not on the rack, on the rack with magazines, or on the rack without magazines based on weight detection. The Data is transmitted via the Ethernet shield to the web-based system, thereby ensuring the rapid and secure transfer of information from the hardware to the web platform.

This research makes an important contribution to the field of military weapon storage and security. It offers a new way to ensure regulatory compliance and improve weapon storage security by using HX711 load cell sensors for SS1-V1 assault rifles. The use of load cell sensors in the military context for magazine detection has not been widely applied before. In addition, the development of a web-based monitoring system that provides real-time notifications supports rapid response from military personnel. The system also reduces time and potential errors in the manual checking of magazines, improving operational efficiency and weapon safety. The results of this research are intended to improve the security of weapons storage in the military, and the implementation of this technology will become standard in future military operations.

The remainder of this paper is as follows: Section two provides comprehensive details on the system design and theoretical material. Section three outlines the implementation of the system design to the test scenarios. Section four outlines the discussion regarding the summary of findings, interpretation, and implications of findings, comparison with existing literature, limitations of the study, and suggestions for future research. The final chapter presents the conclusions.

2 Research Method

The research methodology employed is a prototype model, which has been rigorously tested. The methodology consists of a literature review, meticulous system design for magazine identification, and prototype testing with a wide range of situations. The research is then continued with a thorough evaluation of the test results, to reach robust conclusions.

2.1 Literature Review

This study is based on prior research that has emphasized the significance of storing firearms and their corresponding ammunition separately, as this practice can mitigate the risk of misuse and accidents. The dangers posed by storing firearms in an unsecured or loaded condition, both accidentally or intentionally, have been pinpointed as a major concern in firearm safety.

In the military sector, technology is developed to improve the security of a country, including the protection of sensitive assets such as firearms, especially assault rifles. Related research has involved the use of Deep Learning for the classification of weapon types [11], which is relevant for forensic applications in crime analysis based on the type of ammunition used [12]. The identification of firearms can also be achieved through the acoustic signal analysis method [13]. Furthermore, a smart ammunition library management system has also been developed using Raspberry Pi [14].

This study is informed by previous research that has highlighted the importance of storing firearms with their corresponding ammunition [15] separately, as this can help to reduce the risk of misuse and accidents. The risk of both accidental and deliberate injury caused by storing firearms in an unsecured or loaded state has been identified as a significant concern in firearm safety [16]. Explosive experiments have been conducted inside magazines using small quantities of explosives and small-sized ammunition storage to investigate this issue further [17]. Furthermore, the absence of secure firearm storage among military personnel has prompted the creation of alerts to increase awareness regarding the significance of safe firearm storage [18].

In light of the aforementioned issues, there is a clear requirement for the development of sensors capable of accurately identifying the presence of magazines on firearms. Range types of potential sensor types can be considered; however, load cell sensors are particularly well-suited to the task, offering the advantage of being able to withstand external environmental conditions [19], thereby making them an ideal choice for military applications. The effectiveness of load cell sensors in detecting load sizes across a range of applications has been well-documented [20].

Previous research has employed 5 kg strain gauge load cell sensors and HX711 A/D converters as weight sensors for the measurement of food waste [21]. Another study investigated the performance of load cell sensors in weighing a range of items, including rice, packages, and fruits, to assess their efficiency and accuracy in object identification [22]. Additionally, load cell sensors have been employed to classify a variety of objects, as exemplified by their use in automatic fruit sorting [23]. In the military domain, load cell sensors have been utilized in smart medical applications [24] and in monitoring the environment and health of military personnel [25].

Alternative boards that support data transmission features include the Node MCU [26], the Arduino GSM Shield [27], the Arduino WIFI Shield [28], and the Ethernet Shield [29]. The ethernet shield is a suitable communication method for maintaining security, as it can be utilized on the local network [30]. The use of an Ethernet Shield as a link between the system and the local network or the Internet allows communication and data exchange [31].

