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Smart Traffic Light System Using Euclidean Distance Algorithm To Improve Traffic Efficiency In Small Villages

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ABSTRACT

The traffic management system that exists at traffic intersections on small roads does not have the ability to provide time efficiency in driving and the uncertainty of waiting time at intersections causes drivers to commit traffic violations and decrease productivity. At the intersection of the village area, it was found that vehicle drivers often queued at the intersection but there was no effectiveness in optimizing waiting time according to the volume of vehicles queuing in the next lane because the traffic light system used was still conventional. This research develops a Smart Traffic Light system that can optimize traffic flow at small road intersections on the edge of the city or connecting traffic lanes between villages using the Euclidean Distance method for vehicle density analysis. The system will utilize Infrared (IR) sensors placed at a certain distance to detect the presence of vehicles in every lane. The system can adjust the duration of the green light based on the infrared sensor readings in real-time. Data from the sensors is analyzed using the Euclidean Distance calculation method to determine traffic density conditions based on three clusters, namely quiet, medium, and crowded conditions. Every first 1-2 infrared sensors read will produce a 10-second green light, 3-4 infrared sensors read will produce a 20-second green light, and 5-6 infrared sensors read will produce a 30-second green light. Using this method, traffic conditions can be inferred according to the total number of infrared sensors read.

1. INTRODUCTION

Rapid population growth and an increase in the number of vehicles have resulted in significant traffic congestion, especially at road intersections[1]. In recent years, the Smart City concept has encouraged the integration of information and communication technology (ICT) into various aspects of urban life, including traffic management[2]. The Smart Traffic Light System emerges as an innovative solution that combines sensors, intelligent algorithms, and real-time connectivity to improve traffic efficiency at major intersections in city center points. The system aims to reduce vehicle waiting time, and improve road safety[3][4]. However, the Smart Traffic Light system is still not prioritized for small road intersections that are not city center traffic lanes. The existing traffic management system at small road traffic intersections does not have the ability to provide time efficiency in driving and the uncertainty of waiting time at intersections causes drivers to commit traffic violations and decrease productivity.

In previous research, the use of traffic light systems utilizing the use of sensor algorithms in reading traffic conditions can automatically reduce vehicle waiting time by 25% compared to conventional systems[5]. In addition, a smart traffic light management system utilizing the use of sensors or calculation algorithms can increase the efficiency of vehicle flow by 30% and reduce carbon emissions resulting from vehicle congestion on traffic lanes[6]. According to [1] Smart Traffic Light is a traffic light system that uses intelligent technology to regulate and optimize vehicle flow at road intersections. This system is different from conventional traffic lights because it is able to adapt dynamically to the surrounding traffic conditions. The technology used in this system generally involves sensors, cameras, and artificial intelligence (AI) algorithms to detect vehicle density, waiting time, and also a need to adjust the traffic light cycle in real-time[7][8]. Using algorithmic methods and the use of sensors such as infrared or the use of cameras can produce smart traffic light systems that are able to analyze traffic density conditions by providing decisions on the effectiveness of the length of waiting time at traffic intersections[9][10]. One of the use of calculation methods in analyzing vehicle density the distance between two variables is Euclidean Distance which is one of the calculation methods in the K-Nearest Neighbors algorithm[11][12][13].

Based on existing problems and the development of previous research, the authors developed a Smart Traffic Light system that can optimize traffic flow at small road intersections on the edge of the city or connecting traffic lanes between villages using the Euclidean Distance method for analyzing vehicle density conditions. This system will utilize Infrared (IR) sensors to detect vehicles queuing in each lane. The system uses 6 sensors on each lane of the road intersection. Infrared sensors (IR) can detect vehicles queuing at traffic intersections and produce the length of time for traffic lights according to the sensor readings[14][15]. The system also uses Arduino atmega 2560 as its microcontroller. Arduino atmega is used because it has many input ports that can accommodate the number of sensors used [16][17].

