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Analysis of Gunshot Sensors and Buzzers on Bulletproof Vests in Real Time Based on Internet of Things (IoT)

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INDEXING	ABSTRACT
Keywords: Keyword 1 : Shot Detection Keyword 2 : Impact of Censorship Keyword 3 : Shot Buzzer Keyword 4 : Security Monitoring Keyword 5 : IoT	This research develops a prototype of an Internet of Things-based bulletproof vest that can monitor heart rate and detect gunshots in real time. The test results show that the shot impact sensor has a detection accuracy of 98.5%, the installed heart rate sensor has a sensitivity of 96%, and a notch condition detection accuracy of 95%. The recorded data sending time to the web server was 5.936 seconds, with an average waiting time between 5.5 and 6.3 seconds. Once a dangerous condition is detected, a sound notification will be sent via the buzzer within 0.7 seconds. Overall, this system provides accurate and efficient information on personnel conditions, which is expected to assist in faster tactical responses in field situations.

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INTRODUCTION

Over the years, advances in technology and science have make work easier. Even though several areas still use analog technology, technological advances have entered the digital era (Ciarli *et al*, 2021 ; Nelson *et al*, 2023). Eventually, all devices will be digital-based, which will make things easier to do. Digital-based technology has been widely used in the military world today (Kilag *et al*, 2022). For example, you can control bullets remotely by pressing buttons on a computer or a remote control that allows the drone to spy and even fire (Kreps, 2016).

Conflicts that occur in Papua often cause casualties. Based on the Central Statistics Agency (BPS), in 2018 there were 447 conflict incidents in Papua (Ardiansah *et al*., 2022). Quoted from Papua.news, throughout 2021, 92 shooting cases were recorded. This incident resulted in 44 people dying, 15 of whom were TNI members (Evarukdijati, 2021). The Indonesian National Army (TNI) has the main responsibility to protect the territory of the Unitary State of the Republic of Indonesia from various disturbances and security threats, both from within and from outside. According to (UU No. 17 of 2011, n.d.) concerning State Intelligence, several types of domestic security threats are mentioned, including acts of terrorism and conflict. Based on the Global Firepower (GFP) index, Indonesia is in the top 15 strongest militaries in the world. Indonesia is ranked 13th below Brazil (Umam, n.d.).

The KKB attack injured people other than TNI members. In Beoge District, Puncak Regency, Papu, in March 2022, 8 people died as a result of being attacked by KKB while repairing Telkomsel's Tower Base Transceiver (BTS) 3. To deal with acts of terrorism, the TNI will send a special team or a joint team from three dimensions to normalize and rescue victims or hostages. In carrying out the tasks carried out by the TNI AD, of course, they must be equipped with various military skills which will later be able to support their main duties as TNI AD (Adi *et al.*, 2022). Bulletproof vests are one of the combat equipment used by TNI personnel during military operations. The combat vest is part of the body protection equipment that is always worn by TNI personnel during military operations. Combat vests not only serve as equipment for military operations; they can also be used to store items such as grenades, bullets, HT, flashlights, compasses, and drinking water bottles (Prayogi, 2019). Currently, combat vests are only equipped with bulletproof plates which function to protect the body from enemy fire. During security control and supervision, the personnel on duty still use a manual system, namely radio/HT communication. However, this system has a weakness, namely that it can only find out the condition of personnel via voice messages. As a result, personnel on duty must always communicate via radio to provide information about every situation in the field. The preparedness of soldiers to carry out their duties in the field is a crucial element in maintaining security and military operational effectiveness (Sianturi, *et al*., 2024).

It does not rule out the possibility that military members are injured or injured while fighting with the enemy. The loss of military personnel minimizes material and personnel losses (Kurniawan *et al*., 2025). In this condition, the commander at the monitoring post cannot quickly supervise the personnel on duty because any changes in the situation can only be communicated via radio communication. If radio communications are disrupted, the commander cannot know the condition of the personnel and can hamper the delivery of assistance such as medical teams and aid teams if personnel are injured. Personal Protective Equipment (PPE) has important value in protecting their safety and increasing combat effectiveness (Hu *et al.*, 2023). Of course, the features currently available in combat vests are not enough to support military operational tasks. As far as the author knows, there are no combat vests equipped with modern technology such as tracking personnel status and personnel health online. Therefore, the author carried out technological innovation to improve the quality of bulletproof vests. The aim of using this technology is to reduce the number of casualties experienced by the community and military members in conflict-prone areas. Personnel safety is a top priority (Duwila *et al*., 2024).

The author proposes an innovative bulletproof vest equipped with a gunshot sensor and a feature to monitor the stability of the personnel's heart rate. Thus, the commander at the post can monitor the condition of personnel who are normal or dead through the personnel's heart rate indicator. In this way, commanders can find out whether personnel have been shot or not through sensors designed on bulletproof vests. Commanders can send medical teams and relief troops quickly if a conflict occurs or personnel are in danger. Therefore, the author plans to propose a research title, namely "Analysis of Gunshot Sensors and Buzzers in Bulletproof Vests in Real Time Based on the Internet of Things (IoT)".

RESEARCH METHOD

A. Research methods

This research uses an experimental method to prove the hypothesis through a designed program. The quality of the design can be determined by testing the program regularly to get accurate and good results.

