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Design of Miniature Zebra Crossing Violator Detection at Traffic Lights Based on Internet Of Things

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Abstract – **The problem that often occurs in Riau Province is the problem of traffic lights on the zebra crossing where motorists cross the stop limit on the zebra crossing. zebra crossing is a means of crossing the road for pedestrians. These cases have an impact on traffic safety. Accidents that occur at traffic lights, especially at zebra crossings, are caused by pedestrians who are less careful, lack of traffic signs and drivers driving badly. Therefore this research, will design a miniature design of detecting violations of the zebra crossing line at Iot-based traffic lights, where this research is made in miniature, using pear sensors to detect vehicles. When the sensor detects a vehicle crossing the stop line when the light is red, the speaker will sound to warn the driver who crossed the stop line to back up to the stop line. Furthermore, the system will capture the violation and the screenshot will be sent to a telegram as proof of the violation. As a result of this research, the pear sensor is able to work when a vehicle crosses the limit line when the light is red. Calculation of the time when the buzzer sounds until finally the image is received and displayed on the telegram.**

Keywords: Zebra cross;Traffic light;Esp32-cam;PIR Sensor;Speaker

I. INTRODUCTION

Indonesia is a country with a large population, and almost every inhabitant is a vehicle user (Hasanah et al., 2021). According to police data, on average, 23% of Indonesians use cars and 87% use motorcycles (Ruly Kurniawan, 2023). The density of motorized vehicles and cars is not proportional to the number of road segments they traverse (Yolanda et al., 2021). Riau province is among those with the highest usage rates of motorized vehicles and cars. In 2021, the Riau Regional Police recorded around 2 million motorbike users and approximately 316 thousand car users, and these road users are closely related to traffic lights (Riyadi, 2023). Traffic lights are essential for regulating traffic flow on roads (Rifqo & Aprianti, 2020).

One recurring issue in Riau province is the problem of traffic lights at zebra crossings, where drivers often surpass the stop line (Hafiz et al., 2022). Zebra crossings are designed for pedestrians to cross the road safely. Many drivers, particularly at traffic lights, cross the stop line, causing potential congestion and accidents. Accidents at traffic lights, especially at zebra crossings, are attributed to pedestrians' lack of caution, insufficient traffic signs, and reckless driving (Kurniawan et al., 2019). In 2022, there were cases of drivers surpassing the zebra crossing stop line, with

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approximately 2.6 million violations in Riau province, occurring during peak hours of community activities on the roads (Heru, 2022).

Another issue is the inadequate detection of zebra crossing violations at traffic lights in Riau province, allowing road users the freedom to break traffic light rules (Fathur Rahman et al., 2021). To address this problem, technology is needed to remotely detect and monitor the number of zebra crossing violations. One technological solution is the use of an ESP32 CAM camera module-based IoT and PIR Sensor. The ESP32 CAM module is a development board with dual WI-FI + Bluetooth mode that uses an antenna and is based on the ESP32 chip. This PCB board can be applied for various purposes, such as CCTV surveillance, image capture, and more. Thus, the ESP32 CAM module can capture images and also serve as a Wi-Fi module for data transfer. On the other hand, the PIR sensor is a passive infrared radiation detection device capable of identifying infrared radiation emitted by an object (Siregar et al., 2021).

In related studies on zebra crossing violations, such as the research titled "Prototype Warning of Zebra Crossing Violations at Traffic Lights with Sirens Using Arduino" by (Putra & Oktafiandi, 2022), ultrasonic sensors were found to detect violations within a distance of less than 30 cm. If a violation is detected, the buzzer sounds, and the LCD displays the message "Violation has occurred."

Another study by (Gunawan et al., 2023), on the "Prototype System for Detecting Zebra Crossing Violations at Traffic Lights," recorded sensor, buzzer, and ESP32 CAM response times averaging 1.196, 1.236, and 1.252 seconds, respectively, based on 5 trials.

In the study by (Rahmawati et al., 2022), "Design of Prototype Warning System for Zebra Crossing Violators Based on ESP-32 CAM Microcontroller," the system detected violations only for vehicles crossing the zebra crossing boundary line. The maximum undetected violation distance was 36.9 cm for motorcycles and 18.7 cm for cars.