The reading data from the Infrared (IR) sensor will be analyzed using the Euclidean Distance calculation method to determine traffic density conditions and set the duration of the green light sequentially based on three clusters, namely quiet, medium, and congested conditions. Determination of clusters in the Euclidean distance method is used to determine groups in the range of each variable to be counted. [18][19]. By using this method, traffic conditions can be inferred according to the read counts of the infrared sensors. The contribution of this research is expected to provide a more efficient traffic system for motorists at the village

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road intersection in traffic lane congestion conditions with more effective traffic light waiting time. This research is also expected to be one of the references in the development of intelligent traffic light systems in future research.

2. METHODS

The authors designed a smart traffic light system for small village intersections. This system uses 24 infrared (IR) sensors on 4 intersection lines that can produce more comprehensive sensor reading data output in detecting vehicles. Every line has 6 infrared (IR) sensors placed at each distance length that has been determined. Then, the system will use the Euclidean Distance calculation method in traffic line density conditions as a form of analysis of the results of the system program decisions made in the form of green light duration on the intersection line. Using 24 infrared sensors allows the system to produce more intense decisions and the analysis of the proof of the sensor readings can be validated with the traffic density conditions with a specified range of distances.

2.1. Material

Figure 1 is a circuit design of a smart traffic light system at a small village road intersection. The system uses an Arduino atmega 2560 microcontroller that can integrate the output of 24 infrared (IR) sensors in the process of sending data on the results of reading the density of vehicles that line up in the traffic lane. Arduino atmega 2560 microcontroller has the benefit of other microcontrollers in the form of many input legs so it can integrate the components needed to create a system. [20]. LCD I2C is used as a monitor of the sensor reading results in the form of road density levels according to the number of sensors reading existing vehicles. The results of sending data will produce output in the form of the length of time of the green light according to the density conditions of each traffic lane. In **Figure 2**. Is a prototype design of the system made. Every infrared (IR) sensor is placed at a certain distance as an example in the picture.

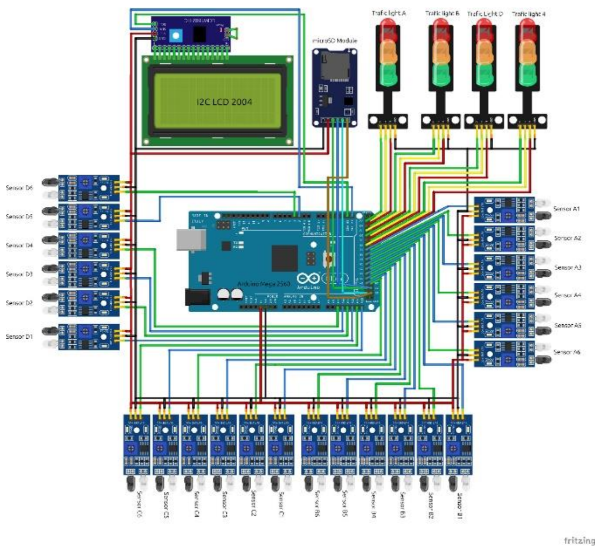

Figure 1. Circuit design of 4- line smart traffic light

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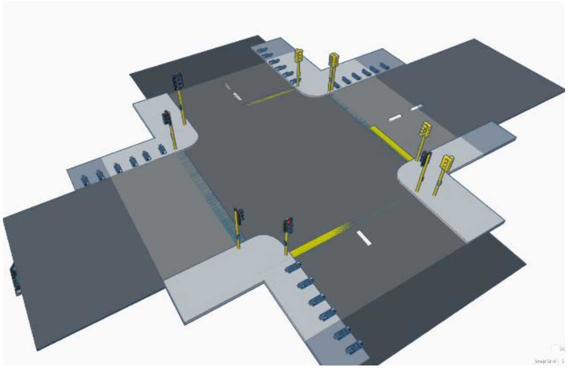

Figure 2. Design Prototype of Smart Traffic Light

Table 1. position of sensor on every line

Sensor Infrared (IR)	Position of sensor from the base of the line	Condition of traffic density (Cluster)	The range of distance in each Cluster
IR1	2 cm	C_1 (Quiet)	0 – 15 cm
IR2	10 cm		
IR3	20 cm	C_2 (Medium)	15 – 35 cm
IR4	30 cm		
IR5	40 cm	C_3 (Crowded)	≥35 cm
IR6	50 cm		

The system is designed with 6 IR sensors that are placed in each line (Line A, B, C, and D) with the distances of each IR sensor placement have been determined according to the three clusters for vehicle density conditions on the line which can be seen in **Table 1**.

