International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 1 (2018) pp. 434-441

A Proposed Design of Traffic Congestion Prediction Using Ultrasonic Sensors

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Abstract

The growing and increasing use of transportation equipment on the congestion on the road is difficult to avoid. Even in big cities, congestion has become a common sight everyday which of course will reduce productivity. The development of transportation equipment increasingly rapidly so as to facilitate the use of appropriate transportation needs. This development also refers to the growing use of transportation so that the impact on congestion on the roads

In this research, the design of traffic congestion monitoring tool with case study of Bandung city. This tool will provide the speed that can be processed by the system to determine the state of the road. Installation of this tool in some roads will provide real time information to road users so it will provide information that can be input to make decisions in choosing the path that will be passed.

Keywords: Ultrasonic Sensor, Traffic Information System, Intelligent Transportation System, Sensor speed of vehicles, Arduino

INTRODUCTION

The development of transportation equipment increasingly rapidly so as to facilitate the use of appropriate transportation needs. This development also refers to the growing use of transportation so that the impact on congestion on the roads.

The rapid economic growth and growth rate of vehicles is one reason for the occurrence of traffic congestion. Traffic congestion is an increasingly serious problem for road users. Congestion is everywhere in the world, especially in big cities. Congestion can be defined as traffic demand exceeds road capacity [7].

In metropolitan city, the number of vehicles that exceed the maximum capacity of the highway can cause traffic congestion. In the crowded hours, many of the people who use the road, the problem of congestion will not be solved by itself. It is impossible for the government to adjust the program for road improvement with an unlimited trend of road user's growth [12].

Lack of information received by road users led to wrong decisions in choosing a road route that impacted the increasingly prolonged traffic congestion.

In 39 major cities in the United States with a population of 1 million or more, with a third of all vehicle travel occurs under solid conditions where the average velocity is half the value of free flow. It is estimated that half of the heavy traffic occurs in an expressive manner, causing more than a half-minute delayed per kilometer traveled. Other residuals use other roads that stop up to 1 minute 12 seconds per kilometer on every trip. It is estimated that 75 million road users have licenses in areas with high density, each having an average delay of 16,000 kilometers a year in the region, there are 1.2 trillion kilometers of road users in major cities, number reaches a total delayed of 6 billion hours [10].

Technological developments in this era of globalization is very rapid, many technologies that can help facilitate and accelerate in solving a problem by providing useful information.

Intelligent transportation systems have many benefit in everyone's life [3] [13]. ITS has been widely used in everyday life, ranging from road safety [14] to emissions reduction [15]. With this system, tourists can make better planning trips to avoid traffic congestion. As a result, time and energy consumption can be reduced. Using intelligent traffic information systems, Bangkok can reduce up to 75% of congestion during peak hours [1].

In this research will be design tool for traffic congestion information system on the main road using Arduino-based ultrasonic sensor, which will provide information for drivers in the form of traffic congestion information, and other alternative routes. So that drivers are not stuck in traffic when driving.

This research aims to create a tool that can detect the occurrence of congestion, which on the tool can calculate the speed of the car, conclude the bottleneck, and send information in real-time.

RELATED WORKS

In this study, an analysis of the benefits of using the technology of real time traffic information system in providing information to prospective users of toll road, about the condition of toll road traffic in real time. So that with the information the user of the road can determine the choice whether to use the toll road or arterial road to achieve the purpose of his journey [2].

To reduce traffic congestion, it is necessary to simulate and optimize traffic conditions and improve transportation management. There are various ways to monitor and analyze traffic conditions using video monitoring and monitoring systems, or the use of sensors that enable real-time traffic monitoring. [4].

Predicting the speed of travel on the main urban road is a tough job, but getting important information in the application of the current ITS application. A loop detector with an AVI system has been used in the past that can get an approximate duration of travel, but the performance of this method is not sufficient. The project has already begun in South Korea, which directly collects and provides road conditions to users on the streets. UTIS at this time has been used in 31 cities in Korea [8].

This paper highlights the multi-modal design of ITS using cellular networks and GPS probe to reduce infrastructure requirements, and accurately predict traffic conditions in real time [11].

The given system can be a new way to see traffic flow that can help improve road conditions and minimize resources. Transportation department can be used to get real-time traffic information, so it can to estimate traffic jam and can reduce the number of vehicle accidents so that it can provide security on the road. IoT will provide a crucial role in traffic regulation that is useful for improving road conditions and as well as safety in traffic, and reducing management burden [16].