The development of web-based systems for identifying the number of enemy aircraft available on the battlefield based on real-time image data is currently underway [32]. An Internet of Things-based ammunition warehouse monitoring system has been developed by this research to lessen the chance of fire [33]. Another study has developed a system to track ammunition allocation for security agencies using HTML, CSS, PHP, and JavaScript [34].

The utilization of research on web-based systems and the constituent technology components serves to reinforce the robustness and efficacy of the underlying infrastructure. The utilization of REST API (Representational State Transfer Application Programming Interface) enables web-based systems to communicate with servers via HTTP, thereby facilitating data exchange and integration between diverse services and platforms [35]. In this system, data security is ensured through the employment of MD5 hashing, which generates a distinctive 128-bit hash value for each data set, thus facilitating the detection of unauthorized alterations or data manipulation [36].

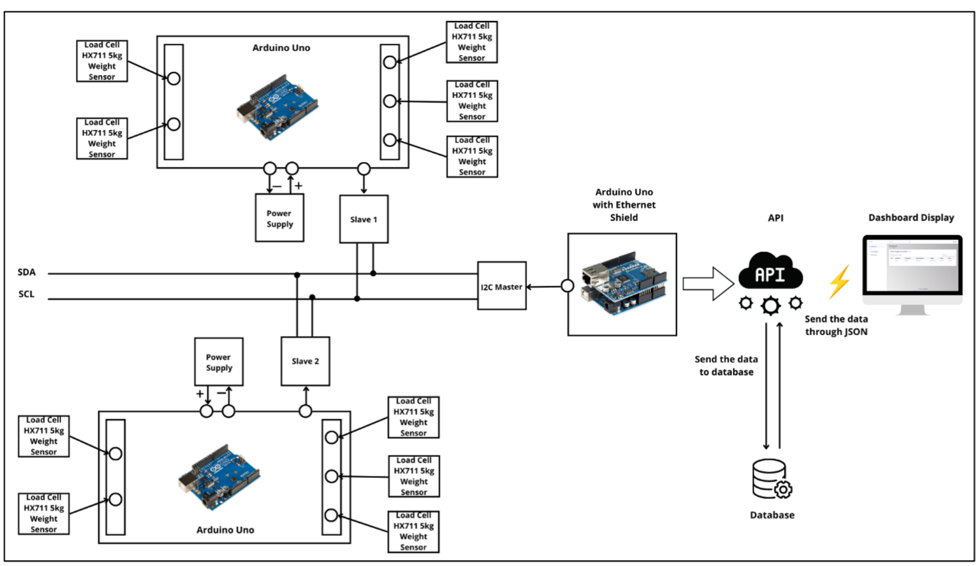


Figure 1: System block diagram.

The objective of this study is to develop a system for multiple military weapon racks, with a particular focus on enhancing the security of weapon storage. Previous research has introduced a multi-cabinet locker system to provide safe storage in public areas [37]. However, this system's methodology is not capable of providing real-time web-based cabinet information. This research has the potential to significantly improve the safety and security of weapon storage in the military sector.

2.2 Proposed System Design

The design of the proposed system represents the advanced literature study stage, as illustrated in Figure 1. The system comprises two slave modules, each of which manages 5 load cell sensors that can measure up to 5kg and are connected to HX711. Each slave module is equipped with an Arduino, which collects weight data from the load cell sensors connected to it and transmits this data to the master Arduino. The Arduino Uno on the slave module functions as a local data manager for the load cell sensors, measuring the weight and sending the data via I2C communication.

The Arduino Uno on the master, which is equipped with an Ethernet Shield, serves as the primary controller in this system. As the master in the I2C communication, the Arduino Uno controls the data flow from both slave modules, requesting and receiving weight data from each slave module. It also manages the overall system operation, including data processing and transmission to the server.

