An Ultrasonic Sensor System for Vehicle Detection Application

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Abstract. This study develops an ultrasonic sensor system that can be used to determine the number, type, and speed of car vehicles passing a point over some specified time period. The proposed system consists of two ultrasonic sensors and a microcontroller equipped with data logging shield. The data were recorded and then analyzed using a computer program written in Java. Actual experiments that have been conducted indicates that this system can give a correct number of vehicles in a given interval of time.

Keywords: Car Monitoring System, Ultrasonic Sensor, Traffic Analyzer

1. Introduction

Electronics devices are capable of replacing human in various non-stop duties. Some typical reasons of why electronic device is more preferable over human is that it can work faster and more reliable as it cannot feel tired. Device that is used to do a continuous measurement is often called monitoring system. Such kind of electronic device can measure physical information about an object with help of sensors. A device equipped with data logging shield can also save the data that has been calculated into a memory card. One of the important applications of electronic monitoring system is vehicle detection system.

Vehicle monitoring system is very important as it can automatically count the number of vehicles entering or leaving an area for security reason. Such system is mostly used in parking lot and highway’s gate. Most of vehicle monitoring systems that are available nowadays use camera as its detection component. Camera capture an image by recording the light waves reflected by object’s surface. Camera can give very clear images if the light intensity captured by the camera is sufficient. However, in a condition with low light intensity or there is a medium interferes with the propagation of light, camera will give poor quality images. This problem of camera based vehicle monitoring system can be solved by combining camera with ultrasonic sensors.

Ultrasonic sensor uses basic principle of sound propagation and reflection by material in the ultrasonic frequency range. By applying this principle, ultrasonic sensors can still function well in conditions where light intensity is low or dark. Ultrasonic sensor also have several advantages over camera such as smaller size, relatively cheaper price, easier to be implemented, and lower power consumption.
The use of ultrasonic sensors has been widely used in various purposes such as determining surface structure, measuring the position, and calculating the speed of an object [1]. To determine the shape or structure of an object using ultrasonic sensors, one can arrange some ultrasonic sensors, mounted parallel, and then place an object within the detection area of these ultrasonic sensors. By gathering data recorded by all sensors, the surface structure of an object then can be redrawn [2].

Determining the position and velocity of moving objects such as cars can also be measured by placing ultrasonic sensors at the side of the road where the cars will pass by [3]. However, human or other object passing the detection spot can distract the measurement. Therefore, this paper proposes another technique of vehicle detection and a computer program for analysing detection data for better calculation results.

2. Measurement Principle of Ultrasonic Sensor

Ultrasonic sensor is a non-contact measurement device which provide precise distance measurement of an object using ultrasonic wave. This sensor has transmitter which transmits ultrasonic waves. When waves hitting an object, part of their energy reflected back to receiver of the sensor as echo signal. A distance $L_0$ (Fig. 1) to the object can be calculated through the speed $v$ of the ultrasonic waves in the media and the angle $\theta$ by Eq. 1 [5]

$$L_0 = \frac{vt\cos\theta}{2} \quad (1)$$

**Figure 1.** Ultrasonic sensor distance measurement (source: Fraden, Jacob. 2010)

The distance of the object from ultrasonic sensors determines the accuracy of measurement. Ultrasonic sensors are suitable for target distance from 20 mm to 10 m [6]. The inclination surface of the object as the waves hit may cause deflected part of it away from the sensor's receiver and then the sensing accuracy is decrease. If the target is inclined more than approximately 12 degrees to the normal of the beam axis, the entire waves is deflected away from the target and the sensor will not respond [7].

**Figure 2.** Reflected waves from various inclined surface target (source: Wilson, Jon S. 2005)
The frequency ranges of ultrasonic waves are from 10 kHz to 1 GHz [8]. These frequencies cannot be heard by human and it may be perceptive by only several animals. So that noise of sound from surrounding cannot affect the performance of this sensor because its frequency still below of the sensors operating frequency. Ultrasonic waves can be reflected by any material regardless of their color because it is an acoustic waves. It is very useful in shiny or foggy environment where other object detection system cannot work well.

3. Construction of Vehicle Monitoring System

The vehicle monitoring system built in this research is consist of two ultrasonic sensors and an Arduino, Uno type microcontroller, which is equipped with data logging shield. Arduino works as a processing unit to calculate distance detected by ultrasonic sensors and save data into memory card in data logging shield. Data logging shield has built in real time clock which provides date and time for Arduino. Data logging shield can easily be stuck over an Arduino to make it works. Figure 4 shows an electrical circuit of how two ultrasonic sensors connected to Arduino.