1. Flowcharts

   The following is a flowchart of the designed tool system

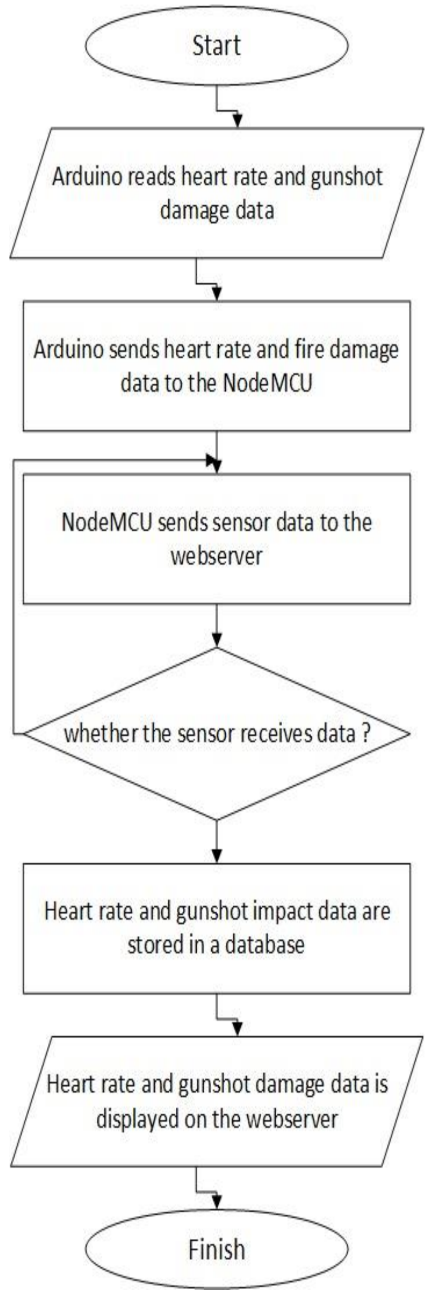


Figure 1. System Flowchart
Source: Processed by Researchers, 2024

1. Planning Shot Impact Sensor and Buzzer

The gunshot sensor is designed using copper cables arranged in series in such a way on the front and back of the vest. The copper cable will be connected to the Arduino nano microcontroller and ESP8266 nodeMCU. The stages of designing a gunshot sensor start from winding a cable measuring 100 m x 0.5 mm on an acrylic medium measuring 15 cm x 25 cm. The ankle cable coils on the acrylic medium are arranged as tightly as possible to obtain maximum research results. The way this sensor works is that if the vest is shot, the copper cable circuit will be disconnected so that the Arduino nano microcontroller will send information to the web server that the personnel has been shot.

The interface system circuit for the gunshot impact sensor adopts a push button circuit. The shooting impact sensor circuit was modified by removing the push button and replacing it with a coil of copper cable according to the design designed by the researcher. An overview of the push button circuit and the gunshot sensor circuit is shown in Figures 2 and 3.

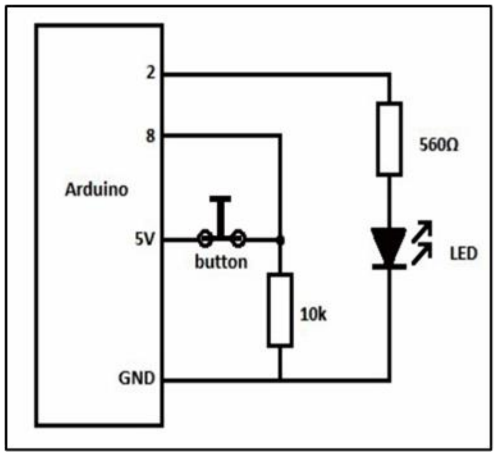


Figure 2. Push Button Circuit Scheme

Source: Processed by Researchers, 2024

Based on Figure 2, is a schematic of a push-button circuit connected to an Arduino microcontroller to turn on an LED. The way the push button circuit scheme works is that when the push button is pressed, pin 8 will be connected to a voltage of 5 V so that it can turn on an LED, otherwise if the push button is not pressed then 8 will not receive a voltage of 5 V so pin 8 will be connected to ground so that LED does not light up. With this analogy, the firing sensor design scheme adopts the working principle of a push button. The design scheme for the gunshot sensor is shown in Figure 3.

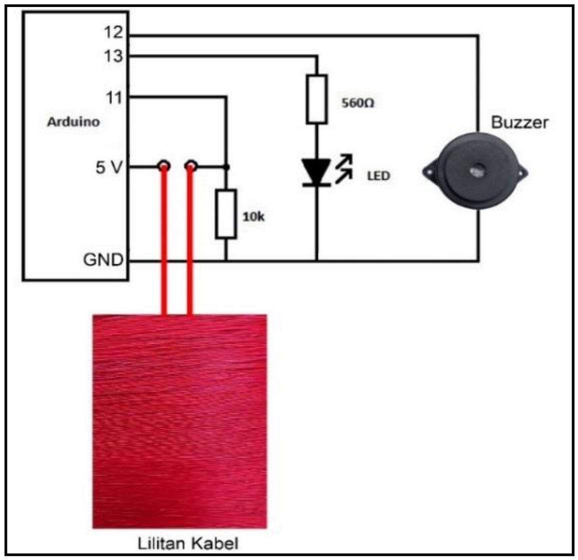


Figure 3. Shot Sensor Design Scheme

Source: Processed by Researchers, 2024

Based on Figure 3, there is a schematic for designing a gunshot sensor that is connected to pin 11 on the Arduino nano microcontroller to turn on the LED. The workings of the firing sensor which adopts the push button working principle is that the cable coils are arranged in series as tightly as possible on the front and back of the vest. When the cable coils are connected, pin 11 will be connected to a voltage of 5 V so that the LED lights up which means whether the condition is safe or not. is shot and the buzzer will not sound, on the other hand, when the cable winding is broken then pin 11 will not receive 5 V voltage so pin 11 will be connected to the ground so that the LED does not light up which is interpreted as a shot condition and will activate the buzzer sound. shot.