The connection between the master and slaves utilizes the I2C communication protocol, which is employed for data exchange among the microcontroller devices. I2C communication on Arduino uses only two pins: SDA (Serial Data Line) and SCL (Serial Clock Line), reducing wiring complexity. The use of I2C communication facilitates system modifications for expansion, with the clock controlling data transmission.

The Arduino Uno is employed for the processing of all load cell sensor data. The HX711 module serves as an intermediary between the load cell sensor and the microcontroller. The HX711 load cell sensor module is utilized for the identification of magazines on firearms in real-time. The process of identifying firearm magazines is based on the load cell sensor values, which are used to determine whether the stored firearm is equipped with a magazine or not. The determination is made by comparing the current weight reading with a predefined weight range for a magazine.

Following this, the HX711 load cell sensor module is strategically positioned at the base of the weapon rack to accurately measure the weight of the SS1-V1 assault rifle, as illustrated in Figure 2. This placement ensures the sensor effectively detects and quantifies the weight applied to the support, providing essential data for subsequent analysis or necessary adjustments. The load cell sensors used in this system, with a maximum capacity of 5 kg, ensure precise measurements according to the weight range of the SS1-V1 assault rifle.

The use of Ethernet Shield LAN W5100 is employed in this system to facilitate communication between the microcontroller and the local network. By leveraging the local network connection, data transmitted by the microcontroller to the server is safeguarded within a controlled and secure environment. The local network offers an additional layer of security as access to data can be restricted solely to users or devices with appropriate access permissions.

The microcontroller can transmit sensor data directly to the server via the Application Programming Interface (API) via an Ethernet connection. The aforementioned API

Figure 2: Load cell sensor position.

serves as a communication interface, thereby enabling interaction and efficient information exchange between the microcontroller and the server. Furthermore, the utilization of a database enables the structured and secure storage of sensor data received by the server. The stored data can then be accessed and analyzed by users with ease. Within the proposed system, MD5 hashing is implemented during the data transmission procedure to improve the security of web-based communication. By employing MD hashing, the system maintains a secure environment for military weapon management applications.

As illustrated in Figure 3, the system is operational upon the initiation of the Arduino microcontroller. The microcontroller then proceeds to read all sensor data. Upon the placement of the weapon on the rack, the load cell sensor detects its weight and outputs a resistance value. This value is subsequently calibrated into a weight measurement in kilograms. The weight measurement in kilograms is interpreted into three discrete states designed as 0, 1, and 2, respectively, based on the weight ranges. If the load cell sensor detects a weight of less than 3.5 kg, the status is 0, which indicates that the weapon is out of the system, and a red lamp indicator will be activated. If the load cell sensor detects a weapon weight exceeding 3.5 kg but not exceeding 4.01 kg, the status is designated as 1, signifying that the weapon is placed without a magazine. This is accompanied by the activation of a green lamp indicator. Conversely, if the load cell sensor detects a weight exceeding 4.02 kg, the status is designated as 2, signifying that the weapon is placed with a magazine. This is accompanied by the activation of a yellow lamp indicator. Subsequently, the status is read and transmitted to the server via an Ethernet shield utilizing the local network. The API will then manage this data and store it in the database. Users can monitor the weapon status in real time by accessing the corresponding web page. This real-time monitoring capability ensures that information about the weapon status can be accessed with ease and in a timely manner, thus ensuring effective monitoring.

The website has been developed using the Hypertext Preprocessor (PHP) programming language with the Laravel framework. Visual Studio Code has been employed as the software for the development of this site, as it is capable of supporting basic web scripts, including CSS, JavaScript, and the PHP programming language. The display on the website can be seen in Figure 4.