![Electrical circuit diagram](image)

**Figure 3.** Ultrasonic sensors and Arduino circuit diagram. Sensors’ echo and trigger pin are connected to Arduino’s digital pins

The system experiment is arranged as follows: both ultrasonic sensors are placed 3.2 meter above the ground on the upper side of a gate, with the sensor’s emitter and receiver directed toward the ground. These two sensors are arranged parallelly with separation distance of one meter. The distance of two sensors is set close to each other to prevent detection of two vehicles at the same time. To understand the data acquisition process, take a look on Figure 4.

![System arrangement](image)

**Figure 4.** System arrangement of data acquisition process.
Arduino will trigger sensor 1 to start measuring the distance of nearest object and then save the result to temporary memory. The system will delay for 50 millisecond before the Arduino do the same procedure for sensor 2. This delay is very crucial to make sure ultrasonic waves transmitted by sensor 1 doesn’t interfere with sensor 2’s. The measurement results of sensor 1 and sensor 2 are then saved in sd card alongside with the date and time of when these data are acquired. This measurement process is then repeated in a loop. This process is shown in figure 5.

**Figure 5.** Data measurement process is done by activating both sensors alternately and the process repeated in a loop.

4. **Data Analysis Prosedure**

Data recorded by this monitoring system, formatted .txt, contains thousands of lines of data, making it impossible to analysis in Arduino processor. A computer program is then developed to do this calculation in a computer with better processor performance. This computer program is written in Java so that it can be executed in various operating system such as Linux, Mac, and Windows. Before actually doing any calculation of vehicle physical information, the first step is to get rid of any unnecessary data, caused by people or bikes crossing sensor detection area, which can interfere with the algorithm for calculating vehicle. This unnecessary data can be in form of a sharp peek in the graph.

Calculation of the number of vehicles is conducted by finding rising and falling values of the distance measured by ultrasonic sensors. One vehicle should have one rising point and one falling point. By counting the total number of rising and falling values, the total number of vehicle can be calculated with a simple algebra. Determining the type of each vehicle detected is simply calculated by finding the maximum value between the rising and falling point in the height data series. After the maximum value is found, then it is compared to standard height of each type of vehicles. A truck should be higher than 2.8 meter, an SUV height should be no less than 1.8 meter and lower than 2.8 meter, and a Sedan should be less than 1.8 meters. This calculation only need data from either sensor 1 or sensor 2. The time difference of rising point data detected by both sensors can be used to approximate the speed of that vehicle.

**Figure 6.** The process executed in the computer program to analyze data.
5. Result and Discussion

5.1. Vehicle Detection Device
This vehicle detection system consists of two main parts which are sensing devices and a processing unit. Figure 5 shows the prototype of vehicle detection system built in this research.

![Prototype of vehicle detection system](image)

**Figure 7.** The prototype of vehicle detection system consists of a processing unit (a) and two ultrasonic sensors (b and c).

5.2. Graphical User Interface of the Computer Program and Results of Measurement
Data that has been recorded by vehicle detection system is then analysed with a computer program. This program can give the number of vehicle passing detection area and give the specific number of three different types of cars which are Sedan, SUV, and Truck. Figure 5 shows the interface of this program. The program interface has *time* and *filename* input, which make the user can easily select which data to be analysed.

![Computer program interface](image)

**Figure 8.** Computer program interface for analysing data recorded by vehicle detection system. (1) Time interval, (2) Filename, (3) Blue lines indicate measurement result of sensor 1, (4) Red lines indicate measurement result of sensor 2, (5) Button to calculate number of car, and (6) Button to save filtered data.
Calculate Button, marked by number 5 in Figure 5, starts the calculation process. The calculation result is then shown with another frame shown in Figure 6. Each peak in Figure 5 represents the shape of the car. The lower line indicates the maximum height of Sedan type vehicle and the upper line indicate the maximum height of SUV type vehicle.

![Vehicle Detail](https://www.microsonic.de/en/support/ultrasonic-technology/principle.htm)

**Figure 9.** Vehicle calculation result gives the number of each type of vehicle within the time interval which is set in the time input.

The calculation result shown by the program is then verified by a video which is recorded with a camera. The results shown by the program give the same number of each type of vehicles as shown by recorded image from the camera. But the calculation can determine the type incorrectly if the vehicle being identified carries something, which causes the maximum height changed, at the top of it.

### 6. Conclusion

Vehicle detection system based on two ultrasonic sensors has been successfully built. The distance between ultrasonic sensors can be varied to adjust the measurement accuracy or to meet the user’s need. A computer program developed in this research was able to calculate the number of each type of cars passing the detection area in certain interval of time, the number of peaks shown in the graph and the calculation result shown in the vehicle detail window give the same values.

### Acknowledgement

This research is fully funded by Department of Physics, Bandung Institute of Technology. The first two authors would like to thank Lembaga Pengelola Dana Pendidikan (LPDP) for giving scholarship to them and makes this research possible.

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