Software design flowchart is the flow of how the system works starting from sensors reading data, and processing data to system output results. The design flow for the gunshot sensor software design is shown in Figure 4.

Figure 4. Flowchart of Shot Sensor and Buzzer Software

Source: Processed by Researchers, 2024

The flow of designing the gunshot sensor software starts with connecting the Arduino Nano with a coil of gunshot sensor cable. Next, the system will take sensor measurements. Sensor measurements will be entered on the firing sensor variable or cable winding. The variable will select 2 conditions, namely the "safe" condition and the "shot" condition. If the firing sensor variable is detected to have a voltage of 5V or the cable coil remains connected, the system initializes it as a "safe" condition so that the buzzer does not sound. Meanwhile, if the firing sensor variable is detected to have a voltage of 0 V or the cable winding is broken, the system initializes it as a "dead" condition so that the buzzer will sound like a gunshot. After going through the condition selection process, the system will send the firing sensor variable data to the web server, then the firing sensor variable will be saved as a database and the output of the firing sensor data system will be displayed on the web server layout.

2. Bulletproof Vest Design

Figure 5. Pulse Sensor Design
Source: Processed by Researchers, 2024

Figure 6. Shot Sensor Design
Source: Processed by Researchers, 2024

Bulletproof vests which are supported by heart rate stability and personnel fire damage monitoring features are integrated with several components, namely the sim808 GPS module, Arduino Nano, NodeMCU ESP8266, IP Camera, USB Modem Router, Pulse sensor, and gunshot impact sensor. However, the author does not discuss the Sim808 GPS module and IP camera. The author focuses the discussion on pulse sensors and gunshot impact sensors.

RESULT AND DISCUSSION

Result

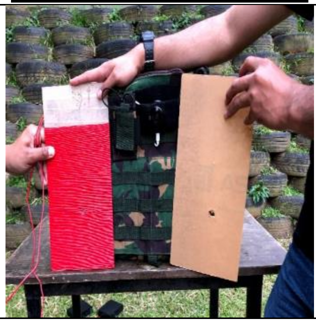
A. Testing of Shot Sensors and Buzzers

This test was carried out to determine the performance of the gunshot sensor in reading the condition of personnel who were shot or not and to test the buzzer notification when personnel were shot or were safe.

1. Shot Intent Sensor Testing

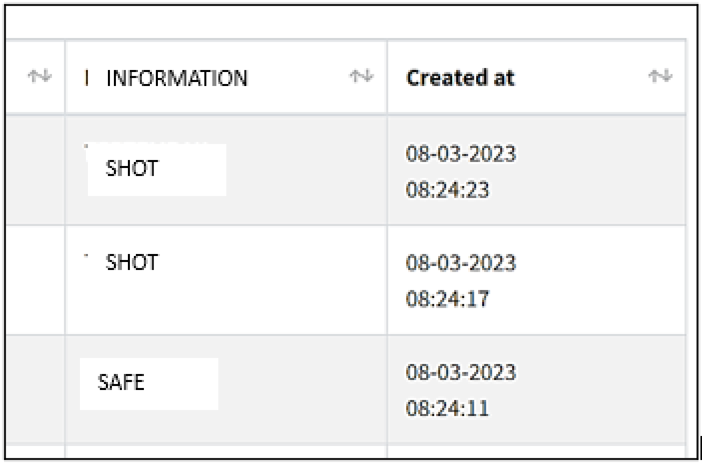
At the testing stage, the firing sensor starts from the firing sensor in the form of a cable winding that will be disconnected and connected. If the cable condition is disconnected, it will indicate that the personnel is in a "shot" condition and if the cable condition is connected, it will indicate that the personnel is in a non-shot/"safe" condition. The results of the fire detection sensor test are shown in Table 1.

Table 1. Gunshot Impact Sensor Indicator

It	Indicators	Connected/ Disconnected Cables	Information
1	Safe/Not Shot	Connected Cables	
2	Shot	Broken Cables	

Source: Processed by Researcher, 2024

The test of the firing sensor was carried out using an air softgun at a distance of 30 meters. The first test is carried out by keeping the cable connected, it will identify whether personnel are in a safe state or not shot. In the second test, it was carried out by firing test so that the cable circuit was broken. When the cable circuit is disconnected, it will identify that the personnel are in a state of being shot. The web server display of the fire sensor data is shown in Figure 7.



	INFORMATION	Created at
	SHOT	08-03-2023 08:24:23
	SHOT	08-03-2023 08:24:17
	SAFE	08-03-2023 08:24:11

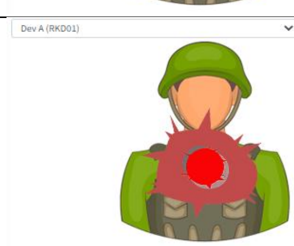
Figure 7. Shot Intent Data Web Server View
Source: Processed by Researcher, 2024

2\. *Buzzer Testing*

In this test, observation of the buzzer sound was carried out to determine the performance of the sound notification on the web server when the personnel were shot. If the personnel are in a state of being shot, the web server that has been accessed will emit a gunshot sound. A picture of the personnel shot will appear indicating that there are personnel who have been shot on the front or back of the vest, but if the buzzer is not active / does not make a gunshot sound, it can be interpreted that the personnel are in a safe condition or no personnel have been shot. The test table for the notification of personnel being shot is shown in Table 3.