In this study, it is proposed the use of LED traffic lights for traffic information systems. It has designed SA as well as evaluated its use. The receiver position, angle, and field of view (FOV) affect the LOS path., and the tendency of the receiver vertical. The SA design uses these parameters and evaluates each performance by studying the numbers. It was found that SC-BPSK was effective. It could be in pairs of receivers with acceptance 5 and can be achieved on SA. By the ratio of the amount of information provided by the system proposed to that given by the optical beacon (160 Kbit), the lowest value of 207 Kbit more and the highest value of 3.56 Mbit about 22 times. If the traffic lights are not yet 75 m from each other, they will not be connected. Mercel optics must be placed on each path, whereas on the proposed system can deliver traffic on traffic lights. In addition, the proposed system uses a power supply to output the visual signal from the beam of light [17].

In this article, presented a new type of wireless sensor a useful platform for urban traffic flow and flood monitoring, complemented by a processing algorithm that allows for monitor both phenomena simultaneously. The proposed sensor consists of ultrasonic rangefinder and infrared temperature sensor [19]

BASIC TEORY

Ultrasonic

Ultrasonic sensor is basically a distance measuring sensor, ultrasonic sensor consists of transmitter unit and ultrasonic wave receiver unit. In ultrasonic wave sensors are generated through a device called a piezoelectric with a certain frequency. Piezoelectric will produce ultrasonic waves when an oscillator is applied to the object. In general this tool will fire ultrasonic waves into an area or a target, after the wave touches the target surface, then the target will reflect back the wave. Ultrasonic sensor HC-SR04 is ultrasonic sensor that very popular to be used, because it has a distance of up to 400 cm / 4 meters jet and the price is relatively cheap and easy to apply. The use of ultrasonic sensors in data delivery in real time can save the usage of bandwidth servers in the reception and delivery of data, so that will make the use of data networks less and more quickly in receiving data.

Ultrasonic waves generally reside at frequencies exceeding 20 kHz. The ultrasonic wave velocity is influenced by several things including air temperature, its speed can be formulated:

Ultrasonic wave velocity=331.5 m/s+(0.61 x temperature) [6]

The position of the angle of the ultrasonic sensor is affected by the ultrasonic frequency, for example, the angle of the sensor spread increases and the ultrasonic frequency decreases.

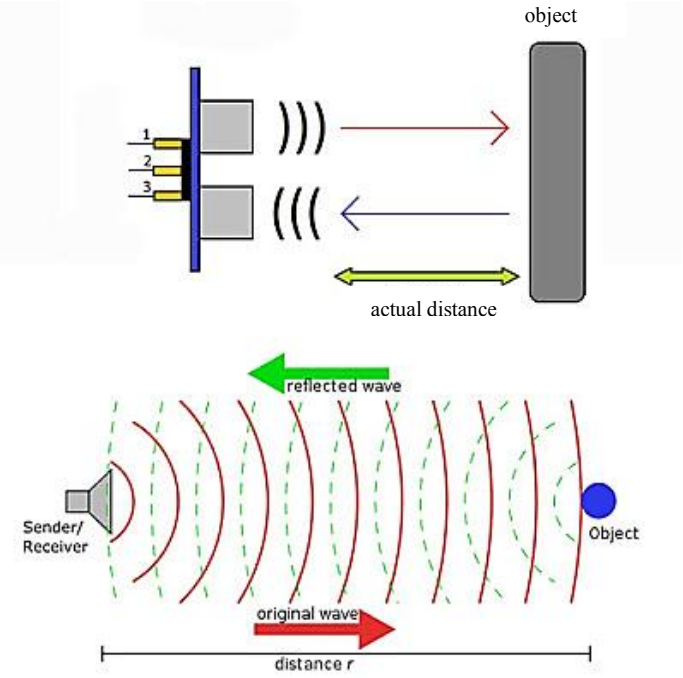

Figure 1. Ultrasonic Wave

Characteristics of ultrasonic waves can be considered when creating and designing systems for vehicle detection. Ultrasonic wave velocity with air temperature affects the detection interval of ultrasonic sensors [6].

