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Ultrasonic Sensor-Based Automatic System for Indonesian Army Physical Fitness Training

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INDEXING	ABSTRACT
Keywords: Keyword 1 : Ultrasonic Sensor Keyword 2 : Physical Fitness Training Keyword 3 : Automated System	Physical fitness is an important factor in supporting the performance and physical readiness of Indonesian Army members. Fitness exercises such as pull-ups and shuttle runs are often used to measure fitness levels. However, manual measurements that have been carried out so far have the potential to cause human error and are less efficient in terms of time and accuracy. To overcome these obstacles, this study aims to develop an automatic system based on ultrasonic sensors that can detect and calculate fitness activities in real-time. The system is designed by integrating ultrasonic sensors to detect changes in distance generated by body movements during pull-ups and shuttle runs. Data from the sensors is processed by a microcontroller to calculate the number of pull-up repetitions or shuttle run travel time. The calculation results are displayed on the LCD screen, providing ease of monitoring and recording data. The research methodology includes hardware design, microcontroller-based software development, and system testing to measure its accuracy and reliability. The test results show that this system has an accuracy of up to 96% in detecting pull-up movements and 94% in measuring shuttle run time. In addition, this system speeds up the fitness evaluation process by eliminating the need for manual calculations. With the implementation of this automated system, physical fitness training in the Indonesian Army environment can be carried out more efficiently, measurably, and accurately. This technology also has the potential to be applied to other fitness activities to support the modernization of physical evaluation in military institutions.

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INTRODUCTION

Physical fitness is a vital component in supporting the operational readiness and performance of TNI AD members. As part of a military institution, TNI AD prioritizes measurable physical training to maintain the strength, endurance, and toughness of its members (Akbar *et al*., 2024). Activities such as pull-ups and shuttle runs have long been used as standard methods for evaluating physical fitness. However, manual measurements used in these exercises are often inefficient and prone to human error, which can affect the validity of the evaluation results (Gumantan *et al*., 2021).

Technological advances provide opportunities to address these challenges through automation. One promising technology is ultrasonic sensors, which have the ability to detect movement and distance changes with high accuracy (Hadi *et al*., 2020). The use of ultrasonic sensors allows for automatic calculation of physical activity, thereby increasing the efficiency of the evaluation process. With the integration of this technology, physical fitness training can be done more quickly, accurately, and consistently (Amin, 2020).

This research aims to develop an automatic system based on ultrasonic sensors that can detect and calculate pull-up and shuttle run activities in real-time (Anugrarista *et al*., 2022). This system is designed to provide precise measurement results through integrated hardware and software. The data obtained will be displayed directly, making it easier for instructors or trainers to monitor and analyze performance (Sabik and Rahayu, 2022).

In addition to improving accuracy, this system is also expected to reduce the instructor's workload and optimize the training implementation time. With more measurable data, the evaluation of the physical fitness of TNI AD members can be carried out more objectively and transparently. This is important to support a more effective physical training program that is relevant to the operational needs of the TNI AD (Dita *et al*., 2021).

The application of this technology is also an initial step towards modernizing physical training in military institutions. The success of this system can open up opportunities for further development of other fitness activities, not only in the Indonesian Army environment but also in other institutions that prioritize physical fitness (Purboyo *et al*., 2024). Thus, this research contributes to the development of automation-based physical fitness-supporting technologies.

LITERATURE REVIEW

The use of ultrasonic sensor technology has been widely applied in various fields, especially those that require precise distance and movement detection. Ultrasonic sensors work by utilizing high-frequency sound waves to detect objects around them (Asmi *et al*., 2020). This technology is often used in robotics applications, industrial automation, and medical devices because of its advantages in measuring distance with high accuracy and without direct contact with the object. In the context of physical fitness, ultrasonic sensors can be used to detect human body movements, such as during physical exercise, making it an ideal tool to support automation systems for measuring fitness activities.

Previous studies have shown that the use of ultrasonic sensors in fitness activities has yielded promising results. For example, in calculating repetitions of exercises such as push-ups and sit-ups, this sensor can detect changes in distance due to body movement in real-time. The developed system based on ultrasonic sensors has been shown to improve calculation accuracy while reducing manual workload. In addition, this sensor also has advantages in terms of response speed and durability, making it suitable for application in dynamic and repetitive physical exercise environments (Aditia *et al*., 2022).

