Control and monitoring system of Railway level crossings for traffic safety based on IoT

Nadillah Lovella[1], Muldi Yuhendri[1,2]
[1]Department of Electrical Engineering, Faculty of Engineering, Universitas Negeri Padang, Padang, Indonesia
[2]Instrumentation, Control and Automation Research Group (ICAARG), Universitas Negeri Padang

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ABSTRACT

Accidents at railroad crossings still frequently occur due to the negligence of road users and the lack of an optimal security system. This study aims to design a prototype of an Internet of Things (IoT)-based level crossing monitoring and control system to improve traffic safety. This system uses an ESP32 microcontroller as the control center, an HC-SR04 ultrasonic sensor to detect the arrival of the train, a servo motor as a driver for the automatic barrier gate, and Blynk IoT as a remote monitoring and control platform. The research method used is the waterfall model, which includes the stages of needs analysis, system design, implementation, testing, and maintenance. The results of the study show that the developed system can work automatically in detecting train arrivals, displaying crossing status on a 16x2 LCD, and providing warnings via LED indicators and buzzers. In addition, users can control the gate manually through a Blynk-based application. Based on the tests conducted, the system has a good level of accuracy in detecting the presence of trains and responding to commands from the application with a response time of less than 1 second. Thus, this prototype is expected to be an innovative solution to improve safety at railroad crossings and reduce the risk of accidents due to human error.

Corresponding Author:

Nadillah Lovella
Department of Electrical Engineering, Faculty of Engineering, Universitas Negeri Padang
Kampus UNP Pusat, Jl. Prof. Hamka, Air Tawar, Padang 25131, Indonesia
Email: Nadillalovella@gmail.com

1. INTRODUCTION

The public frequently uses trains, which are traditional modes of transportation. Thus, this vehicle is significant and has a big impact on people's everyday lives. In order to prevent traffic jams and accidents on the roadway, infrastructure and facilities are therefore required. In particular, traffic jams or mishaps near railroad crossings, which can be brought on by a variety of reasons. Accidents near railroad crossings are among the most common types of accidents. The railroad crossing is situated between the roadway that connects the two routes and the railroad track [1]-[3].

Accidents that occur at railroad crossings are not only caused by drivers or negligence of road users, but also by the facilities and infrastructure that support level crossings with highways [4]-[7]. With the installation of railroad crossing gates, namely a series of technologies that function to prevent vehicles or other parties from passing through the crossing lane when a train passes. Based on the statement by PT Kereta Api Persero, the crossing gates are only a tool to secure the crossing lane. However, accidents that occur around railroad crossing gates still occur frequently and are sometimes caused by the negligence of the gate guards and the indiscipline of other vehicle drivers [8]-[11].

In order to reduce these accidents, a renewable and automatic railway crossing system is needed. This railway crossing will be equipped with a system that can control the door automatically to reduce negligence of officers or human error. However, the door can also be controlled manually if necessary. Several similar studies have been conducted by other studies, such as the Arduino Uno-Based Automatic

Railway Crossing Prototype Using the Hc-Sr04 sensor [12]. The proposed automatic railway crossing is equipped with an ultrasonic sensor and controlled by a NodeMCU ESP8266 microcontroller. The mechanism of this tool is, the ultrasonic sensor reads the train crossing the railway crossing, then the servo motor will close and reopen after the train crosses the track, this automatic crossing is designed so that the operator can easily control the automatic crossing. Another study is the Automatic Railway Crossing Crossing System With Arduino-Based Wireless Communication [13]-[16].

In this paper, a monitoring and control system for railroad crossings based on IoT is proposed for securing railroad traffic. The application of IoT allows the monitoring system to be carried out remotely [17]-[21]. This allows railroad crossings to be controlled and monitored remotely. Some of the components used in the design of this automatic railroad crossing are: A microcontroller is useful as a control center in controlling the automatic railroad crossing, a servo motor and a sensor that works as a detection tool in detecting trains that will cross and sending signals to the microcontroller to be given commands to the servo motor so that it can move.