Speed is the vector quantity that indicates how fast the object moves. The magnitude of the vector is expressed in meters per second (m / s). According to Ministerial Decree 14 of 2016 on Management and Traffic Engineering on the Road: Speed is the ability to travel a certain distance in units of time, expressed in kilometers / hour.

To calculate the speed of the vehicle can use the formula:

$$V = S / \Delta t$$

Where:

V = speed of vehicle (km/h, m/s)

S = distance traveled (km, m)

Δt = total time required, t2-t1 (h, s)

To determine the speed of the vehicle then used two ultrasonic sensors that are within 5 meters on a microcontroller. The first sensor will await the reflection of the passing vehicle, when the first sensor receives the reflection, the microcontroller will begin to calculate the reflection time of the first sensor (t1) until there is a reflection on the second sensor (t2), so that the total time required.

ESP8266

ESP8266 is a chip created to create a wireless micro controller module. ESP8266 is used to send data from Arduino Uno microcontroller to webserver Geeknesia so that data from microcontroller can be accessed by car application. ESP8266 has 8 pins, i.e. pin GND, GPIO2, GPIO0, RX, TX, CH_PD, RST, and VCC, but on this tool only 5 pins are used GND pin, VCC, CH_PD, TX, and RX.

Arduino Uno

Arduino Uno is an ATmega328-based microcontroller consisting of 14 input and digital output pins, of which 6 pins are pwm output, 6-pin analog input, 16 MHz resonators, USB connections, power supplies, ICSP headers and reset buttons.

Arduino Uno is different from previous types because it does not use the FTDI USB-to-serial driver chip. Instead, the Atmega16U2 (Atmega8U2 to R2) feature is programmed as a USB-to-serial converter.

Arduino Uno can use the battery or directly from the USB port.

To turn on Arduino Uno can be through a variety of ways, among others, connected to a USB port or can use a power supply where it can choose a power source.

In mode with USB cable is power coming from USB port power supply on computer (personal computer / laptop) equal to ± 5V. Pin 5 V is the output of the regulator on the Arduino UNO board and Pin GND serves as ground.

In non-USB external mode the power can come from either the DC AC adapter or the battery. The Arduino UNO can operate at the recommended input voltage range of 7-12 V.

Arduino Uno has a number of facilities to communicate with computers, other Arduino, or other microcontrollers. ATmega328 provides UART TTL (5V) serial communications, which are available on digital pins 0 (RX) and 1 (TX). The ATmega16U2 on board transmits this serial communication via USB and appears as a virtual com port to the software on the computer. Firmware '16U2 uses a standard USB COM driver, and no external drivers are required. However, on Windows, a .inf file is required. The Arduino software includes a serial monitor that allows simple textual data to be sent to and from the Arduino board. LED RX and TX on board will blink when data is sent via USB-to-serial chip and USB connection to computer (but not for serial communication on pins 0 and 1). A Software Serial library allows serial communication on one of Arduino Uno's digital pins.

ATmega328 also supports I2C (TWI) and SPI communications. The Arduino software includes the Wire library to simplify the use of I2C buses; for SPI communications, use the SPI library.

Arduino Uno can be programmed with Arduino software. ATmega328 in Arduino Uno is equipped with a bootloader that allows uploading new code into it without using an external hardware programmer. Another way to program a microcontroller is through an ICSP (In-Circuit Serial Programming) header using an Arduino ISP or something similar.

Intelligent Transportation System

Intelligent Transportation Systems (ITS) have been considered important technologies to mitigate urban traffic congestion. Accurate traffic prediction is one of the critical steps in the operation of an ITS [9].

Intelligent Transportation System (ITS) has the basic purpose of creating a transportation system that can help transportation users and transport users to:

a) Getting information,

b) Simplify transactions,

c) Increase the capacity of infrastructure and transportation facilities,

d) Reduce congestion and queue,

e) Improve security and comfort,

f) Reduce environmental pollution, and

g) To streamline transportation management.

In principle of ITS is the application of advanced technology in the field of electronics, computers and telecommunications combined with the principle of strategy management to improve the overall transportation function. This system is able to provide information to the owner of goods or passengers and transport operators in such a way that the transportation process can run effectively and efficiently. In addition, ITS is also able to provide real-time information. Some examples of ITS applications that have been proven to increase the effectiveness and efficiency of transportation are transit system, vehicle / fleet management system, emergency and security system, electronic payment, traffic management system and others. In order to understand more about ITS, its necessary to understand first the potential function of ITS of 4 (four) key components that will form this system. The four components are vehicle, user, infrastructure and communication system.