The study titled "Real-Time Zebra Crossing Violation Detection System Prototype at Traffic Lights Using Arduino" by (Nugraha et al., 2019), noted a program execution time of 66 seconds using the Millis function. After 10 loop tests, the average system time to complete one scheduling cycle was 66.004 seconds, with a time accuracy error percentage of 0.006%.

Furthermore, the research by (Idham et al., 2023), on the "Prototype Ban on Drivers Passing Zebra Crossings at Traffic Lights Based on ESP32 CAM," showed that when the sensor detects a vehicle, the speaker sounds, and the ESP32 captures an image.

Therefore, this study aims to create a device that can detect drivers exceeding the stop line at zebra crossings, designing a miniature IoT-based zebra crossing violation detection system at traffic lights. The miniature device consists of an Arduino as the control center, ESP32 CAM camera module for capturing videos and images of zebra crossing violations, PIR sensor for detecting drivers crossing the stop line, and DF Mini player for audio output. The programming language used is Arduino IDE. The system will utilize the ESP32 CAM module to detect violations and can be controlled remotely and in real-time, both automatically and manually.

II. METHOD

1. The Role of Hardware

The hardware block diagram is shown in Figure 1, where the research will be divided into three parts: input, process, and output. The input in the system is a PIR sensor to detect violators. In the process, Arduino will process the data received from the PIR sensor and pass it on to the DF Mini player, while the ESP32 CAM will capture an image. For the output, the DF Mini player will send input to the speaker, and the ESP32 CAM will send the captured violation photo to a smartphone.

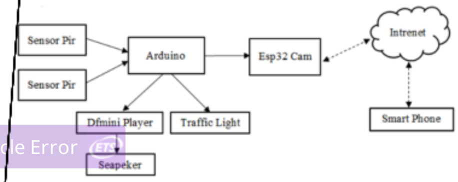

Figure 1. Hardware block diagram.

2. Wiring Diagram

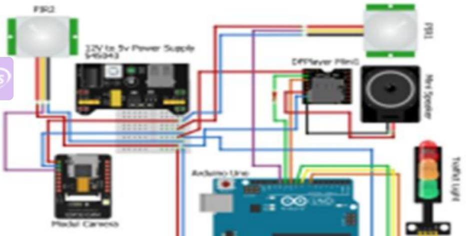

Figure 2. Wiring Diagram

3. Telegram

Telegram is a messaging application known for its lightweight, fast, and ad-free features. Within this platform, there is a bot system called Telegram bot, enabling communication with microcontroller devices. Additionally, Telegram is a cloud-based instant messaging service that can be accessed for free. Telegram clients are available for mobile and desktop systems, allowing users to send messages and share photos, videos, stickers, audio, and various other types of files.

/start 14:51

Welcome , Lukman
Silahkan akses menu berikut :
/photo : mengambil foto
/piron : mengaktifkan sensor
/piroff : mematikan sensor
/pelanggaran : mengirimkan jumlah pelanggaran yang terjadi
/reset : menghapus data jumlah pelanggaran
/streamon : mengaktifkan mode streaming
14:51

Figure 3. Telegram bot.

Figure 3 shows the Telegram bot after the device is turned on, and users can directly access several features connected to the device manually.