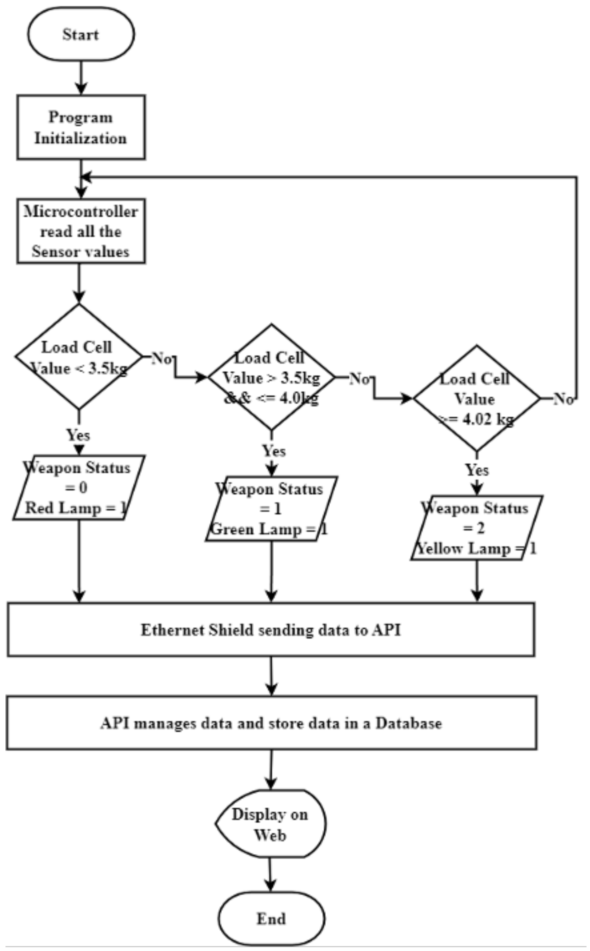


Figure 3: The flowchart system works.

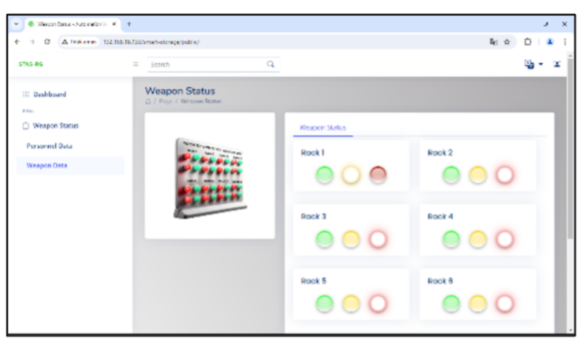


Figure 4: Display on the website.

2.3 Experiments

A testing scenario was conducted in the Research Laboratory to evaluate the proposed system. This testing included response time testing and black box web testing. In response time testing, the system was tested 30 times. Meanwhile, black box web testing involved checking the web display for each status sent, ensuring that it conformed to expectations.

According to the proposed system design, the load cell sensor is placed at the bottom of the rack, based on Figure 5. This test involves the weapon's entry and exit with or without a magazine on the rack. The data obtained from the load cell sensor is then recorded for subsequent analysis to ensure the success of this project.

Figure 5: Implementation of load cell sensor on the system.

3 Results

The findings were evaluated using the previously stated test scenarios. The test results were reported following the success of magazine detection, as measured by response time and the system's response to monitoring on the website display.

3.1 Results of Response Time Testing

In this study, response time testing involves calculating the time required for sensor data transmission until it is displayed on the web. This test was conducted 30 times, resulting in an average data transmission response time under different conditions.

The testing was conducted on a single rack with two scenarios: SS1-V1 with the magazine inserted into the rack and SS1-V1 with the magazine removed from the rack. Both scenarios entail calculating the response time required to read the status and display the notification on the web page. The response time is expressed in seconds.

The results of the testing, as presented in Table 1, indicate that the average response time from the moment the weapon is removed from the rack until the notification is displayed on the web page is 2.7 seconds. The mean response time for the weapon with a magazine inserted into the rack and notification displayed on the web page was 3.3 seconds. In

Table 1: Test response time for one rack

No	Testing Scenario	Response Time (s)		
		Average	Min	Max
1.	SS1-V1 with magazine inserted into Rack	3.3	1.7	5.26
2.	SS1-V1 is not in Rack	2.71	0.31	4.57

comparison, the longest time taken for the detection process was between 4.57 and 5.26 seconds. This was due to the time required to process the transmission of the weapon weight data, which is then stored in the database before being displayed on the web with the appropriate status.