2.2 Method

Figure 3 illustrates the process flow of the smart traffic light system. The research process in developing the Smart Traffic Light system begins with the System Initialization stage, where all preparations are made to operate the components (Microcontroller, IR, I2C LCD, and LED) optimally. Next, the system starts reading data from the infrared (IR) sensors installed on each lane to detect the amount of vehicle density present. The IR sensor sends a signal based on the presence of vehicles detected by the IR sensor at the IR sensor installation point according to the distance that has been determined in each lane (A, B, C, and D). The microcontroller will display the reading results on the I2C LCD and at the same time the system will set the duration of the LED lights as traffic lights in each lane of the intersection according to the reading results of each sensor installed in each lane. I2C LCD components are used as monitoring sensor readings when the system is working. With LCD I2C the author does not need to open a serial monitor when taking data[21]. After the system gets the data from the high (1) or low (0) readings on each infrared sensor, the author can use the Euclidean Distance calculation method to analyze the level of traffic density conditions. The duration of the traffic light is then set according to the reading results of each detected infrared sensor.

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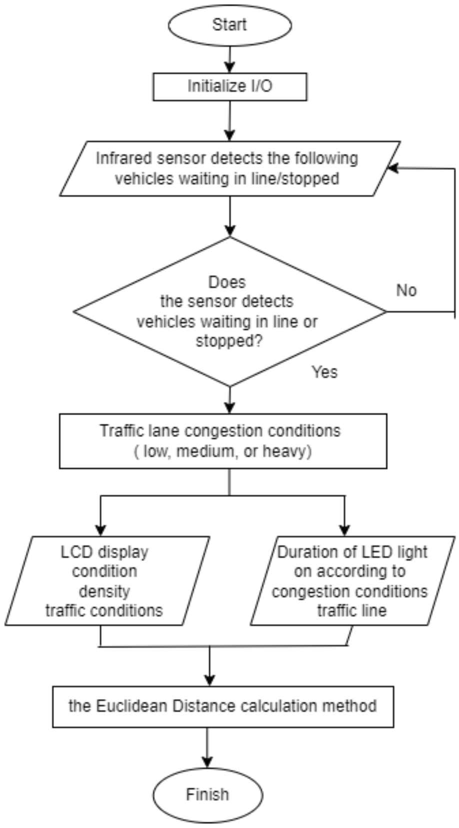

Figure 3. Flowchart diagram of traffic light system.

2.3 Evaluation
2.3.1 Accuracy

Calculation of the distance between one location and the other used the Euclidean Distance algorithm. This algorithm is related to the Phytagoras theorem and is commonly applied to dimensions 1, 2 and 3. Euclidean Distance is a method of finding the proximity of the distance value of 2 variables[22][23]. Before doing calculations using the Euclidean distance formula, 2 variables as a point of proximity value must be determined first[24].

According to [25] the basic formula of Euclidean Distance in one-dimensional space is:

$$d\ (x, y) = \left|\sqrt{(x\ - y)^2}\right| \quad (1)$$

With the system that will be created in this research, x and y are two variable points used to analyze the condition of the nearest traffic flow from one of the clusters (low, medium, and congested) according to the results of the readings of 6 sensors placed at a certain distance in each lane of the intersection. Variable x is the total number of readings from 6 infrared (IR) sensors on one line. Meanwhile, variable y is the condition of the density of intersection lanes that have been determined in the form of three clusters, namely the low, medium, and congested condition clusters. The three clusters have been determined how many infrared (IR) sensors are read according to the determination of the traffic lane density conditions.