4. Software Design

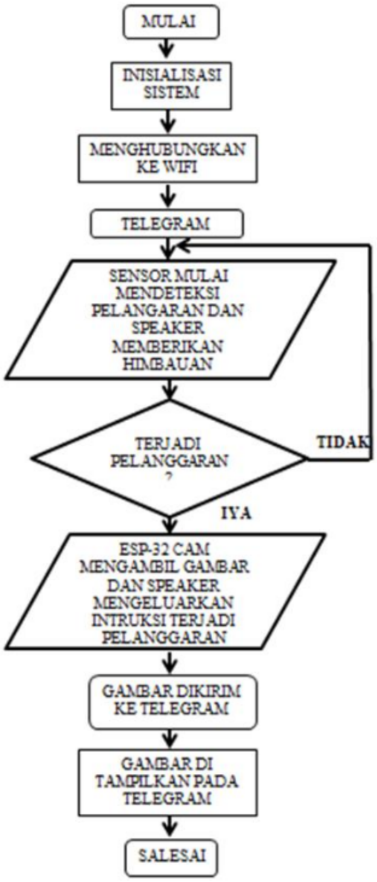

Figure 4. *Folwchart Software*

The software flowchart can be seen in Figure 4. When the device is powered on and starts analyzing the system, if the device is connected to Wi-Fi, Telegram becomes active, the traffic light and sensor become active, and the sensor will start detecting objects. If a violation is detected, the speaker will issue a warning, and the ESP32 CAM will capture an image. Subsequently, the image is sent to Telegram and displayed in the Telegram application.

III. RESULTS AND DISCUSSION

A. Design

The results of the hardware and software design are implemented in a construction that depicts a simulation of an intersection with traffic lights. This construction utilizes a PIR sensor as a tool to detect vehicles crossing the pedestrian crossing boundary. The warning system will produce sound from the speaker if a driver crosses the stop line when the light is red, and the violation will be automatically recorded by the ESP32 CAM, then sent directly to Telegram. In the 5th illustration, the design of the traffic light intersection construction is depicted.

Figure 5. Design

B. Violation Detection System

The system will operate when the traffic light is red. If a vehicle crosses the stop line and enters the zebra crossing area, the PIR sensor installed at the initial line of the zebra crossing will detect this violation. Consequently, the speaker will immediately sound an alert, issuing a warning: "Please do not stop in the zebra crossing area; respect the rights of pedestrians.

Figure 6. Violation Detection System

The installation of PIR sensors on the zebra crossing must be positioned accurately, specifically at the vehicle stop line, not on the zebra crossing itself. The purpose is to ensure that the sensor does not detect pedestrians using the zebra crossing but rather detects vehicles crossing the predetermined stop line when the traffic light is red.

C. Telegram Notification Testing

Whereas, the results of the sensor detection, when a violation occurs, will prompt the ESP32 CAM to capture an image. Subsequently, the captured image from the ESP32 CAM will be sent and displayed on the Telegram screen.

Terdeteksi pelanggaran!!
Foto akan segera dikirim 15:24

Figure 7. Notification of esp32 cam result to Telegram

C. Pengujian System

Table 1. Tool Testing

No	Parameter	Sensor Pir 1	Sensor Pir 2	Buzzer
1	Green Light	Off	Off	Off
2	Yellow Light	Off	Off	On
3	Red Light	On	On	On
4	Red Light	On	On	On

Table 2. Hasil Pengujian Alat

No	Parameter	Violation	Telegram	Camera
1	Green Light	There isn't any	There isn't any Photo	Off
2	Yellow Light	There isn't any	There isn't any Photo	Off
3	Red Light	There is	There is Photo	On
4	Red Light	There isn't any	There isn't any Photo	On

The test results above systematically display which components are active. When the light is green, all components will be off. When the light is yellow, only the buzzer will be active to notify drivers to prepare for the upcoming green light. In the red light condition, there are two scenarios: in the first scenario, all components will be active, and in the second scenario, all components will be active, but there is no violation, as seen in the table display above.

Table 3. Indoor Equipment Response Testing

No	Banyak pengetesan	Respon Sensor 1 (Detik)	Respon Sensor 2 (Detik)	Respon Buzzer (Detik)	Respon Esp32 Cam (Detik)	Respon Telegram (Detik)	Jarak Kedaraan (Cm)
1	Pelanggaran 1	00,34 detik	00,55 detik	00,34 detik	00,55 detik	01,00 detik	1 cm
2	Pelanggaran 2	01,39 detik	01,35 detik	01,39 detik	01,35 detik	06,14 detik	6 cm
3	Pelanggaran 3	01,92 detik	01,45 detik	01,92 detik	01,45 detik	03,05 detik	12 cm
4	Pelanggaran 4	02,71 detik	02,93 detik	02,71 detik	02,93 detik	03,10 detik	16 cm
5	Pelanggaran 5	03,11 detik	03,45 detik	03,11 detik	03,45 detik	06,81 detik	19 cm