2. METHOD

The research method used is the waterfall research method. The waterfall model is a linear development method. Where each phase must be completed before the next phase begins. In this study, the waterfall method was chosen because the development process is structured and systematic. The stages of this research are carried out continuously, starting with needs analysis, system design, implementation, testing, and tool maintenance. In the needs analysis stage, data and information are collected to understand the needs of users and the system as a whole. The functional and non-functional needs of the system will be identified, including hardware specifications: ESP32 Microcontroller, HC-SR04 Ultrasonic Sensor, Servo Motor, LED (Light Emitting Diode), Buzzer, and Button. As well as some of the software needed, namely: Arduino IDE Software, Wokwi.com Web simulator, and Blynk.com IoT Platform. In the system design, the design framework is made to describe the design of the prototype so as to obtain results and functions that are in accordance with the design. The system block diagram in Figure 1 illustrates the system structure consisting of several components with different functions

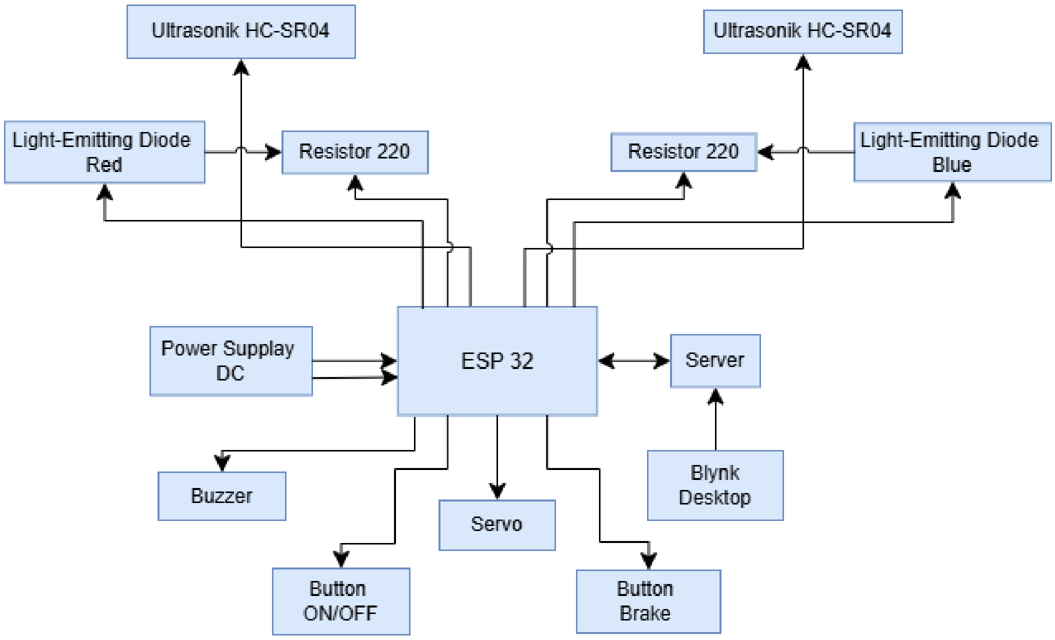

Figure 1. Block diagram of tool design

The prototype of an IoT-based level crossing monitoring and control system for traffic security system works by detecting the arrival of a train from the right or left using the HC-SR04 ultrasonic sensor. When the sensor detects the presence of a train, the LED will flash and the buzzer will emit a warning sound. The ESP32 microcontroller then sends a signal via a Wi-Fi network to the Blynk IoT database, where the user can receive and act on the signal. Based on the user's decision, the servo will be moved to close the railroad crossing gate. When the two ultrasonic sensors no longer detect the presence of a train, a signal will be sent back to the user, who can then reopen the railroad crossing gate via the Blynk system.

In the implementation stage, the designed design will be made into hardware and program code. The ESP32 microcontroller will be programmed according to the design and the components will be connected and configured. The system will also be integrated with the Blynk platform to enable control and monitoring through the application by the user. Figure 2 shows the circuit schematic of the Prototype of the IoT-Based Level Crossing Monitoring and Control System for Traffic Security with details of the relationships between the components used in the system.

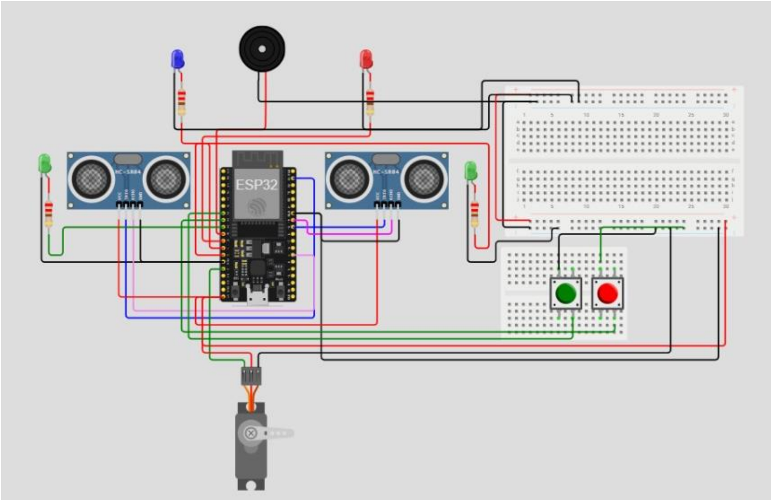

Figure 2. Circuit diagram of IoT-based Level Crossing Monitoring and Control System Prototype

The testing phase is carried out to ensure that the system is in accordance with the specifications that have been set. Testing includes hardware and software functionality, control responsiveness, and network stability testing. Testing is planned to be carried out 9 times with testing on the functionality and responsiveness of the system to the components of the system with the condition of the train coming from the right or left.