For example, the program system of the tool to be made in this study will produce input in the form of sensor readings of the presence of an object or the vehicles queued on the traffic

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line, then the reading results on each infrared sensor will be processed and output in the form of the length of the green light on each line of the intersection in accordance with the program made. The duration of the green light in each line is adjusted to the program's determination of the high or low condition when reading the infrared sensor from the first 1-2 infrared sensors in high condition for a 10-second green light, 3-4 first infrared sensors in high condition for a 20-second green light, and the first 5-6 sensors in high condition for a 30-second green light. In the research that will be made, the system cannot analyze the density conditions at the intersection so that it requires the calculation of Euclidean Distance as an analysis method in the form of three clusters, namely traffic density conditions in the form of low, medium and congested which have been determined.

The calculation using the Euclidean distance algorithm method can be see in the case example of the conditions of one of the traffic lanes (A) with the reading results of the Infrared sensors (IR1; IR2; IR3; IR4; IR5; IR6), the value is (1; 0; 0; 0; 0; 0) with a value of 1 as High which indicates that the infrared sensor has detected a vehicle that queues. While the value of 0 as Low indicates that the infrared sensor does not detect any queued vehicles. If IR1 and or IR2 is 1, the traffic light system will produce output in the form of vehicle density conditions in the form of C1 (Quiet) and the duration of the green light on the traffic light is 10 seconds. So as to analyze the condition of the traffic line density according to the results of infrared sensor readings can be calculated in the following way;

x = results of infrared sensor readings on one traffic lane

y = the total number of detected infrared sensors in each cluster

$$d\,(x, y) = \left|\sqrt{(x\ - y)^2}\right| \tag{2}$$

After doing the calculation using the Euclidean distance method, the analysis of density conditions on the traffic line can be determined according to the total number of infrared sensors that detect queued vehicles. In the example above, the density conditions can be included in the first cluster, which is quiet, because of the three clusters, the first cluster value results in fewer calculations than other clusters.

3. RESULTS AND DISCUSSION

3.1. Results

The created system results in the design of a device in the form of a 4-lane prototype smart traffic light intersection. Every lane is given 6 infrared sensors. The prototype design can be shown in **Figure 4** below;

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Figure 4. Prototype of smart traffic light

After designed a smart traffic light prototype using 24 infrared sensors, the author carried out testing of the device that has been designed whether the performance of the device is in accordance with the smart traffic light system desired. **Table 2** is the result of device testing on the system.

Table 2. Results of device testing on the system

Device	Projection	Results Yes/ No	Description
Atmega 2650 microcontroller	Connected to a computer	Yes	Success
	Connected to serial port	Yes	Success
	Connected to infrared sensor	Yes	Success
	Connected with serial communication	Yes	Success
	Connected to Traffic Light Module	Yes	Success
	Can display data from the serial monitor program	Yes	Success
LED Traffic Light	As a traffic light	Yes	Success
LCD I2C	Monitoring output in form of duration of green light on	Yes	Success
Infrared Sensors	can detect objects in front of the sensor	Yes	Success

When taking data, the author at the same time measures the voltage on all sensors to determine the sensitivity of every sensor in detecting a stopped or waiting vehicle at a road intersection. **Table 3** below is the result of measuring the voltage generated by each sensor infrared in the presence or absence of a stopped vehicle. When the sensor detects a vehicle queuing or stopping, the sensor will be High / active with a voltage range of (4.1-4.3V). When the sensor does not detect the presence of a queued or stopped vehicle, the sensor is Low/inactive with a voltage range of (0.2-0.6V).

Table. 3 the result of voltage measurement for infrared sensors

Pattern	Traffic Line	Voltage Measurement for infrared sensors (Volt)					
		IR_1	IR_2	IR_3	IR_4	IR_5	IR_6
1	A	4,2V	4,3V	4,3V	4,2V	4,2V	4,2V
	B	4,2V	4,2V	4,2V	4,1V	0,3V	0,3V
	C	4,3V	4,2V	0,2V	0,2V	0,3V	0,6V
	D	0,2V	0,3V	0,3V	0,3V	4,1V	0,3V
2	A	0,3V	0,2V	0,2V	0,2V	0,3V	4,2V
	B	0,4V	4,3V	0,6V	0,3V	0,2V	0,3V
	C	0,3V	4,2V	4,1V	4,2V	0,3V	0,2V
	D	4,2V	0,3V	0,2V	0,2V	0,3V	4,1V