Several categories of scope of ITS :

a) Advanced Traveler Information System, in principle is the information system which guides the vehicle to get an optimal road route.

b) The Advanced Traffic Management System is used by road managers to monitor traffic and provide real time information to road users.

c) Incident Management System is an information system used for various emergency events, such as accidents, landslides or other disasters.

d) Electronic Toll Collection System The classic problem on the toll road is the length of time it takes for customer transactions at toll gates.

e) Assistance For Safe Driving is a very advanced form of ITS. The vehicle is equipped with a number of sensors that can steer the driver safely.

f) Support for Public Transportation, this type of ITS is applied to common transportation modes, for example: bus / truck, ship, ferry and airplane.

THE PROPOSED SYSTEM DESIGN

Modified ultrasonic sensor function, which was originally a sensor to measure the distance to the sensor for measuring the speed of vehicles to be used as a parameter to determine whether there is congestion of road conditions or not. In general, ultrasonic sensors will fire ultrasonic waves into an area or a target, after the waves touch the target surface, the target will reflect back the wave. The concept is used to detect the speed of the vehicle passing through the road when the appliance is installed, on one sensor device used there are two sensors with a distance between the sensor 5 meters, the first sensor reflects the wave and when the wave is received then the microcontroller will start to count the time required until the second sensor get the reflection of the wave, so it can be calculated vehicle speed is the distance between sensors (5 meters) divided by the time obtained from the calculation of microcontroller.

In designing a traffic congestion detection tool. The device uses an ultrasonic sensor HC-SR04 to detect the presence of objects in front of it, Arduino as microcontroller, Wi-Fi module ESP8266 to send data information to the database server, Figure 2 shows the block diagram of the system using ultrasonic sensor as input. Ultrasonic sensors as data input in the form of time difference of vehicle passing in front of tool. Data from ultrasonic sensors will be processed by Arduino microcontroller to produce vehicle speed output, then the data will be forwarded to the cloud server of Geeknesia so it can be accessed in the mobile application. The main components of this system are;

- Microcontroller: The microcontroller used in this tool is Arduino Uno. Arduino Uno becomes the main device of all input and output devices used in this system. Arduino Uno is connected with sensor, ESP8266 and power supply. For Arduino Uno power supply using power bank solar cell.
- Sensor: Sensors used are ultrasonic sensors that are modified into sensors to detect vehicle speed, Ultrasonic sensors used are HC-SR04 which has a range of 400cm (4 meter). Ultrasonic sensors used there are 2 pieces, where each sensor has a different function but has a linkage. Ultrasonic sensor has 4 pins, i.e. pin GND, ECHO, TRIG, and VCC.
- Wi-Fi module: Wi-Fi module used is esp82366, is a chip made to create a wireless micro controller module. ESP8266 is used to send data from Arduino Uno microcontroller to webserver Geeknesia so that data from microcontroller can be accessed by mobile application.
- Wireless Cellular Modem: The IoT concept is incorporated by using an embedded cellular modem that handles all communications using a Machine-to-Machine (M2M) connection over 4G networks [5]. Modem used is internet modem from provider Smartfren..