Microcontrollers are key components in ultrasonic sensor-based automation systems. This device functions to process data from sensors and convert it into understandable output, such as displaying the number of repetitions or travel time. Arduino and Raspberry Pi are some of the microcontroller platforms that are often used because of their ease of programming and flexibility in hardware integration. Previous studies have shown that the combination of ultrasonic sensors with a microcontroller is capable of producing an automatic counting system that is efficient, accurate, and easy to operate (Kraus, 2016).

In the military context, the modernization of physical fitness equipment is an urgent need to support personnel performance. The application of ultrasonic sensor-based automation technology in the military environment, such as the Indonesian Army, is expected to provide a solution to the challenges in the fitness evaluation process which has so far been carried out manually. This technology not only has the potential to increase measurement accuracy but also provides more objective data for individual performance analysis. Therefore, this study focuses on the development of an ultrasonic sensor-based automated system to support physical fitness training in the Indonesian Army environment as a step to modernize and improve the efficiency of physical training (Mahfud *et al*., 2020).

RESEARCH METHODS

Figure 1 shows the research method proposed by the study.

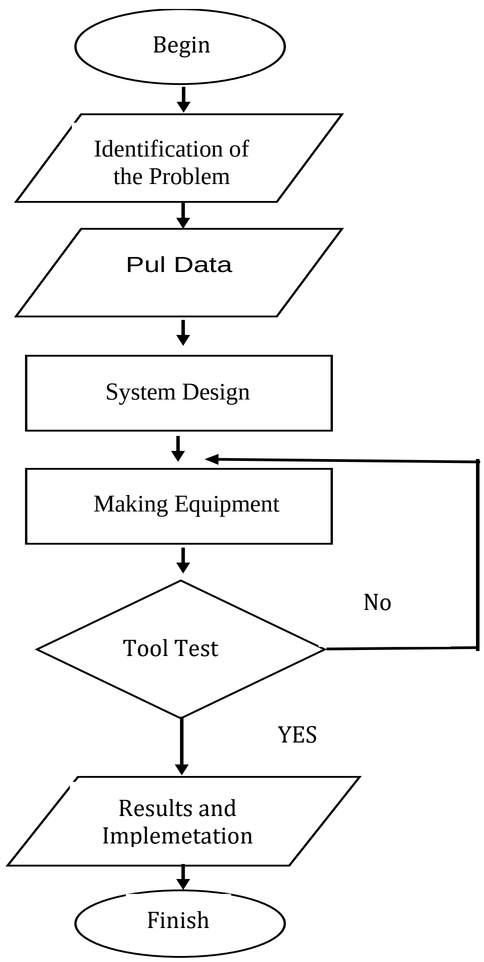

Figure 1. Research Flow Chart
(Source : Author, 2024)

The initial step of the research is very important, namely reading related literature, as shown in Figure 1. The initial step of the research begins with problem identification. This stage aims to understand the main problems that will be solved in the research, such as how to create an automatic system based on ultrasonic sensors to support physical fitness training. This process involves analyzing user needs, research objectives, and the scope of the problem (Riskiono *et al*., 2020).

Once the problem is identified, the next step is data collection (Pull Data). The data collected includes technical information related to ultrasonic sensors, characteristics of the movements to be detected (such as pull-ups and shuttle runs), and references for automatic system designs. This data is obtained from literature, initial experiments, or direct observations, which will be the basis for designing the system (Sudrajat and Rofifah, 2023).

The next stage is system design, where the overall structure of the tool is designed by considering the data that has been collected. This design includes the selection of ultrasonic sensors, microcontroller architecture, data processing algorithms, and integration between hardware and software. The design process is carried out iteratively to ensure that the tool can function properly according to needs (Pratama *et al*., 2022)

After the system design is complete, the research enters the tool-making phase. At this stage, all components that have been designed are integrated into one complete system. The tool that is made will be tested to ensure that each component functions properly and according to its purpose.

The next stage is the tool test, where the system that has been created is thoroughly evaluated. If the system fails to meet the criteria or experiences problems, then the process returns to the tool improvement stage until the system functions according to specifications. If the test results show success, the research continues to the next stage.

