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Traffic Light Control Prototype Using PIR Motion and Microcontroller-Based Ultrasonic Sensors

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ABSTRACT

Traffic lights at crossroads help regulate the flow of vehicles so they can run smoothly and avoid congestion. One of the causes of traffic congestion is a traffic control light system that is not optimal because it still uses a fixed timer system, so the lights' duration is less efficient in its application. When the green light is on, the streets are deserted. But there is a traffic jam on another road. Therefore the concept of traffic light timing needs to be developed to get efficient timing. This study aims to create a traffic light control system that uses a PIR (Passive Infrared) motion sensor and an ultrasonic sensor based on the Arduino Mega2560 microcontroller based on the congestion level. The method used in this traffic control prototype is an experimental method of reading vehicle objects mounted with PIR sensors and ultrasonic sensors. This system can detect the movement of vehicles approaching a traffic light, measure the distance between the car and the traffic light, and set the timing of the light signal according to the level of congestion detected. This system has been tested using vehicle movement simulations brought closer to the PIR and ultrasonic sensors at different distances. The test results show the system can work properly and produce the light signal according to the detected traffic conditions. For its application to traffic lights in the future, it is feasible to help the traffic unit.

Keywords: *Traffic Light*, *Congestion*, *Ultrasonic Sensor*, *PIR Motion*, *Arduino Mega2560*

Introduction

Recently, the number of two- and four-wheelers have increased traffic. This situation can lead to congestion in busy urban areas [1]. At road intersections, there is often a density of traffic flow on the road, so traffic lights are needed to regulate traffic flow [2]. Traffic lights in Indonesia still mostly use timings for changing lights on with a fixed duration on each side and are also commonly regulated by the police on duty manually [3]. Sometimes this method is less efficient and effective when there is a road section at an intersection there is no crowded vehicle or no vehicles at all, which makes the driver have to wait a long time for the change time while there are no vehicles. Because of this, there is even a buildup of cars on other road sections. Then it is necessary to introduce traffic lights to create traffic with the right to move relatively and regularly [4].

The determination of the performance of traffic lights is currently regulated by the Minister of Transportation of the Republic of Indonesia, Number PM 49 of 2014, and the methodology is held in the Indonesian Road Vehicle Manual (MKJI) 1997. Once implemented, it was incompatible with the duration of traffic lights and the volume of vehicles that often change every time [5]. The duration of traffic lights is not adjusted when vehicle flow is dense at a crossroads, especially at certain times [6]. To solve this problem, a traffic light control device was created that was expected to solve congestion based on the density of vehicles in each lane of the road [7]. Desert lanes should have a longer green light duration than other roads [2]. Therefore, the author aims to create a tool that is used to regulate traffic lights based on the level of road density so that no time is wasted on green lights with empty road conditions while roads with congested road conditions get red lights. So, in each traffic lane, ultrasonic sensors are installed that are useful for detecting or reading the length of congestion in the street and using PIR Motion to detect or read vehicle movements in the lane. This is done to make the vehicle readings in that lane more accurate. The author uses an Arduino Mega microcontroller to design and develop this Traffic Light control tool. This microcontroller is a professional tool or the brain of a traffic light control device, while other modules that will be used in this traffic light control device itself are in the form of an ultrasonic sensor and PIR motion that functions to detect road conditions.

Based on previous research from [8], [9], who made a "Traffic Light Control System Based on Vehicle Density Using Image Processing," this research is designed to utilize image processing technology to process vehicle density data detected by camera sensors installed at each intersection. Furthermore, research from [10] and [5] which made "Design and Build Arduino-Based Traffic Light Control Three," this research is designed so that the intersection of three traffic lights is equipped with different rush hour settings every time and can be controlled with buttons so that they can be selected and adjusted.

Research from [11] which made "Design and Build a Traffic Light Control System Based on Vehicle Digital Image Recognition Using the Faster R-Cnn Method," this research was designed using the Faster R-CNN method, namely detecting vehicle objects in real-time on the highway where the system will calculate the number of vehicles on the road to determine the duration of green and red lights according to the level of density. And research [12][11][6] made the "Traffic Light Time Effective System by Utilizing CCTV ATCS (Auto Traffic Control System) and Background Subtraction Method" this research was designed using the Background Subtraction method and the Design and Creation methodology and waterfall development method resulted in a simulation system of traffic light operation by giving spare time green based on the degree (number) of the conditions of intersection density.

Based on research [13][14], who made a "Traffic Light Prototype with Adaptive Timing," this research works based on the results of camera footage then enters the mini PC and is processed by OpenCV (OpenSource Computer Vision Library) after the object is recognized, the results of this indicator are used as meaning in determining the time allocation at traffic lights[1].