The following is a table of testing the notification of personnel being shot.

Table 2. Testing Personnel Shot Notification

It	Personnel Conditions	Picture on Web Server	Buzzer (Sound on Web Server)
1.	Safe/Not Shot		No Sound
2.	Shot		Gunshot Sound

Source: Processed by Researchers, 2024

B. Overall Circuit Testing

The overall test is carried out to be able to find out whether the system embedded in the bulletproof vest can work as expected, while the stages of the overall series test include the overall series test, data transmission test, and data transmission delay test.

a. Overall Range Testing

The overall series test is carried out by combining the results of the designed system so that the tool designed by the researcher can work as expected. The results of the overall series test are shown in Table 3.

Table 3. Overall Range Test Results

It	*Pulse sensor*	Shot Sensors	Condition	Status	*Buzzer*
1.	123 BPM	Connected	Tachycardia/Elevated	Safe	No Sound
2.	91 BPM	Connected	Usual	Safe	No Sound
3.	43 BPM	Disconnected	Bradycardia/Decline	Shot	Sound
4.	110 BPM	Connected	Tachycardia/Elevated	Safe	No Sound
5.	122 BPM	Connected	Tachycardia/Elevated	Safe	No Sound
6.	89 BPM	Connected	Usual	Safe	No Sound
7.	74 BPM	Connected	Usual	Safe	No Sound
8.	124 BPM	Connected	Tachycardia/Elevated	Safe	No Sound
9.	106 BPM	Connected	Tachycardia/Elevated	Safe	No Sound
10.	0 BPM	Disconnected	Die	Shot	Sound

Source: Processed by Researcher, 2023

a. Testing of Transmission of Heart Rate Data and Personnel Shot Detection to Web Server

This test was carried out to find out whether the system embedded in the bulletproof vest could work as expected, namely sending heart rate data and personnel fire coverage to the web server. This test starts from the system on which the vest is run and then shown on the serial monitor in the Arduino IDE application and checks if there are "200" and "301" code notifications. If there is a "200" notification, it can be interpreted that the heart rate data and the firing of personnel have been successfully sent to *the* web server. However, if there is a "301" code notification, it can be interpreted that the data sent was not successfully received by the web server. The display showing successful or unsuccessful delivery is shown in Figure 8 and Figure 9.

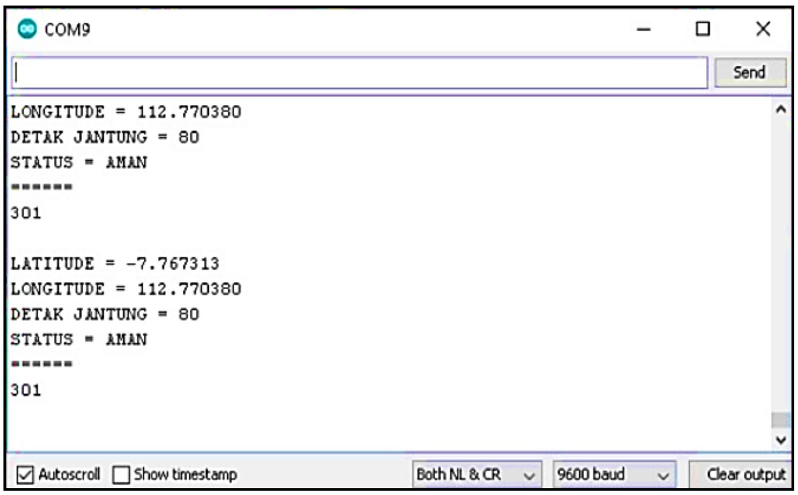


Figure 8.Display Data Sent with Code 200
Source: Processed by Researcher, 2024

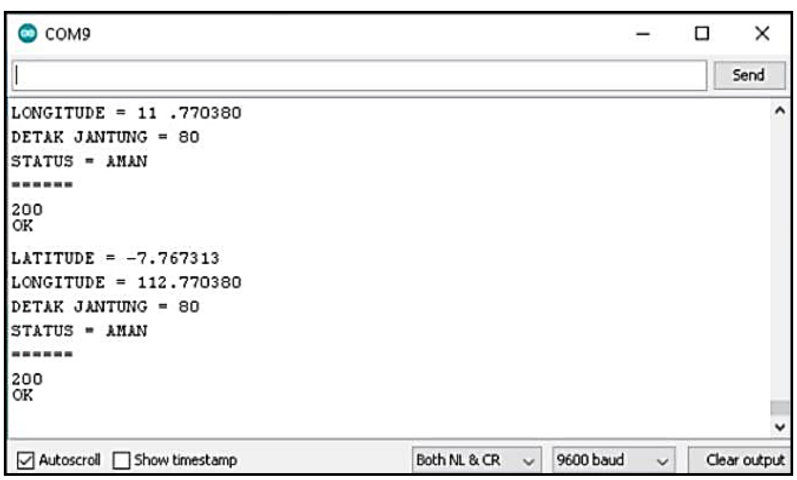
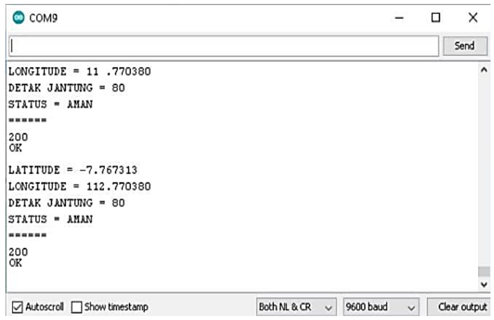
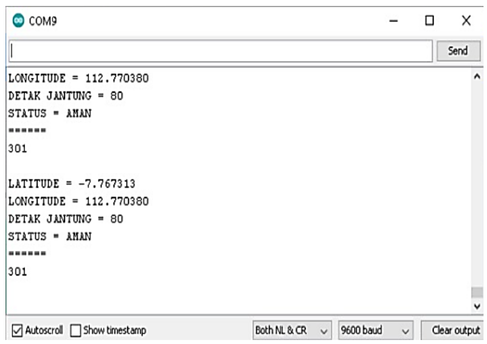