The final step is the results and implementation, where the tools that have been successfully tested are applied to real scenarios. The implementation results are then analyzed to ensure the effectiveness of the system in supporting the TNI AD physical fitness training. Thus, this study contributes to the development of automation-based physical fitness technology.

Design

The following is the block diagram that we made:

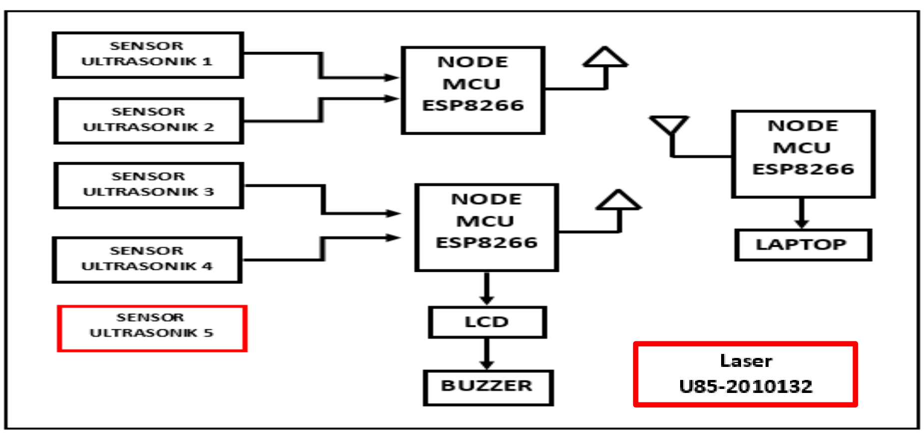

Figure 2. Block Diagram
(Source : Author, 2024)

The main tools needed are NodeMCU ESP8266, Ultrasonic sensor, 128x64 graphic LCD, buzzer and Arduino IDE. Each part has the following functions:

- The NodeMCU ESP8266 serves as the main microcontroller that integrates all components. In addition, NodeMCU supports Wi-Fi connectivity, allowing training data such as the number of repetitions or travel time to be sent to other devices, such as smartphones or servers, for further analysis.

- Ultrasonic Sensor: Used to detect changes in distance during physical activity, such as pull-ups or shuttle runs. This sensor emits ultrasonic waves and measures the reflection time to determine the user's precise position or movement.
- 128x64 Graphic LCD: Used to display real-time training information in a clearer and more informative format, such as a progress graph, number of repetitions, or time. This LCD supports more complex data visualization than a regular LCD screen.
- Buzzer: Provides audible notifications to provide feedback to the user. For example, a buzzer sounds every time a pull-up rep is counted, or to signal the end of a training session.
- Arduino IDE: Is a programming software used to write, upload, and test code on the NodeMCU ESP8266. By using the Arduino IDE, programs to control sensors, LCDs, and buzzers can be developed and optimized as needed.

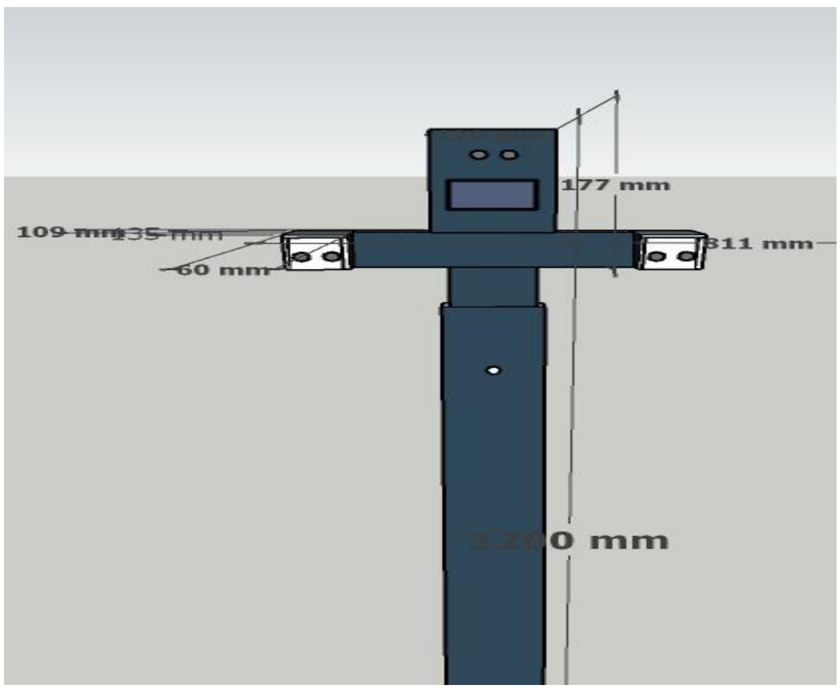

Figure 3. Tool Design
(Source : Author, 2024)