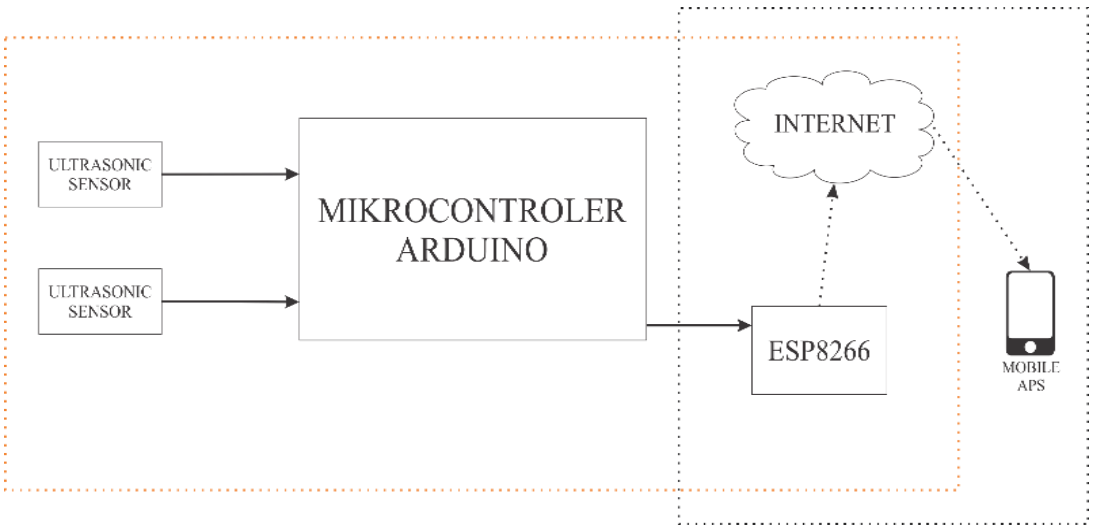

Figure 1. The Proposed Block Diagram

In the figure 3 beside flowchart diagram can be explained that this system there are two ultrasonic sensors that stand alone. When the vehicle passes through the ultrasonic sensor A then the system will start to calculate the time until the vehicle passes ultrasonic sensor B, the determination of the state of the road congestion is by speed factor, where the congestion limit is the speed of vehicle <10 km / h stated jammed.