Figure 9. Display Data Not Sent with Code 301
Source: Discussed by Researchers, 2024

The following are the results of the data transmission test from the serial display of the IDE Arduino monitor shown in Table 4

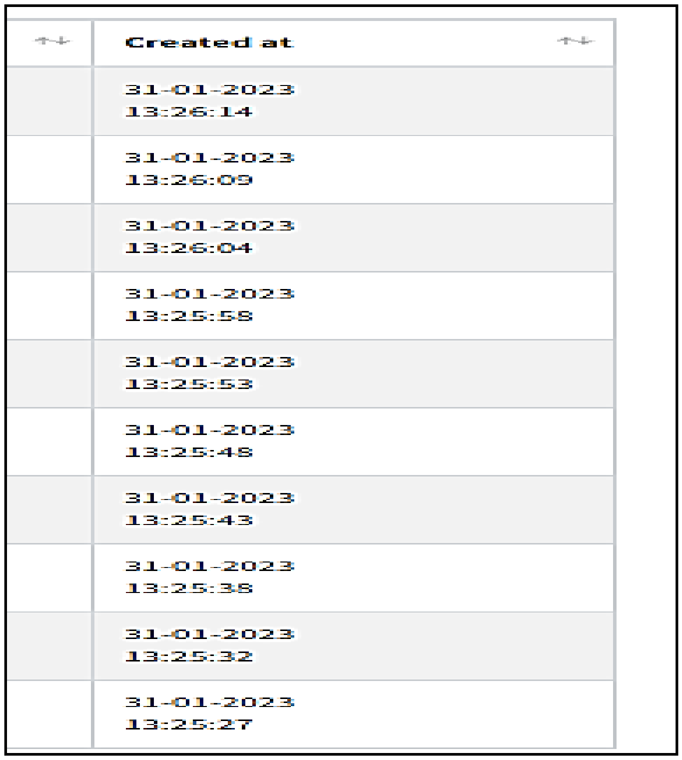
Table 4. Data Delivery Testing

1		Data Sent Code : 200
2		Data Not Sent Code : 301

Source: Processed by Researcher, 2024

b. Delay Testing of Heart Rate Data Transmission and Personnel Shooting Intent

This test was carried out to determine *the delay* in sending heart rate data and the firing of personnel. This test starts with the system embedded in the bulletproof vest being run and then observes how long the *delay* of sending heart rate and shot detection data to the web server. The observation of this delay time is carried out by analyzing the "created at" display, which is a column representing the clock and date of the last data received by the web server. The "created at" column is shown in Figure 10.



	Created at
	31-01-2023 13:26:14
	31-01-2023 13:26:09
	31-01-2023 13:26:04
	31-01-2023 13:25:58
	31-01-2023 13:25:53
	31-01-2023 13:25:48
	31-01-2023 13:25:43
	31-01-2023 13:25:38
	31-01-2023 13:25:32
	31-01-2023 13:25:27

Figure 10. Created at Column Display on Web Server
Source: Processed by Researcher, 2024

In the delay test, the transmission of heart rate and shot detection data was carried out using 10 data samples displayed on the web server display shown in Figure 5 The results of the delay test of heart rate and shot detection data transmission are shown in Table 5.

Table 5. Test Results of *Delay* in Transmission of Heart Rate and Shooting Data

It	*Created* at	Time required
1	13:26:14	5.58 seconds
2	13:26:09	5.75 seconds
3	13:26:04	6.25 seconds
4	13:25:58	5.06 seconds

Table 5. Continued

5	13:25:53	5.98 seconds
6	13:25:48	5.96 seconds
7	13:25:43	5.44 seconds
8	13:25:38	6.36 seconds
9	13:25:32	5.95 seconds
10	13:25:27	7.03 seconds
	Average	**5,936 seconds**

Source: Processed by Researcher, 2023

Based on table 5. Delay testing of heart rate and shot detection data transmission using the parameter "created at" or data transmission time using a sample of 10 tests in cloudy weather, it can be concluded that the weather can affect the speed of the internet so that it can hinder the process of sending data which requires an internet network. The formula for calculating the average delay of data transmission is shown in the following equation.

$$average\ delay = \frac{Total\ Data\ Amount}{Number\ of\ Tests} \ldots\ldots\ldots\ldots (4.4)$$

$$average\ delay = \frac{5{,}58 + 5{,}75 + 5{,}25 + 5{,}06 + 5{,}98 + 5{,}96 + 5{,}44 + 6{,}36 + 5{,}95 + 7{,}03}{10}$$

$$average\ delay = \frac{59{,}63}{10}$$

$$average\ delay = 5{,}936\ seconds$$

c. Web Server Layout Design Testing

The web server layout is a medium used to display the results of the overall output of the designed tool system, the web server layout is made to make it easier for the troop commander to know the condition of the personnel through the output of each processed data so that the overall data will be sent and displayed on the web server layout. The web server display is shown in Figure 11.