3. RESULTS AND DISCUSSION (10 PT)

The proposed system is validated through experiments of the prototype that has been built. Figure 3 shows the prototype of the tool that will be tested in this study.

Figure 3. Prototype of the proposed device

Based on the prototype that has been designed, it will then be tested and analyzed to determine whether the designed prototype has been able to work or function properly as desired. From the testing, data and evidence will be obtained that the system that has been created can work properly. In testing the system control to ensure that the display on the Blynk application, namely Servo, Buzzer, LED, and Ultrasonic Sensor, is in accordance with the designed function as shown in the following Table 1.

Table 1. Test results of all components

No	Control Testing			Train Condition			Information
	Input	Output	Status	In	Out	Mid	
1.	Sensor Ultrasonic HCSR-04 In (left/right)	ON	Detecting	✓	X	X	Correct
		OFF	Not Detecting	X	X	X	Correct
2.	Sensor Ultrasonic HCSR-04 Out (left/right)	ON	Detecting	X	X	✓	Correct
		OFF	Not Detecting	X	X	X	Correct
3.	Warning LED (right)	ON	Turn On	✓	✓	X	Correct
		OFF	Turn Off	X	X	X	Correct
4.	Warning LED (left)	ON	Turn On	✓	✓	X	Correct
		OFF	Turn Off	X	X	X	Correct
5.	Buzzer	ON	Sound	✓	✓	X	Correct
		OFF	No Sound	X	X	X	Correct
6.	Railroad Gate Servo	ON	Closing (180)	✓	✓	X	Correct
		OFF	Opening (90)	X	X	✓	Correct

Table 1. shows that all components have worked as expected. Next, a complete test is carried out to validate the system. The measurement of tool accuracy is based on how long it takes for the system to Blynk to be able to respond and monitor the arrival/departure conditions of the train. The following table is the result of measuring the accuracy of the response time (s: second, ms: millisecond) of the system with blynk. Table 2 shows the results of the tool testing.

Table 2. Tool test results

Experiments	Condition	Blynk	Respond Time	Status
1	Train In	Train from left	6s 85ms	Detected
	Train Out	Train from right	5s 6ms	Detected
2	Train In	Train from right	6s 5ms	Detected
	Train Out	Train from left	5s 19ms	Detected
3	Train In	Train from left	6s 36ms	Detected
	Train Out	Train from right	5s 03ms	Detected
4	Train In	Train from right	6s 3ms	Detected
	Train Out	Train from left	5s 4ms	Detected
5	Train In	Train from left	6s 1ms	Detected
	Train Out	Train from right	4s 5ms	Detected
6	Train In	Train from right	6s 9ms	Detected
	Train Out	Train from left	5s 06ms	Detected
7	Train In	Train from left	6s 12ms	Detected
	Train Out	Train from right	5s 05ms	Detected
8	Train In	Train from right	6s 44ms	Detected
	Train Out	Train from left	5s 04ms	Detected
9	Train In	Train from right	6s 83ms	Detected
	Train Out	Train from left	4s 85ms	Detected

The table shows that from 9 successful trials tested, it shows that the accuracy of blynk's response to the system ranges from 4-6 seconds. Which occurs in the program that is input into the ESP32 there is a delay. This delay is useful so that when the ESP32 runs the designed program, there is no overlap between the automatic and manual train detection programs later. Figure 4, 5 and 6 shows the testing process.

