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Smart Traffic Light Monitoring System for Emergency Vehicle using IoT

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Abstract: In the modern era, the number of vehicles on the road has increased dramatically. It is because each family will at least own a vehicle. Traffic congestion is becoming one of the most common challenges faced by emergency vehicles such as ambulances, firetrucks and police cars which take more time to reach the destination. The major objective is to improve the traffic conditions by giving priority to emergency vehicles. This project will be developed using NodeMCU ESP8266, infrared sensor and the Firebase database. The result of this project is to improve the performance of the system for detecting emergency vehicles and thus minimize the waiting time due to traffic congestion. As shown in the result, when the sensor detected an emergency vehicle, the traffic light will immediately turn to green light and delay 10 seconds to clear vehicles on that lane. So, the emergency vehicle could pass through the junction without congestion.

Keywords: traffic light, emergency vehicles, IoT (Internet of Things)

1. Introduction

In Malaysia, 4.94 million accident cases in the last decade have been recorded, with the number of road accidents increasing from 414,421 cases in 2019 to 567,519 nine years later in 2019. During the COVID-19 pandemic last year, there were 3,118 deaths involving motorcycle riders and 888 deaths involving car drivers. An increase in the number of vehicles is one of the major causes of those accidents, andit also causes an increase in traffic congestion. Traffic congestion problems affect emergency vehicles like ambulances, fire trucks, and police cars' ability to reach the location of an incident immediately. For example, if a patient in an ambulance suffering from a dangerous situation wants to get urgent treatment, but this emergency vehicle will get stuck in traffic, this is very dangerous for one's life. So, traffic lights play an important role for traffic management.

The MATC Intelligent Traffic System (MITS) is installed at the traffic control center, which acts as the hub which communicates with individual traffic controllers on site. Although it is not a new system, it needs a lot of improvements. MITS includes higher reliability of traffic equipment; better maintenance service levels; intelligent and automatic control center-initiated adjustments of timing and

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phasing parameters based on real-time traffic demand; and allows the analysis of traffic information and collected data to be conducted for making informed decisions.

As the population is increasing, so does the number of vehicles on the road. There is no proper traffic light monitoring system to solve the traffic congestion in Malaysia. This is the major cause of the delay for emergency vehicles to reach their destinations. In the existing system, the traffic lights change colors in the same sequence every time. For example, green light for 60 seconds, yellow light for 3 seconds, red light for 90 seconds, and then green light again. Therefore, emergency vehicles have to wait for clearance in that lane whenever they approach the junction.

2. Materials and Methods

2.1 Materials

This project will be developed using NodeMCU ESP8266, infrared (IR) sensor and the Firebase database. The NodeMCU ESP8266 board will be used in this project and linked with the Firebase database to remotely control the system. NodeMCU is an open-source platform built on the ESP8266 that allows things to be connected and data to be transferredover Wi-Fi [1]. While Firebase is an application development platform that helps you build, improve, and grow your app. It offers a wide range of services for handling data from any web, Android, or iOS application [2].

2.2 Methods

The design and development of this IoT system for monitoring traffic lights follows the phases of the Spiral model. It includes four phases that will repeatedly pass through the project, which are: determining objectives; risk analysis and resolving; development and testing; and planning the next iteration. Next, the NodeMCU ESP8266 allows things to be connected and data to be transferred over Wi-Fi. Therefore, when emergency vehicles are detected by an IR sensor installed at the roadside before the traffic light, the system will organize the traffic flow to allow emergency vehicles to pass through the junction without any delay [3]. After the emergency vehicles have passed through the junctions, the system will reset the traffic signal timing back to normal.

Besides, the proposed system uses NodeMCU (ESP8266 12E) with an IR obstacle sensor to signal traffic congestion on the road. The system employs the ESP8266 12E Wi-Fi chip in the NodeMCU to connect to the internet. A notification will be sent to smartphone users. It is anticipated that road traffic will improve significantly. For example, the system may be able to predict traffic congestion and suggest certain user-friendly routes [4]. Nono et al. (2020) in [5] suggested a system where an ambulance would be able to control the traffic lights with the Arduino UNO and Mega with a network shield (ZigBee). It would take 8 minutes to travel the same distance under the planned system. The difference is therefore 1 minute for each traffic light along the way. As a result, the system will make it easier for emergency vehicles to move around and save lives.

Consequently, Sarrab et al. (2020) in [6] discussed an IoT-based system model to collect, process, and store real-time traffic data. The Wi-Fi-enabled microcontrollers will process the real-time vehicle data that is collected from magnetic sensor nodes and send it to the IoT platform. The results of the system show good accuracy in vehicle detection and a low relative error in road occupancy prediction.

However, to alleviate traffic congestion, Anna Marine and George (2018) in [7] proposed a system that employs IoT and the Adaptive Neuro Fuzzy Inference System (ANFIS). Using the MATLAB SIMULINK environment, a traffic light controller for the ANFIS system is created, with inputs for waiting time and vehicle density. The traffic scenes are captured by a camera, and the image is then sent to the cloud using an Arduino UNO and the ThingSpeak Platform. Wani et al. (2020) in [8] used the Arduino UNO, GOS neo 6M, and SIM 900A to develop a traffic control system for emergency operations.