In research carried out previously by researchers, the author tried to make a prototype tool for traffic light control that can divide the duration of the red traffic light into three conditions based on the congestion level or the length of the vehicle queue for the first normal state. The red light will be on for 30 seconds, then the form of a traffic jam, the red light will be on for 45 seconds, and the last one is empty, then the red light will light up for 15 seconds. It is hoped that this tool can help control traffic lights efficiently to reduce congestion at road intersections[15].

Research Methods

Stages of Research

I am completing this traffic light control research using an experimental method by making block diagrams and testing the system thoroughly. The following is a flowchart showing the research stages conducted in this study[14][1], [15]–[17].

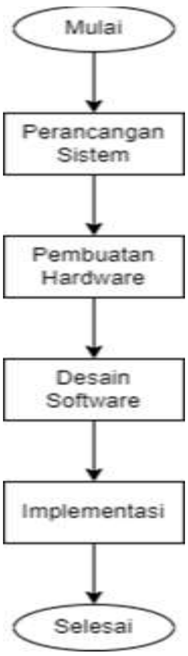

Figure 1. Stages of Research

System Design

The system's design consists of a block diagram and a flowchart of how the cross-light control prototype works. The traffic light control system method begins with making a block diagram divided into three stages, namely input, process, and output. This three-part process has an equally important function and requires particular components. Below is a picture of the block diagram of the traffic light control device:

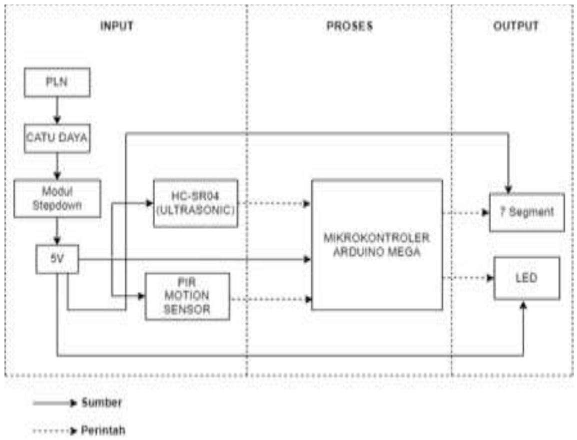

Figure 2. Block Diagram

The next step is to create a flowchart. Creating a flowchart is crucial because the stages of developing and building this tool are explained. Figure 3 is a flowchart of this study's traffic light control prototype.

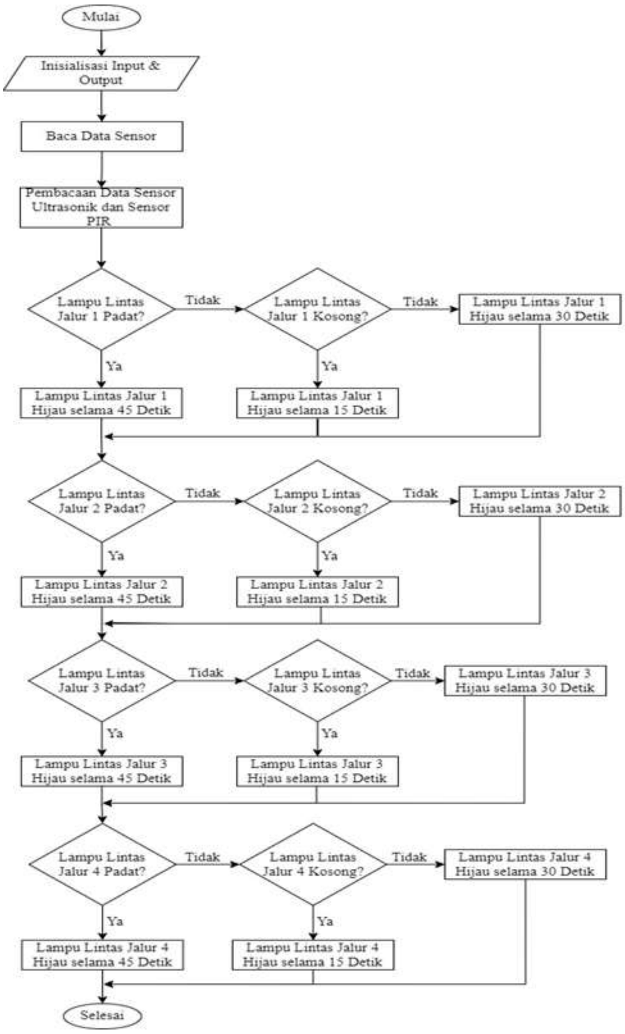

Figure 3. Traffic Light Prototype Flowchart

Results and Discussion

The results of the design of a traffic light control prototype device using PIR motion and microcontroller-based ultrasonic sensors.