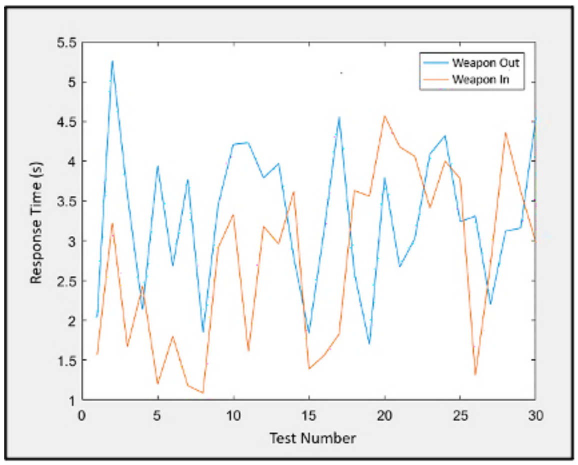


Figure 6: MATLAB graph of response time test results.

The graph in Figure 6 illustrates the system's response time in the fast scenario. It shows the response time of the process when a weapon with a magazine is placed in the rack, measured, and detected, and then the weapon is subsequently removed. The system's response time during the weapon removal is calculated. The graph clearly shows a significant difference in the time taken for a status change when the weapon is removed and when the weapon is inserted, with an average time difference of 1.22 seconds. This difference is crucial as it underscores the system's ability to quickly adapt to changes in the rack's status.

Furthermore, the magazine identification system was tested on multiple weapon racks functioning as slaves, with the potential for expansion to accommodate hundreds of racks. The experiment was conducted to measure the response time of status changes on rack Slave 1 and rack Slave 2. The experiment was repeated 30 times to acquire an average value. The test results can be seen in Table 2.

The test results show that the average response time from placing the weapon with the magazine into rack Slave 1 to displaying the notification on the web is 14.16 seconds. The minimum response time recorded was 4.79 seconds, while the maximum response time was 22.89 seconds. The average response time for the weapon to be inserted into the rack Slave 2 and the notification to be displayed on the web is 15.01 seconds, with a minimum of

Table 2: Response time results for master rack and slave rack

No	Testing Scenario	Time	Response Time (s)		
			Average	Min	Max
1.	Rack in Slave 1	Time in	14.16	4.79	22.89
2.	Rack in Slave 2	Time in	15.01	6.74	23.38

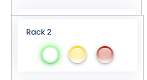
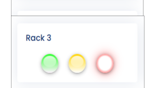
6.74 seconds and a maximum of 23.38 seconds. The slave rack is relatively time-consuming because it necessitates the transmission of data to the master and the subsequent transmission to the web.

3.2 Web and Load Cell Testing Results

The web-based application form magazine identification on the SS1-V1 was tested using the Black Box method, a testing approach that focuses on the system's external behavior without considering its internal structure. The results of this testing, presented in Table 3, demonstrate the system's performance under various load conditions. The load cell, which measures the weight of the rifle and indicates if a magazine is installed, was used to provide additional information about the system's status.

Web and load cell testing was conducted on four weapon racks concurrently, with varying test scenarios. On Rack 1, weapons with magazines were placed into the rack. On Rack 2, weapons without magazines were placed into the rack. Subsequently, the weapon was removed from Rack 3. Finally, the weapon equipped with the magazine was stored in Rack 4.