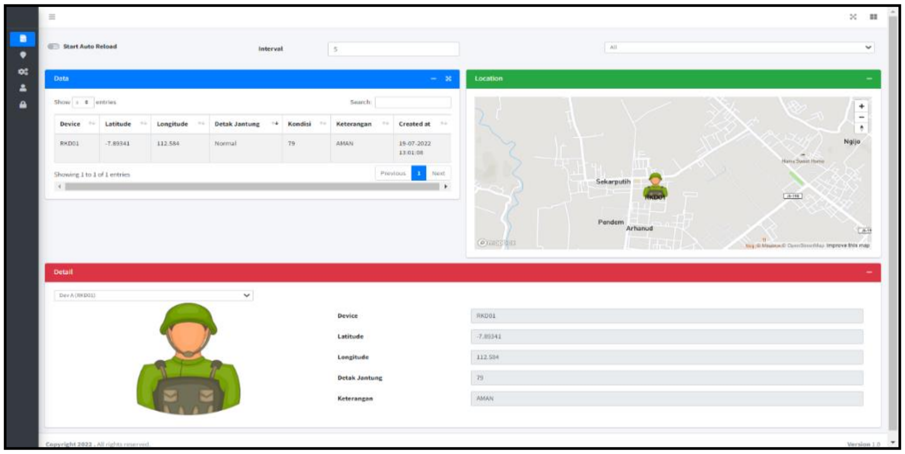


Figure 11. Web Server Layout View
Source: Processed by Researcher, 2024

The web server layout designed by the researcher has several system outputs or parameters including device, longitude, latitude, heart rate, condition, description, and created at. The following are the steps on how to access the web server layout.

1) Open google and type the domain name according to the web server address, which http://bmsrompirkd.link/auth

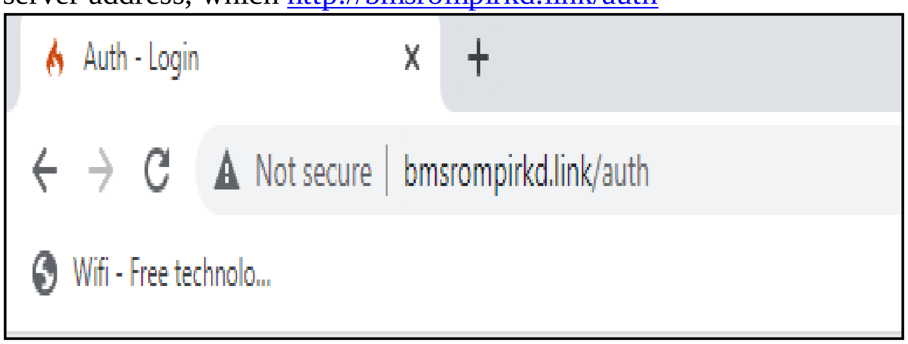


Figure 12. Web Server Address
Source: Processed by Researcher, 2024

2) After that, the web server login display will appear as shown in the following image.

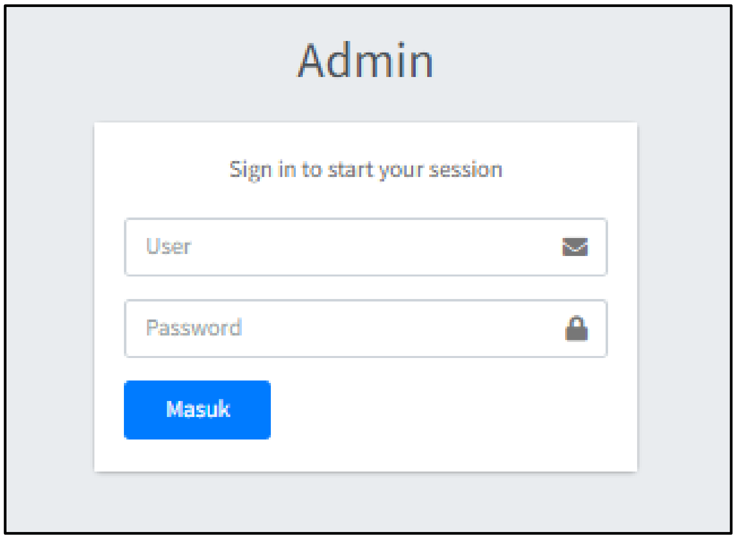


Figure 13. Web Server Login View
Source: Processed by Researcher, 2024

3) To be able to access *the webserver*, fill in the "admin" *user* and *password* "123456" fields shown in the following image.