This automated system is designed to support physical fitness exercises such as pull-ups and shuttle runs. During exercise, ultrasonic sensors detect user movements based on changes in distance. These sensors send distance data to the NodeMCU ESP8266 as a data processing center.

The NodeMCU ESP8266 processes the data received from the ultrasonic sensor to calculate the number of repetitions (in pull-up exercises) or travel time (in shuttle runs). The results of these calculations are then displayed in real-time on a 128x64 Graphic LCD in numeric or graphical format, making it easier for users to monitor their performance during training.

The buzzer is used to provide audio notifications to the user. For example, the buzzer sounds every time a pull-up rep is counted or when the workout time is over. This provides immediate feedback to the user without having to constantly look at the LCD screen.

This system was developed using Arduino IDE to program NodeMCU and set the operational logic, including data processing from ultrasonic sensors, LCD display control, and notification settings via buzzer. The system can also be further developed by utilizing Wi-Fi connectivity from NodeMCU to send training data to a server or other device for analysis or storage purposes

RESULTS AND DISCUSSION

The test results show that the system with ultrasonic sensors has been tested 10 times using 6 different distance variations. This test aims to evaluate the accuracy of the sensor in detecting objects at a certain distance. From the test, it is known that at a distance of 65 cm, the ultrasonic sensor can detect objects well and provide accurate results. This shows that the system can work optimally under certain conditions according to the specified distance specifications.

However, when the detection distance exceeds 65 cm, an error occurs in the measurement. The sensor no longer provides consistent results, reducing its reliability in detecting objects at a greater distance. This can be caused by limitations in the ultrasonic sensor specifications or environmental interference, such as irregular sound reflections. Based on these results, it can be concluded that the ultrasonic sensor used in the system has a limited detection distance, and further evaluation or adjustment is needed to improve its performance at a greater distance. These are the results:

Figure 4. Ultrasonic Sensor Test Results
(Source: Designer, 2024)

From the results of the distance test in Figure 4.7 above, it can be explained that the distance of 25 cm to 65 cm the sensor can read with a 100% success rate. The following are the results of the 65 cm and 70 cm distance tests on the Arduino IDE serial monitor shown in Figures 4.8 and 4.9 as follows:

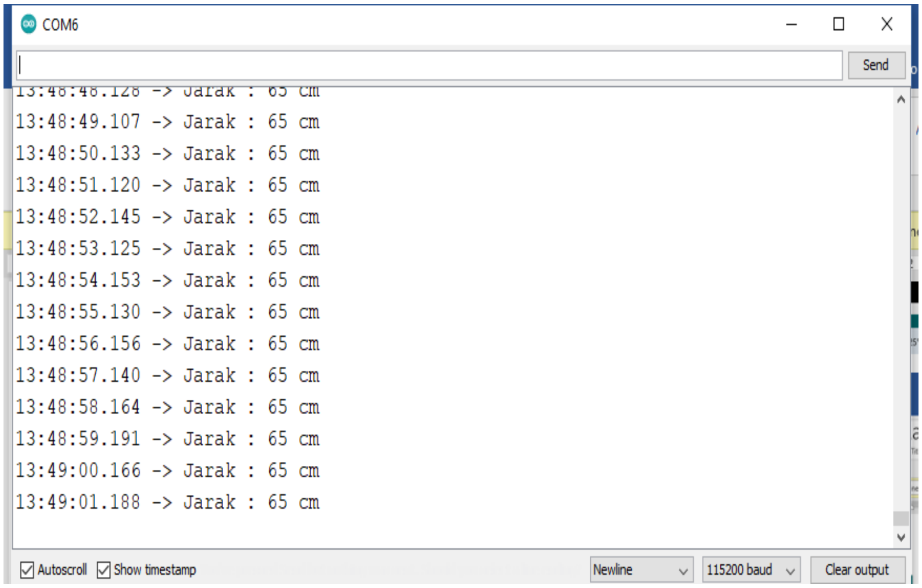

Figure 5. Result of 65 cm distance test on serial monitor (Source: Designer, 2024)