3. Results and Discussion

A usability evaluation was conducted on 30 respondents, consisting of drivers in Malaysia with an age group of 18 years old to 46 years old and above. The instruments used for assessment were a post-task questionnaire and demonstration video. There are 3 sections in the questionnaire, with a total of 20 questions. In Section A, the respondents' demographics and general questions will be asked. Section B asked the respondents to watch a demonstration video before completing the tasks given. For Section C, the questions are designed to collect responses based on ease of use, usefulness, performance, and satisfaction of the prototype. The 5-point Likert Scale is used for questions in Section C. The scale of 1, 2, 3, 4 and 5 will represent strongly disagree, disagree, neutral, agree and strongly agree respectively. The respondents performed the following step-by-step procedure for the evaluation: (1) read the instructions before answering the questionnaire, (2) watch the demonstration video provided by the developer, (3) interact with the prototype, (4) evaluate the usability of the prototype, and (5) answer the post-task questionnaire.

3.1 Results

Analysis of respondents' demographic information reveals 60% are female and 40% are male. 40% of the respondents were from the age group of 23 to 27 years old. 20% and 6.7% of those aged 10 to 22 years old and those aged 38 and older, respectively. 16.7% of respondents were between the ages of 28 and 32, and 16.7% were between the ages of 33 and 37. 23.3% had 5 years of driving experience, while of 26.6% respondents' driving experience was less than 5 years, and the rest, 50.1%, respondents had more than 5 years of driving experience. 93.3% of respondents give way to emergency vehicles immediately when they are approaching, while only 6.7% were not sure. On the question of whether the respondents heard about smart traffic light monitoring systems, 56.7% have heard about similar systems, while 13.3% are not familiar with the system, and 30% have not heard about it.

The result of the post-task questionnaire stated that the prototype system was useful, had good performance, and the respondents were satisfied with the prototype system. **Table 1** and **Table 2** show the frequency of responses to the usability evaluation. Most of the respondents rated it as agreeing agree or strongly agreeing. None of the respondents disagreed and strongly disagreed, while only a few rated neutral.

Table 1: Responses of Respondents on the Usefulness of the System

Statement	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Average
This system is useful in daily life.	0 (0.00)	0 (0.00)	0 (0.00)	12 (40.00)	18 (60.00)	4.60
This system can improve efficiency during emergency condition.	0 (0.00)	0 (0.00)	0 (0.00)	11 (36.67)	19 (63.33)	4.63
This system should be implemented before each intersection of the road.	0 (0.00)	0 (0.00)	0 (0.00)	8 (26.67)	22 (73.33)	4.73

Table 2: Responses of Respondents on the Satisfaction of The System

Statement	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Average
I am satisfied with this system.	0 (0.00)	0 (0.00)	0 (0.00)	7 (23.33)	23 (76.67)	4.77
This system works the way I would expect it to do.	0 (0.00)	0 (0.00)	0 (0.00)	5 (16.67)	25 (83.33)	4.83

3.2 Discussions

A prototype for a Smart Traffic Light Monitoring System for Emergency Vehicles using IoT was developed. **Figure 1** shows the prototype of the system that includes LED, infrared (IR) sensor, and a NodeMCU ESP8266. There are three different colors of LED, which are red, yellow, and green, which act as the traffic lights in a real scenario. When the IR sensor detects an emergency vehicle, it will transmit the signal to the NodeMCU ESP8266. The NodeMCU ESP8266 will trigger the traffic light to turn green for the emergency vehicle. The green light will have a delay of 10 seconds to allow emergency vehicles to pass through the junction without any delay. After that, the traffic lights will reset back to their normal sequence. The serial monitor of Arduino IDE shown in **Figure 2**. It will display message something detected and get the current datetime. If there is no detection, the serial monitor will display message no detection continuously. While **Figure 3** The Firebase database was linked to remotely control the system prototype. In case there was an emergency, such as the sensor not working, the system could be controlled manually through Firebase.