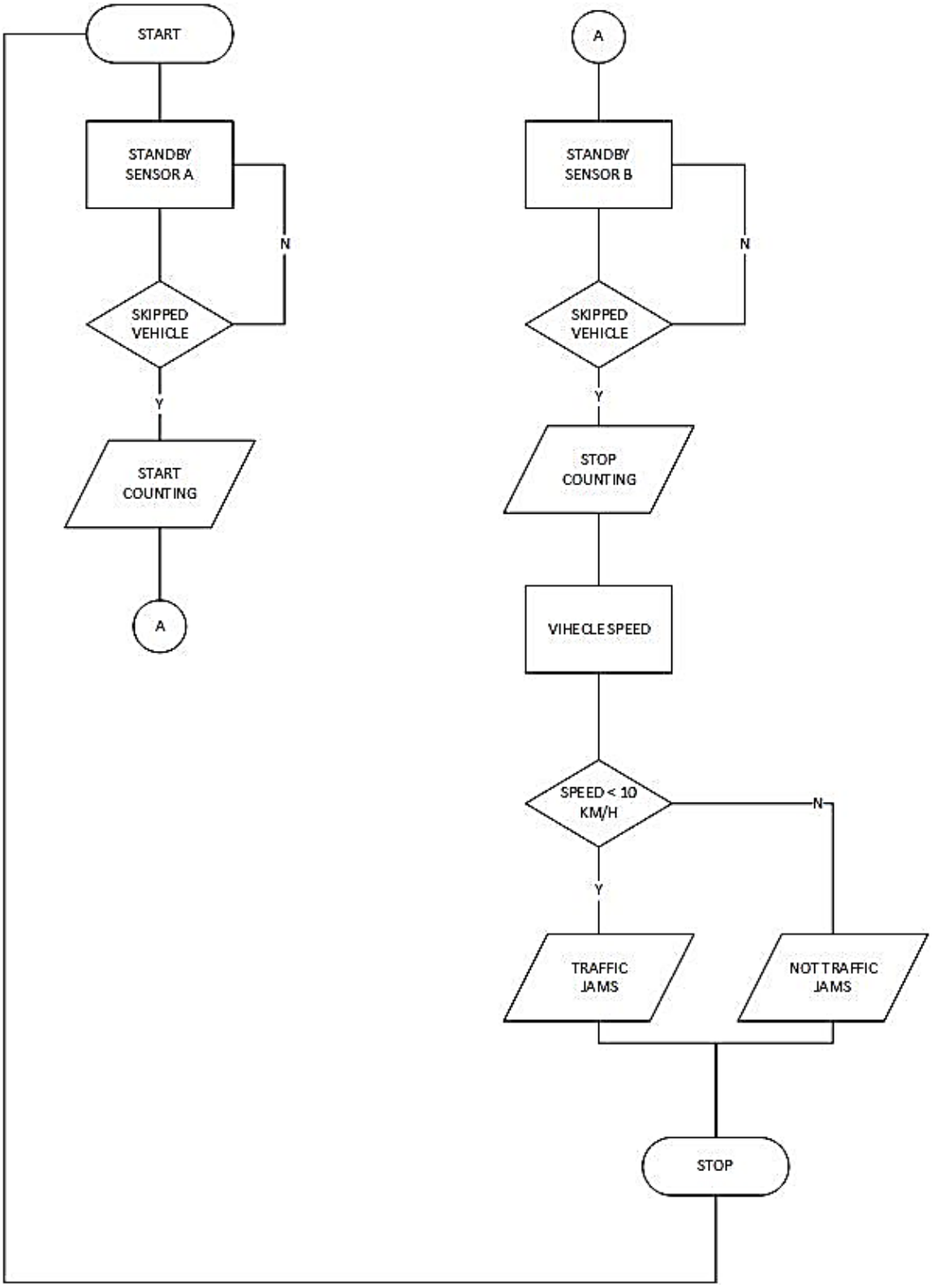

Figure 2. The Proposed Flowchart System

Configuration pin on Arduino Uno microcontroller connected with ultrasonic sensor as follows,

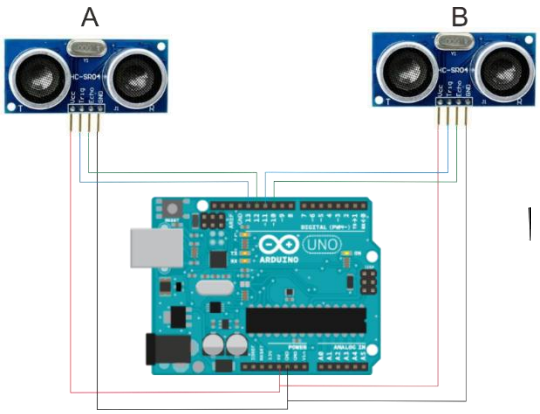

Figure 3. Ultrasonic Pin Sensor Installation Scheme

Red wire (VCC): connected to pin VCC 5v in Arduino

Black wire (GDN) : connected to pin GND in Arduino

A blue wire (Trig) : connected to pin Digital 13 in Arduino

A green wire (Echo) : connected to pin Digital 12 in Arduino

B blue wire (Trig) : connected to pin Digital 11 in Arduino

B green wire (Echo) : connected to pin Digital 10 in Arduino

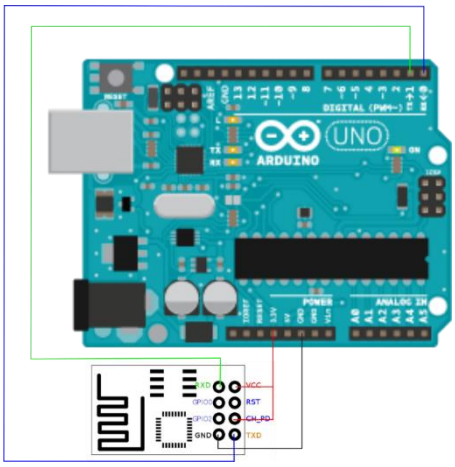

Figure 4. ESP8266 Pin Installation Scheme

Red wire (VCC & CH_PD): connected to pin VCC 3,5v in Arduino

Black wire (GDN) : connected to pin GND in Arduino

Blue wire (TX) : connected to pin Digital 1 in Arduino

Green wire (RX) : connected to pin Digital 2 in Arduino

Testing is done by means of tools that have been installed on the roadside with a stable speed that has been determined.

Table 1. Testing at Speed 10Km/hours

Experiment to-	Speed in Car	Speed in the display
1	10 Km/h	10,07 Km/h
2	10 Km/h	9,73 Km/h
3	10 Km/h	10,10 Km/h
4	10 Km/h	11,82 Km/h
5	10 Km/h	11,30 Km/h
6	10 Km/h	10,56 Km/h
7	10 Km/h	10,14 Km/h
8	10 Km/h	9,76 Km/h
9	10 Km/h	12,03 Km/h
10	10 Km/h	10,05 Km/h
Average	10 Km/h	10,556 Km/h

From the first experiment with a vehicle speed of 10 km/h to determine the fit between the vehicle real speeds with the sensor in the results can be like the table above, for the average result there is a difference of 0.556 Km/Hour between the actual car speed results with the results captured by the tool.