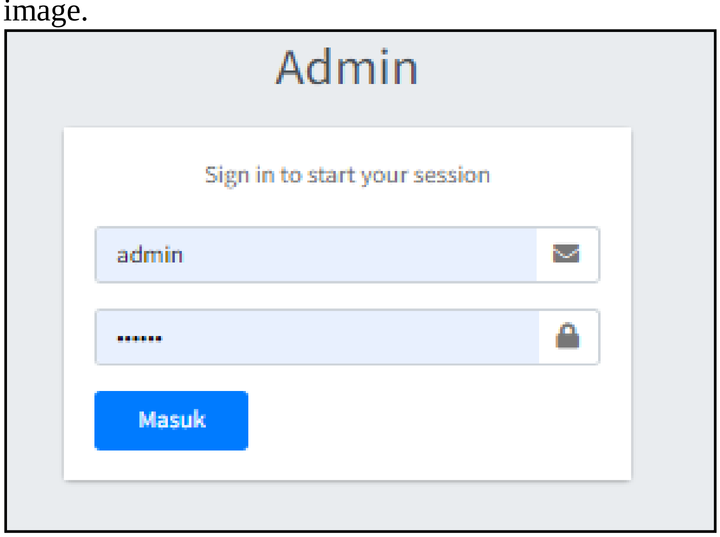


Figure 14. User and *Password* Column Display
Source: Processed by Researcher, 2024

4) Next, a web server layout display will appear

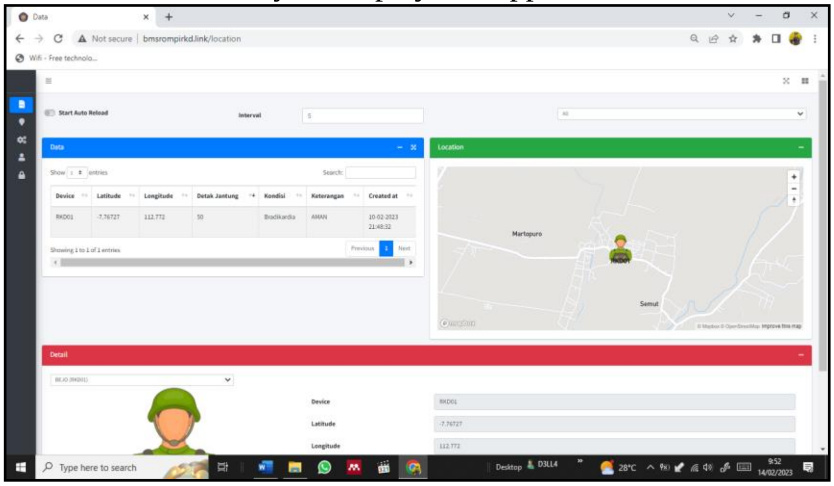


Figure 15. Web Server Layout Display Results
Source: Processed by Researcher, 2024

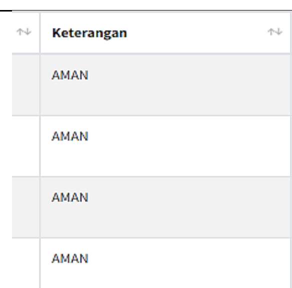
Discussion

A. Discussion of Shooting Sensors and Buzzers

1. Discussion of Shooting Sensors

At this stage, the researcher designed a shot detection sensor using ankle cables that are wound in series on acrylic media and placed on the front and back of the vest. The parameters used in this test are connected and disconnected cables. The test of the reading of the gunfire was carried out several times with a sample of 2 indicators, namely safe and shot conditions. In testing the condition of being shot, the researcher conducted a test shot using an air softgun-type sniper weapon at a distance of 25 meters. In the safe condition test, it is analogous to the way the cable winding is connected, so that the cable winding will still receive a voltage of 5 Volt which will produce *the output* of the system with a safe/non-shot indicator while the test of safe condition parameters is shown in Table 6.

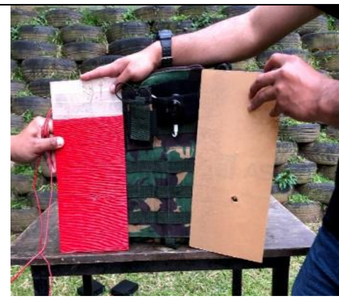
Table 6. Safe Condition Fire Sensor Testing

It	Indicators	Connected/ Disconnected Cables	Information	Web Server
1	Safe	Connected Cables		 Keterangan AMAN AMAN AMAN AMAN

Source: Processed by Researcher, 2024

Furthermore, the test of the shot condition is analogous to the way the cable winding is disconnected, so that the cable winding will not receive voltage which will produce the output of the system with the shot indicator while the test parameters for the reading of the shot with the shot condition are shown in Table 7.

Table 7. Shot Sensor Testing

It	Indicators	Connected/ Disconnected Cables	Information	Web Server
1	Shot	Broken Cables		

Source: Processed by Researcher, 2023

2. *Buzzer Discussion*

At this stage, the results of testing the notification of personnel being shot on the web server will be described. The series of shooting sensors designed by the researcher is equipped with a buzzer feature that will be connected to a web server with 2 indicators, namely the sound of gunshots and a picture of personnel. The concept of a series of fire sensors and buzzers is shown in Figure 16.

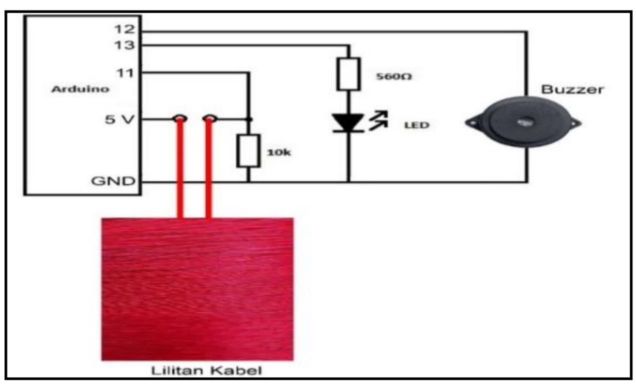


Figure 16. Firing Sensor and *buzzer* series
Source: Processed by Researcher, 2024

Based on Figure 10. It is explained that when the cable winding on the vest is connected, pin 11 will be connected with a voltage of 5 V so that it can turn on the LED which is interpreted as a safe condition, then the web server will not emit a gunshot sound and the picture of the personnel is shown in Table 8.