Figure 4. Testing the servo motor as a sign driver

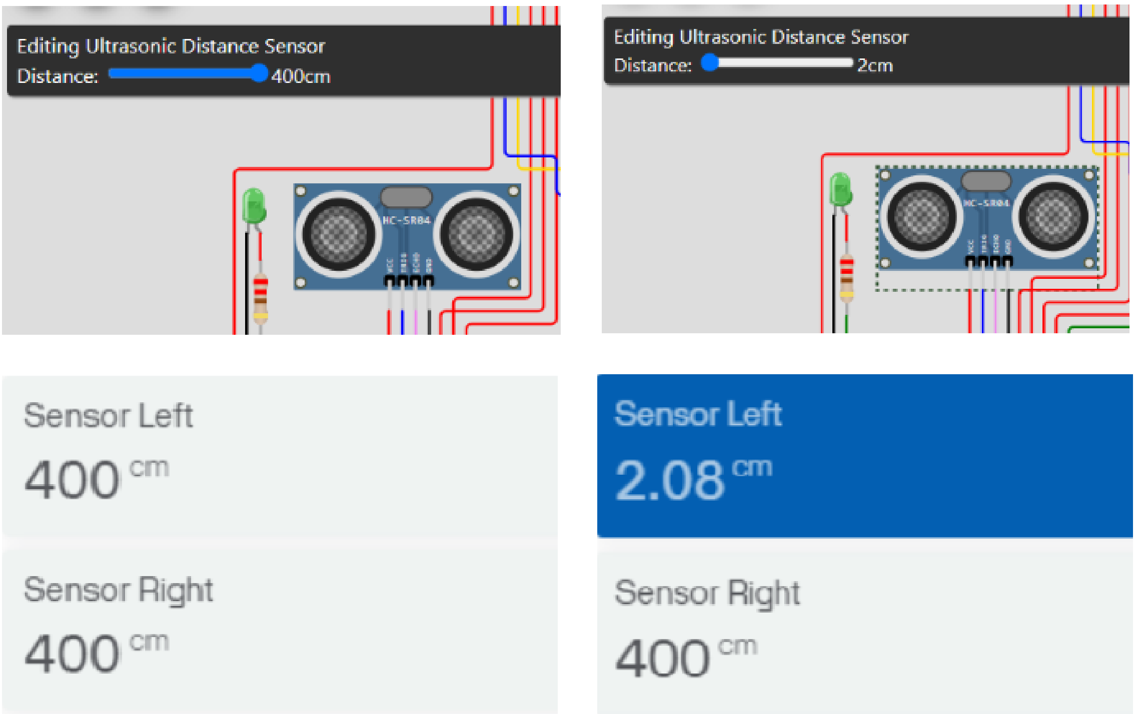

Figure 5. Ultrasonic sensor testing

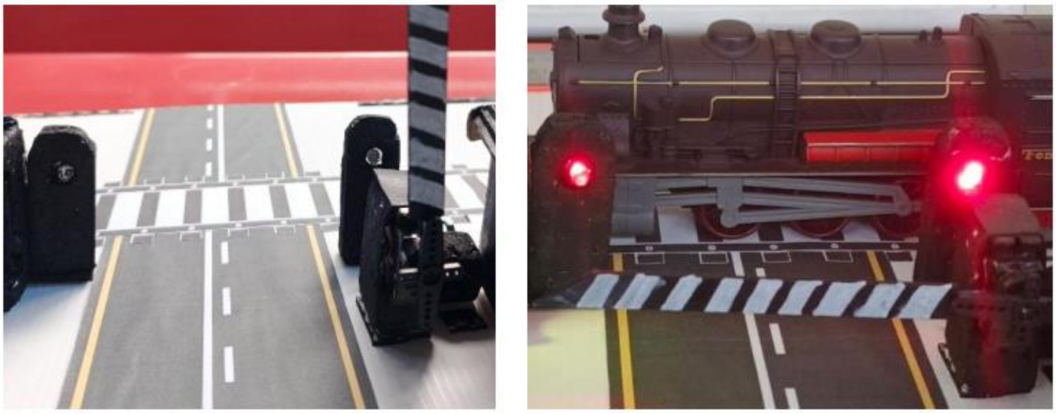

Figure 6. Testing the indicator light

4. CONCLUSION

From the results of observations made during the design, implementation, and testing processes, it can be concluded that a Prototype of an IoT-Based Level Crossing Monitoring and Control System for Traffic Security has been developed to improve the safety of railway crossings. This system allows real-time monitoring of crossing conditions and automation of gate control to reduce the risk of accidents. With the integration of IoT-based sensors and communications in the Bliynk application, the system can detect the presence of trains, activate early warnings, and provide information to users via digital notifications. Testing shows that the accuracy of the blynk response system to the system ranges from 4-6 seconds. Because the delay is in the program inputted into the ESP32 which is useful so that when the ESP32 microcontroller runs the designed program, there is no overlap between the automatic and manual train detection programs later. It is hoped that further research related to further development will be carried out, so that this system can be a more optimal solution in improving the safety of level crossings based on IoT technology.

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