Table 3: Web testing using black box

No.	Testing Scenario	Load Cell Status (kg)	Output
1.	SS1-V1 with Magazine into Rack 1	4.20	
2.	SS1-V1 without Magazine into Rack 2	3.95	
3.	SS1-V1 not in Rack 3	0.10	
4.	SS1-V1 with Magazine into Rack 1	4.45	

As can be seen in Table 3, the monitoring results confirm the system's correct functioning in all four scenarios. When a weapon with a magazine is placed in Rack 1, the status indicator activates the yellow light while the other lights remain off. This indicates that the weapon is still loaded and that the magazine needs to be removed.

Upon the insertion of a weapon lacking a magazine into Rack 2, the green lamp indicator is activated, while the other lamp indicator remains deactivated. The presence of the green lamp indicator signifies that the weapon is securely stored and may be placed in the rack. Moreover, when Rack 3 is devoid of any weaponry, the red lamp indicator is illuminated while the remaining lamps are extinguished. This signifies that the weapon is not currently accessible within the rack. Ultimately, upon the return of a weapon with a magazine to Rack 4, the status indicator and yellow lamp indicator are activated, indicating that the magazine should be promptly removed from the weapon and that the in Rack 1 should be observed.

Under the conditions described, the system can provide accurate and timely information, and the load cell's performance can provide data that is in line with the actual situation in the rack. The load cell's ability to accurately measure the weight of the rifle, both with and without a magazine, is demonstrated in the graphical representation labeled Figure 7.

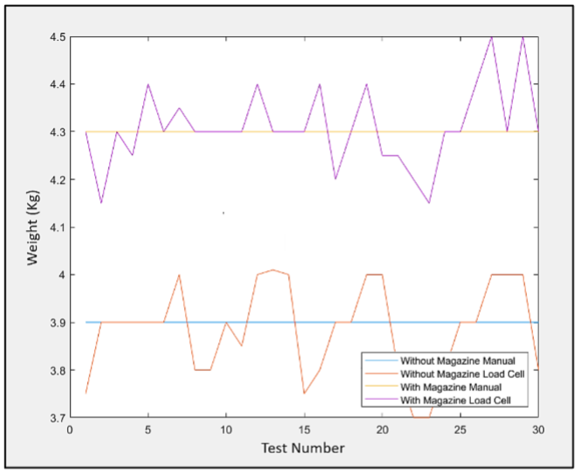


Figure 7: MATLAB graph of load cell comparison.

As illustrated in Figure 7, the manual measurement of the weight of a rifle without a magazine is 3.9 kg. The weight value of the rifle without a magazine measured by the Load Cell shows a more significant variation than that of the manual measurement. The weight ranged from about 3.6 kg to 4.1 kg. For comparison, the weight of a rifle with a magazine loaded with 30 bullets measured manually is 4.3 kg. Meanwhile, using the load cell sensor showed a weight ranging from 4.2 kg to 4.6 kg.

The experiment was conducted sequentially 30 times, which indicated inconsistency between the weight measurements obtained from the load cell measurements on the rack. The system was not affected by the variation, as it only produced a range of 0.1 kg to 0.2 kg. Variations in weight measurement values can be caused by sensor calibration, as well as weapon placement that affects the weight distribution captured by the load cell.

4 Discussion

This research introduces a novel magazine identification system for SS1-V1 assault rifles, utilizing the HX711 load cell sensor and web-based technology. The system's effectiveness in providing rapid and accurate information regarding the presence of magazines on the rifle, with a web interface that displays the status according to the condition of the rifle. The load cell sensor's ability to measure the rifle's weight with minimal variation ensures precise magazine detection, thereby enhancing the operational effectiveness of military personnel.

The results of this study demonstrate the potential to significantly enhance the operational capabilities of military personnel. By providing accurate and real-time information on the status of magazines, the developed system can greatly improve situational awareness, support decision-making in the field, and enhance the effectiveness and safety of military operations. The application of the HX711 load cell sensor in a security environment showcases the flexibility of the sensor, and its integration with web-based technologies expands the potential application of the Internet of Things (IoT) in a military context.