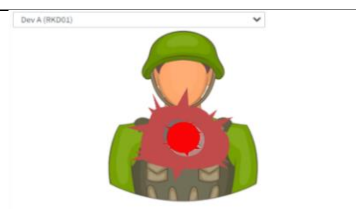
Table 8. Safe or Non-Shot Notification Display

It	Personnel Conditions	Picture on Web Server	Buzzer (Sound on Web Server)
1.	Safe/Not Shot		No sound

Source: Processed by Researchers, 2024

Furthermore, when the cable winding on the vest is disconnected or not connected, pin 11 will not receive the 5 V voltage so that pin 11 will be connected to the ground so that the LED does not light up which is interpreted as a shot condition, then the web server will make the sound of a gunshot and the picture of the personnel will change to being shot which means shown in table 9.

Table 9. Shot Notification Display

It	Personnel Conditions	Picture on Web Server	Buzzer (Sound on Web Server)
1.	Shot		Sound

Source: Processed by Researchers, 2024

B. Discussion of the Overall Series

1. Discussion of the Overall Series

   Discussion of the overall circuit to synchronize input and output. The researcher used 10 data samples to test the overall circuit shown in Table 4.6. In the first test, the pulse sensor value was found to be 123 BPM with the condition "tachycardia/increasing", so it can be concluded that the pulse sensor system designed by researchers can work accurately according to the initial design. Furthermore, testing the firing sensor with the cable connected indicated that the status was "safe" and the buzzer did not sound, so it could be concluded that the firing sensor system could work accurately. Furthermore, in the final test, the pulse sensor value was found to be 0 BPM with the condition "dead", and testing the firing sensor with the cable disconnected informed the status of "shot" and the buzzer sounded, so it could be concluded that the pulse sensor and firing impact system could work accurately.

2. Discussion of sending heartbeat data and personnel shooting to the web server

At this stage, the results of testing for sending heartbeat data and exposure to personnel fire to the web server will be described, which are categorized into 2 conditions, namely conditions when the NodeMCU is connected to the wireless router and conditions when the NodeMCU is not connected to the wireless router. Connectivity between the NodeMCU ESP8266 and the wireless router is a supporting factor in being able to connect to the internet network, this plays a very important role in sending sensor output data. If the NodeMCU ESP8266 is not connected to the wireless router, certainly, data cannot be sent and the server will not receive sensors marked with the code "301" on the Arduino IDE serial monitor. Meanwhile, if the NodeMCU ESP8266 is connected to a wireless router, it can be ensured that the sensor output data can be sent and received by the server marked with the code "200" on the Arduino IDE serial monitor, so it can be concluded that the factors that influence the transmission of heart rate data and personnel fire damage are found in connectivity between NodeMCU ESP8266 and wireless router.

3. Test Results for Delay in Sending Heartbeat Data and Personnel Shot Impact

At this stage the researcher analyzes the delay time through the created column on the web server, which is the date when the data was sent, assisted by using a stopwatch measuring tool starting from the active sensor until the created data is displayed on the web server. In this test, the researcher used 10 data samples displayed on the web server with details of the initial test data delivery time, which was sent at 13:25:27 until the last data was sent at 13:26:14. The researcher tested the delivery delay time by calculating the difference between the first and second tests. To increase the accuracy value, the researcher used a stopwatch as a tool to measure the data delivery delay time.

In the first data it is explained that the data was sent at 13:26:14 and the second data was sent at 13:26:09. Researchers measured the delay time by calculating the difference value from the second and first tests, resulting in a time of 5 seconds. The researchers also tested the first and second data delays using a stopwatch starting from the activation of the sensor until the data was sent to the web server and obtained a delay value of 5.58 seconds. Next, the researchers tested the delay value using 10 sample data and obtained an average delay of 5.936 seconds.

4. Discussion of Web Server Layout Design

The web server designed by the researcher is a medium for displaying overall data information from the system output which includes the device name, longitude, latitude, heart rate, condition, and created at, based on some of the system output data the researcher focuses on discussing heart rate data and gunshot impact output results. How to access the web server start by opening Google and then typing the domain name according to the web server address, namely "http://bmsrompirkd.link/auth", after the web server display appears which includes the user and password, fill in the user column "admin" and password "123456 ” so that the web server layout display will appear. The web server display consists of several indicators that support the features of the bulletproof vest, including the GPS output results, namely longitude and latitude, the output results from the heart rate, namely the normal condition of death, the heart rate increases and decreases, the output results from gunfire, namely being shot and safe, and created at is the date when the data was sent.

CONCLUSION

A. Through shooting tests, it can be concluded that the gunshot sensor can operate accurately by providing 2 indicators, namely safe conditions and being shot. When the cable coil is shot and disconnected, it will inform the web server with the statement "Shot", whereas when the sensor remains connected it will inform the web server with the statement "Safe".

B. The results of reading heartbeats and gunshots will be displayed on the base monitoring system by accessing the web server via the domain www.bmsrompirkd.link. The condition for successful data transmission lies in the connectivity between the NodeMCU and the router which must always be connected to the internet so that data transmission can be successful and received. by the web server so that data can be displayed on the web server layout.

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