Table 4. Outdoor Equipment Response Testing

No	Banyak pengetesan	Respon Sensor 1 (Detik)	Respon Sensor 2 (Detik)	Respon Buzzer (Detik)	Respon Esp32 Cam (Detik)	Respon Telegram (Detik)	Jarak Kedaraan (Cm)
1	Pelanggaran 1	00,40 detik	00,59 detik	00,40 detik	00,59 detik	01,00 detik	1 cm
2	Pelanggaran 2	01,40 detik	01,30 detik	01,40 detik	01,30 detik	05,10 detik	6 cm
3	Pelanggaran 3	02,00 detik	01,50 detik	02,00 detik	01,50 detik	03,30 detik	12 cm
4	Pelanggaran 4	02,75 detik	02,90 detik	02,75 detik	02,90 detik	03,10 detik	16 cm
5	Pelanggaran 5	03,20 detik	03,50 detik	03,20 detik	03,50 detik	06,40 detik	19 cm

The testing in table 3 above was conducted indoors using a stopwatch and involved 5 violation experiments. From the calculation results, the lowest values obtained were 0.34 seconds for sensor 1 response and 0.55 seconds for sensor 2 response. Meanwhile, the lowest response time for the buzzer was 0.34 seconds, for the ESP32 CAM was 0.55 seconds, and for data transmission through Telegram was 1.00 second. The average response time was found to be 6.98 seconds for sensor 1 and 6.97 seconds for sensor 2. The average response time for the buzzer was 6.98 seconds, for the ESP32 CAM was 6.97 seconds, and for data transmission through Telegram reached 14.65 seconds.

Testing in table 4 above was conducted outdoors, similar to indoor testing, using a stopwatch and involving 5 violation experiments. From the calculation results, the lowest values obtained were 0.40 seconds for sensor 1 response and 0.59 seconds for sensor 2 response. Meanwhile, the lowest response time for the buzzer was 0.40 seconds, for the ESP32 CAM was 0.59 seconds, and for data transmission through Telegram was 1.00 second. The average response time was found to be 7.19 seconds for sensor 1 and 6.99 seconds for sensor 2. The average response time for the buzzer was 7.19 seconds, for the ESP32 CAM was 6.99 seconds, and for data transmission through Telegram reached 13.78 seconds.

IV. CONCLUSION

Based on the results of the system design and analysis, it can be concluded that the device can operate as planned. The PIR sensor can detect vehicles crossing the stop line, and the ESP32 CAM can capture images of these violations, sending them to Telegram as evidence of the violation. The PIR sensor can detect violations within a distance of 20 cm, and beyond that range, the sensor cannot detect the violation. If a violation is detected, the speaker will sound, saying, "Please do not stop in the zebra crossing area; respect the rights of pedestrians."

For indoor testing, five violations were conducted using a stopwatch to measure the response time of the device. Sensor 1 and 2 detected violations the fastest at 0.34 seconds and 0.55 seconds, respectively. The buzzer had a response time of 0.34 seconds, the ESP32 CAM had a response time of 0.55 seconds, and Telegram had a response time of 1.00 second. The longest response time occurred at a distance of 19 cm, with Sensor 1 and 2 detecting violations in 3.11 and 3.45 seconds, respectively. The buzzer had a response time of 3.11 seconds, the ESP32 CAM had a response time of 3.45 seconds, and Telegram had a response time of 6.81 seconds.

For outdoor testing, Sensor 1 and 2 detected violations the fastest at 0.40 seconds and 0.59 seconds, respectively. The buzzer had a response time of 0.40 seconds, the ESP32 CAM had a response time of 0.59 seconds, and Telegram had a response time of 1.00 second. The longest response time occurred at a distance of 19 cm, with Sensor 1 and 2 detecting violations in 3.20 and 3.50 seconds, respectively. The buzzer had a response time of 3.20 seconds, the ESP32 CAM had a response time of 3.50 seconds, and Telegram had a response time of 6.40 seconds.

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