Table 2. Testing at Speed 20 Km/hours

Experiment to-	Speed in Car	Speed in the t display
1	20 Km/h	21,88 Km/h
2	20 Km/h	21,91 Km/h
3	20 Km/h	20,83 Km/h
4	20 Km/h	21,71 Km/h
5	20 Km/h	26,41 Km/h
6	20 Km/h	21,88 Km/h
7	20 Km/h	23,79 Km/h
8	20 Km/h	22,74 Km/h
9	20 Km/h	20,14 Km/h
10	20 Km/h	19,90 Km/h
Average	20 Km/h	22,119 Km/h

From the second experiment with the vehicle speed of 20 km/h to determine the fit between the vehicle real speeds with the sensor in the results can be like the table above for the average result there is a difference of 2.119 km/h between the actual car speed results and the results captured by the tool.

Table 3. Testing at Distance 1 meter from Sensor

Experiment to-	Speed in Car	Speed in the tool display
1	10 Km/h	9,53 Km/h
2	10 Km/h	9,54 Km/h
3	10 Km/h	9,54 Km/h
4	10 Km/h	9,52 Km/h
5	10 Km/h	9,53 Km/h
average	10 Km/h	9,532 Km/h

In the third experiment was done with the aim of seeing how far the range of the sensor to the vehicle and the match between the actual speeds with the speed generated tool. For the average result there is a difference of 0.468 Km / Hour between the actual car speed results with the results captured by the tool.

Table 4. Testing At 2 Meter Distance from Sensor

Experiment to-	Speed in Car	Speed in the display
1	10 Km/h	9,54 Km/h
2	10 Km/h	9,53 Km/h
3	10 Km/h	9,52 Km/h
4	10 Km/h	9,54 Km/h
5	10 Km/h	9,54 Km/h
average	10 Km/h	9.53 Km/h

In the fourth experiment was done with the aim of seeing how far the range of the sensor to the vehicle and the match between the actual speeds with the speed generated tool. For the average result there is a difference of 0.466 Km / Hour between the actual car speed results with the results captured by the tool.

CONTRIBUTION

Ultrasonic sensors are actually sensors to measure the distance has been very much modified and used in everyday life, especially in the field of transportation, including ultrasonic sensors have been used to be a warning sensor at the time of car parking[18] or a counter the number of vehicles passing.

In this paper ultrasonic sensors are modified to be able to detect the speed of the vehicle, where the speed of the vehicle becomes the foundation to determine the condition of the highway.

In general, ultrasonic sensors will turn on ultrasonic waves into targets or regions, after the waves touch the target surface, the target will reflect back the wave. This concept is used to detect the speed of vehicles passing through the road when the device is installed, on one sensor device used there are two sensors with a distance between the 5 meter sensor, the first sensor reflects the wave and when the wave is located. Then the microcontroller will start to calculate the required time until the second sensor get the reflection of the wave, so it can be calculated vehicle speed distance between the sensor (5 meters) divided by the time obtained from the calculation of the microcontroller. Then the result will be sent using Wi-Fi module in real time to the webserver so that it can be accessed by mobile device.

The installation of roadside equipment parallel to the road so as to provide a wide range, from the results of the study on the tables 3 & 4 known the sensor range can be up to 2 meters.

CONCLUSION

Ultrasonic sensor is a sensor that aims to measure the distance between the sensors with objects that prevent it, with such capabilities ultrasonic sensors can be modified for other uses more, one Ultrasonic sensors can be used as vehicle speed detectors, with the mechanism of use of two sensors installed with a distance of 5 meters to find the time generated when the vehicle through the tool, the time generated used to find the speed, where speed is the distance divided by time, where the speed of the vehicle is used as a reference in providing a decision about the condition of the road if it is traffic congested or not.

Information obtained will be directly sent to the database server that will be processed into an information that will be useful for road users.

Based on the experiment at a speed of 10 km / h between the actual speed in the vehicle with the tool has a difference of 0.556 km / h while at a speed of 20 km / h there is a difference of 2.119 km / h, it can be known the accuracy of the tool is 89% to 94%.

While in the experiment based on the distance of the sensor with the vehicle then get the difference between the actual speed with the speed of the tool is 0.468 km / h at a distance of 1 meter and 0.466 at a distance of 2 meters, it can be generated accuracy of the tool to detect the speed is 95%.

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