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In the research results, the authors collected data by sending data two times from the readings of every infrared (IR) sensor that has been placed at a certain distance on 4 traffic intersection lanes. The data transmission is processed by the microcontroller and produces output data in the form of green light time duration in each traffic lane. The system will operate the traffic lights sequentially from lane 1 to lane 4, with the current lane getting a green light while the other lane will get a red light. The following **Table 4** shows the results of the sensor readings on each traffic lane and the output data results in the form of traffic density conditions along with the length of time the green light is on. The data in the **Table 4** is accompanied by the results of the calculation of the Euclidean distance method as a method for analyzing traffic density conditions according to the number of infrared (IR) sensors detecting the presence of vehicles when queuing at traffic intersections.

Table 4. Result of Infrared (IR) sensors detection

Pattern	Traffic Line	Infrared (IR) Sensors						Duration Of Green Led	Euclidean Distance Result
		IR_1	IR_2	IR_3	IR_4	IR_5	IR_6		
1	A	1	1	1	1	1	1	C_3 (30 s)	C_3
	B	1	1	1	1	0	0	C_2 (20 s)	C_2
	C	1	1	0	0	0	0	C_1 (10 s)	C_1
	D	0	0	0	0	1	0	C_3 (30 s)	C_1
2	A	0	0	0	0	0	1	C_3 (30 s)	C_1
	B	0	1	0	0	0	0	C_1 (10 s)	C_1
	C	0	1	1	1	0	0	C_2 (20 s)	C_2
	D	1	0	0	0	0	1	C_3 (30 s)	C_1

Table 4 is the result of data collection with two data sending patterns in the form of the reading results of each infrared sensor against the density conditions of the traffic intersection. The creation of a smart traffic light system using infrared sensors as a detector of the density of vehicles queued at traffic junctions produces output in the form of the duration of time the green light is on. This system has been integrated into a predetermined cluster of traffic density conditions.

By using the Euclidean distance calculation algorithm method, the analysis of vehicle density conditions can be determined according to the number of infrared sensors in detecting vehicles queuing at a certain distance. It can be viewed in **Table 2**, there is an output from the smart traffic light system in the form of determining the density condition cluster is not the same as the calculation results using Euclidean Distance. This is because the determination of every sensor that is grouped into clusters of traffic density conditions cannot be concluded as an actual traffic density condition. So that the use of the Euclidean Distance method can help the author in analyzing traffic density conditions when there are stopped or queued vehicles with the initial distance state still empty or the previous sensor does not detect any vehicles queuing on the traffic lane.

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4. CONCLUSION

The design of a smart traffic light system at rural road intersections using the Euclidean Distance algorithm method has successfully collected data according to the condition of queued vehicles and can be detected by each infrared sensor placed at a certain distance. This system uses 24 infrared sensors to facilitate the reading of vehicle density conditions that waiting in line at traffic intersections. With the data from the reading of every infrared sensor, it can be used to analyze the condition of the vehicle density according to the three clusters that have been determined. The total number of infrared sensors in detecting queued vehicles affects the results of the Euclidean Distance algorithm calculation in determining the density conditions of the traffic lane.

For future research, it can develop a smart traffic light system that can be used at road intersections, especially in villages by using data storage either website-based or data loggers, so that traffic conditions at intersections can be monitored regularly.

5. ACKNOWLEDGMENT

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6. AUTHORS' NOTE

This research examines the application of Smart Traffic Light Systems using the Euclidean Distance algorithm to improve the efficiency of traffic flow in small villages. The opinions, analysis, and conclusions are the authors' responsibility and remain free from plagiarism. The authors also declare that there is no conflict of interest related to the publication of this article.

7. AUTHORS' CONSTRIBUTOR ROLE

Khoirotun Uswah: Conceptualization, Methodology, Writing Original Draft, Investigation, Formal Analysis, Review & Editing, Software Review & Editing.

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