The proposed system is in line with previous studies on weapon security, such as the use of Deep Learning technology for weapon classification [11], which in the future is likely to be used in weapon clustering in warehouses, as well as web-based system web-based systems for ammunition management that only detects humidity and temperature in warehouses [14]. However, this research extends the existing literature by focusing on magazine detection using load cell sensors, an area that has not been extensively researched before. This novel approach to weapon security management sets this research apart and provides a unique contribution to the field. Other studies have applied load cell sensor applications for weight measurement of food and general objects [21, 22], whereas this study integrates this technology in a real-time weapon monitoring system, providing innovation in weapon security management.

It's important to note that while the system has shown effectiveness in a controlled environment, some limitations need to be addressed. These include the accuracy of the load cell sensor which can be affected by the weapon's placement on the rack and the system's scalability, which can impact the response time to weapon status changes. Further testing in field situations is necessary to fully understand the system's performance.

For future research, the test with 25 racks was completed in less than 1 minute; the scale is still considered small for wider use. So further development is needed for a larger scale, especially in the design of the relationship between master and slave to reduce response time and improve efficiency. In addition, the application of the Kalman Filter in load cell calibration to reduce noise in sensor data and the integration of face recognition technology can be an additional layer of security.

Based on the above discussion, this system has significant practical implications. It can contribute to identifying magazines on web-based weapons in real-time, making it easier for military personnel to check the presence of weapons and improve weapon security. The system also contributes to improving the efficiency and responsiveness of military personnel by providing information in emergencies, which can minimize risks related to weapon safety. These findings not only apply theories regarding the use of load cell sensors and web technologies in the context of security but also extend and refine those theories by demonstrating effective practical applications in military operations.

5 Conclusion

This research has successfully developed a prototype magazine identification system for the SS1-V1 assault rifle using the HX711 load cell sensor and web-based technology. The system is meticulously designed to swiftly and accurately provide data on the presence of magazines on the rifle. It does so through a web interface that consistently displays the status, ensuring the rifle's condition is always known.

The system was subjected to a series of tests to assess its accuracy and rapidity in providing information. The test was conducted by testing the response time when the system detects a change in weapon status and displays the results on the web page. The test results demonstrate that the response time on a weapon rack for detection when the weapon is inserted into the rack is about 3.3 seconds, while when the weapon is removed from the rack is about 2.7 seconds. In addition, the system was tested on multiple weapon racks, Slave 1 rack, and Slave 2 rack. The average response time when a weapon with a magazine is placed on the rack in Slave 1 is about 14.16 seconds, while the result of testing the response time in Slave 2 is about 15.01 seconds.

The web interface, purposefully developed for this system, successfully integrates data from load cell sensors with clear and informative visualizations. Testing using the Black Box method confirms that the web interface displays the weapon's status based on the presence of the magazine. The test results indicate that the system is capable of correctly distinguishing between weapons with magazines installed, weapons without magazines, and weapons not in the rack, as indicated by the corresponding indicator lights on the web interface.

During testing, weight discrepancies between 0.1 and 0.2 kg were observed due to the inherent instability of the load cell sensor. Nevertheless, the system was able to accurately identify the weapon status based on the data received from the sensor, despite minor variations in weight measurements.

This research significantly contributes to simplifying the process for military personnel to verify the presence of a magazine on the rifle. The system also contributes to enhancing the efficiency and responsiveness of military personnel, particularly in emergencies, by providing rapid and accurate information in emergencies, thereby reducing risks related to weapon safety.

It's important to note that while this approach remains susceptible to limitations when a rack at the slave undergoes alterations in weapon status, the system has shown great potential for future improvements. Further enhancements are necessary in the domain of data transmission. For future research, this system can be improved to optimize data transmission from the slave. In particular, optimizing the communication protocols and enhancing the reliability of data transfer will be pivotal areas of attention. Apply Kalman Filter in load cell calibration to reduce noise in sensor data. Furthermore, the integration of supplementary security technologies, such as facial recognition, can be investigated to reinforce the system holistically.

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