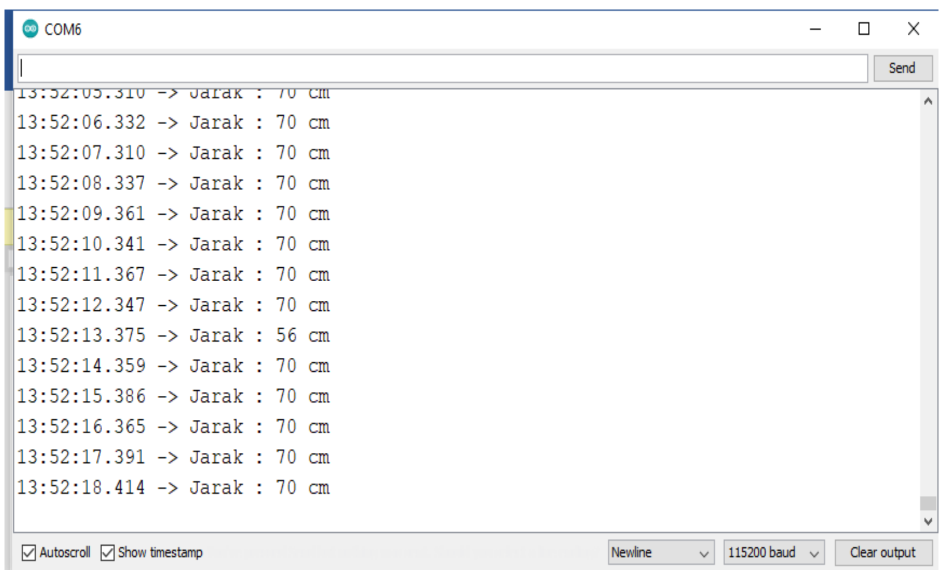

Figure 6. Result of 70 cm distance test on serial monitor (Source: Designer, 2024)

Table 1.Table of Results of Data Waiting Time To Be Sent

No.	Distance					
	25 cm	35 cm	45 cm	55 cm	65 cm	70 cm
1.	Detected	Detected	Detected	Detected	Detected	Detected
2.	Detected	Detected	Detected	Detected	Detected	Detected
3.	Detected	Detected	Detected	Detected	Detected	Detected
4.	Detected	Detected	Detected	Detected	Detected	Detected
5.	Detected	Detected	Detected	Detected	Detected	Detected
6.	Detected	Detected	Detected	Detected	Detected	Detected
7.	Detected	Detected	Detected	Detected	Detected	Detected
8.	Detected	Detected	Detected	Detected	Detected	Detected
9.	Detected	Detected	Detected	Detected	Detected	Not detected
10.	Detected	Detected	Detected	Detected	Detected	Detected

In the table above, it can be seen that testing has been carried out with different distances and the following percentage success results have been obtained:

Success rate $= \frac{\text{Number of Success}}{\text{Number of Experiments}}\ x\ 100\%$

Success rate$= \frac{59}{60} x\ 100\%$

= 98.3%

So from the results of the ultrasonic sensor reading test, an error of 1.2% can be presented.

CONCLUSION

Ultrasonic sensor-based systems can improve efficiency and accuracy in monitoring physical activity during fitness training. These sensors allow for automatic and real-time measurement of distance, speed, or number of repetitions, so that training results are more measurable. With this technology, fitness training can be tailored to individual and group needs more objectively, supporting the improvement of the physical readiness of Indonesian Army soldiers. This automated system reduces the need for manual supervision by instructors, allowing greater focus on developing training techniques and strategies. Ultrasonic sensor-based automated systems demonstrate that the integration of modern technology into military training can accelerate the achievement of fitness targets while supporting operational efficiency.

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The author hopes that this research can provide a positive contribution to the development of ultrasonic sensor-based technology in supporting physical fitness training, especially in the Indonesian Army environment. In addition, hopefully this research will be useful as a reference for the development of automation systems and further research in the future.

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