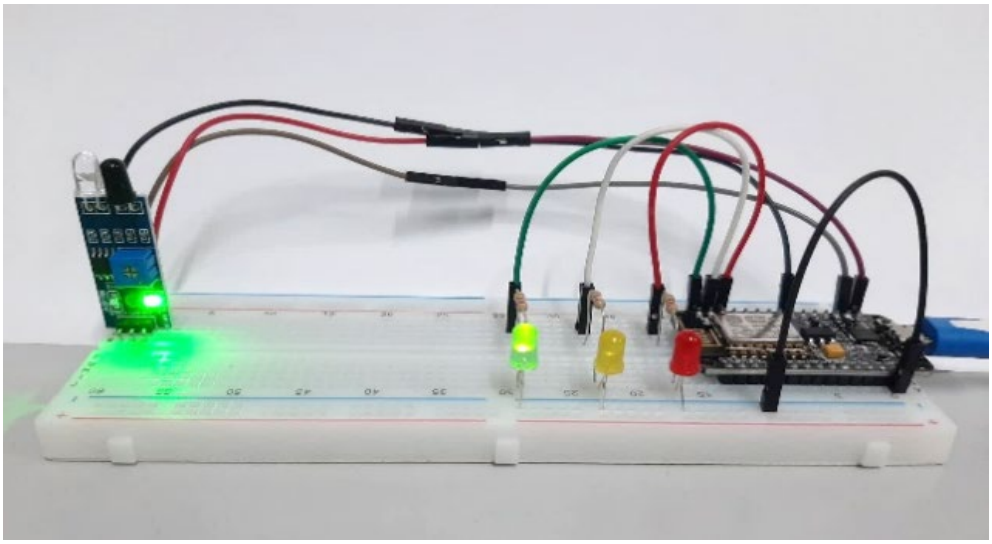

Figure 1: Assembled of Smart Traffic Light Monitoring System (On)

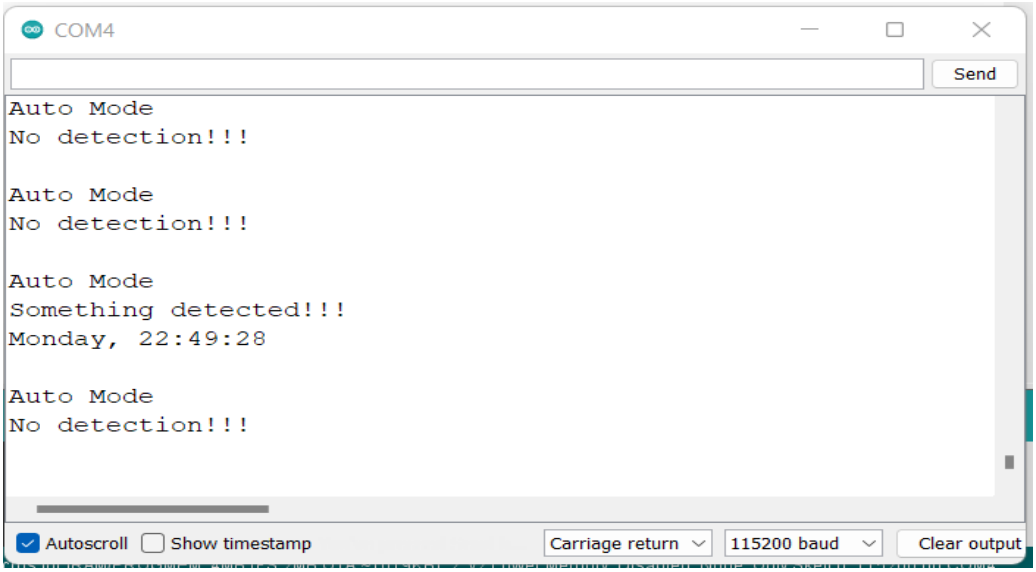

Figure 2: Serial Monitor of Arduino IDE

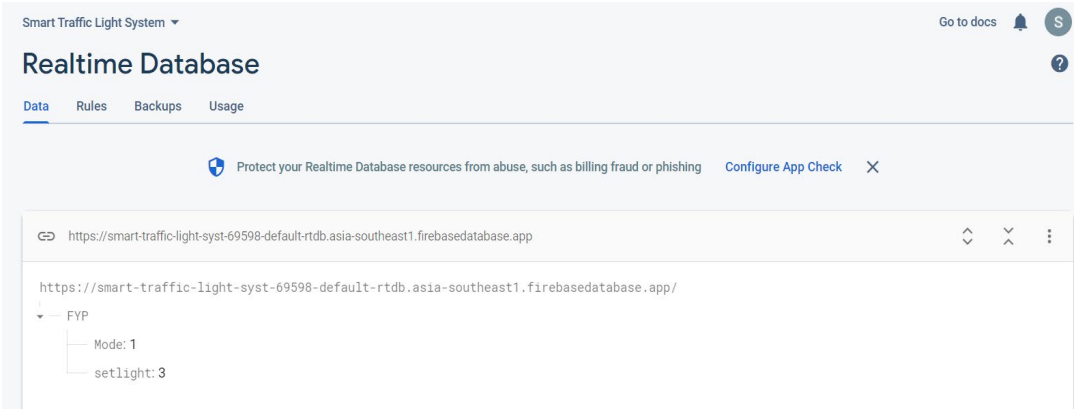

Figure 3: Firebase of Smart Traffic Light Monitoring System

4. Conclusion

In this project, a system prototype for emergency vehicles using IoT was developed. The requirements of the prototype have been successfully achieved. When the sensor detects an emergency vehicle, the traffic light will immediately turn green and delay 10 seconds to clear vehicles in that lane. So, the emergency vehicle could pass through the junction without congestion. The Firebase database was linked to remotely control the system prototype. In case there was an emergency, such as the sensor not working, the system could be controlled manually through Firebase. The future scope of this research is expected to be implemented in a real- world environment by using other wireless technologies. Also, focus on the sensitivity of the sensor for distances and speed of emergency vehicles approaching.

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