Figure 4. Traffic Light Control Prototype Using PIR Motion and Microcontroller-Based Ultrasonic Sensors

PIR Motion Sensor Testing

PIR (Passive Infrared) motion sensors can be tested in detecting vehicles by installing the PIR sensor strategically and directing the sensor to the vehicle's path to be tested [16]. Then, perform vehicle movement in that lane and observe the response of the PIR motion sensor[17].

Table 1. PIR Motion Test Results

No	Ultrasonic Sensors in the Traffic Lane	Status	Ultrasonic Sensors	Case	Length of Detection	Information
1	Line 1	Detected	ON	10cm clearance	1 second	Succeed
2	Line 2	Detected	ON	9cm clearance	1 second	Succeed
3	Line 3	Detected	ON	8cm clearance	1 second	Succeed
4	Line 4	Detected	ON	10cm clearance	1 second	Succeed

PIR Motion Sensor Voltage Testing

Voltage testing of PIR motion sensors aims to determine the magnitude of the value or result of the tool that has been made to determine the success rate. In this test, there were eight tests of PIR motion sensors in each traffic lane.

Table 2. PIR Motion Sensor Voltage Test Results

No	PIR sensor to-	Legible voltage	Information
1	1	0,05	Object Detected
2	2	0,05	Object Detected
3	3	5	Undetectable Object
4	4	5	Undetectable Object
5	5	5	Undetectable Object
6	6	5	Undetectable Object
7	7	5	Undetectable Object
8	8	5	Undetectable Object

Ultrasonic Sensor Testing

By testing ultrasonic sensors in detecting vehicles, we can find out how well the sensors work in detecting vehicles at various distances and speeds so that they can be used to develop vehicle detection systems. When conducting tests, it is necessary to pay attention to several factors that can affect the performance of ultrasonic sensors, such as interference from objects other than vehicles that can cause interference.

Table 3. Ultrasonic Sensor Test Results

No	PIR Sensors in Traffic Lanes	Status	Sensor PIR	Case	Length of Detection	Information
1	Line 1	Detected	ON	10cm clearance	1 second	Succeed
2	Line 2	Detected	ON	9cm clearance	1 second	Succeed
3	Line 3	Detected	ON	8cm clearance	1 second	Succeed
4	Line 4	Detected	ON	10cm clearance	1 second	Succeed

Ultrasonic Sensor Voltage Testing

Testing on each ultrasonic sensor is carried out to ensure that all ultrasonic sensors can work adequately in detecting nearby vehicles to produce accurate data.

Table 4. Ultrasonic Sensor Voltage Test Results

No	Ultrasonic sensors to-	Legible voltage		Information
		Pin Echo	Pin Trig	
1	1	5	4,8	Object Detected
2	2	5	4,8	Object Detected
3	3	5	4,8	Undetectable Object
4	4	5	4,8	Undetectable Object
5	5	5	4,8	Undetectable Object
6	6	5	4,8	Undetectable Object
7	7	5	4,8	Undetectable Object
8	8	5	4,8	Undetectable Object

Conclusion

After conducting studies on relevant references, the prototyping of Traffic Light Control Using PIR Motion and Microcontroller-Based Ultrasonic Sensors can be realized and work based on the density of road queues as expected. PIR motion sensors and ultrasonic sensors are placed on each section of the road to detect vehicles to set the duration of traffic lights based on road conditions. The period of the green light time can be determined based on the predetermined road conditions. There are three conditions on this prototype, namely: empty, average, and stuck. Pear motion sensors and ultrasonic sensors placed on the side of the road will detect vehicles according to these conditions. If the sensor detects traffic jam road conditions, the green light lasts 45 seconds. If the sensor detects normal conditions, then the duration of the green light is 30 seconds, while if the sensor detects empty streets, then the time of the green light is 15 seconds, which can be changed as desired. So that this tool can be a solution to congestion at road intersections because it can minimize waiting times and queues of vehicles that are waiting for traffic lights to change. The limitations of this tool are the possibility of false positives and false negatives, namely PIR motion sensors and ultrasonic sensors that are triggered by the interference of passing pedestrians or wild animals that start the sensor, as well as the limited range of sensors so that they cannot be used at intersections with roads that are too wide. The possibility of a power outage causes the system to stop functioning, thus requiring backup power such as solar panels.

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