Multiple Sensing Method Using Moving Average Filter for Automotive Ultrasonic Sensor

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Abstract. Distance sensing on vehicles is a trend in the development of autonomous cars. So that the use of proximity sensors such as ultrasonic and infrared, is very important. This research paper focuses on developing a reading of 4 ultrasonic sensors simultaneously. Where the reading method is done using 4 pin echo and 4 pins trigger and 1 pin echo with 4 pin triggers. In order for better reading, the programming algorithm for each method is integrated with the moving average filter. The use of this filter is able to correct the noise that occurs when reading the distance. The test was carried out at the computer simulation stage using a microcontroller. The final results of the study obtained a very small reading error.

1. Introduction
Vehicles are tools used by many people. Day by day, technological developments are increasing. This causes technology development in vehicles to be increased. The development of the internet makes a transportation vehicle able to communicate between cars and can move automatically according to the track or often called autonomous. The development of autonomous technology cannot be separated from the use of sensors that are often used to detect parameters such as objects, distances, lines, and others. Using these sensors, of course, there will be some problems that often occur, such as the amount of incoming noise.

A distance sensor is a device used to detect distance. Where the distance sensor can use light or ultrasonic reflections [1], [2]. In autonomous vehicles, this sensor is very important and is used to detect obstructions. With this sensor, obstacles can be passed without being hit by the vehicle [3]–[6].

Some of the literature discusses a lot about the use of distance sensors such as ultrasonic. Ultrasonic sensors are sensors that generate sound waves, which are then reflected and received back by the receiver [4], [7]–[10]. So, it can be said that this sensor consists of 2 devices, namely a transceiver and a receiver. As materials develop, transceivers and receivers can be integrated into 1 component. This greatly facilitates the design process and simplifies electronic design. However, the use of these components requires a converter that is capable of generating waves on ultrasonic sensors [11], [12]. So that in an application, sensors often experience additional noise from ultrasonic sensors and modules. Module output is a digital signal so that the noise on the module output can be above. But the noise that occurs on the ultrasonic sensor and module is certainly a problem in itself, so there is a need for a method to suppress the noise that is generated on either the sensor or the ultrasonic module. Several methods can be used to reduce noise such as low pass filters.

This paper focuses on the use of a moving average filter in reducing noise caused by ultrasonic sensors and modules. Where the results of the filter are compared with the results of sensor readings.
and the use of other filters such as Kalman filters [8], [13]. So that the results of the study will be obtained the use of an effective filter for the use of filters in ultrasonic sensor readings.

2. Literature study

Literature is used in designing and designing filters for ultrasonic sensors.

2.1. Ultrasonic

The specifications of the ultrasonic sensor used in the study can be seen in Table 1.

| Table 1. Ultrasonic Sensor Specifications |
|------------------------------------------|
| Parameter   | Value          |
| Type        | JSN-SR04T      |
| Spanning    | 3.0 – 5.5V     |
| Frequency   | 40 Hz          |
| Detection angle | <50°        |
| Measuring range | 4 m          |

Where, the type of ultrasonic sensor uses the JSN-SR04T, where this sensor is able to operate in wet conditions. The frequency of the distance reading on the ultrasonic sensor is 40 Hz. The angle for detecting obstacles is less than 50°. The maximum ultrasonic measuring distance is 4 meters.

To get the signal speed (v), it can be seen in equation (1).

\[ v = \frac{d}{t} \] (1)

Where is the distance, \( t \) is time. To get the calculation speed value on the ultrasonic sensor, the value of \( v \) is multiplied by 2. The equation for getting the value of the wave velocity can be seen in equations (2) and (3).

\[ v = 2 \frac{d}{t} \] (2)

\[ d = v \frac{t}{2} \] (3)

Where the value of 2 is obtained based on \( v \) when the wave is sent to hit an obstacle and the second \( v \) is obtained when the reflected wave is received by the ultrasonic sensor transceiver. If the value of the wave velocity is known to be 340 m/s, then the distance between the ultrasonic sensor and the obstruction is obtained using equation (4).

\[ d = t \times \frac{340 \text{ m/s}}{2} \] (4)

If you use multiple ultrasonic sensors, the time needed to detect the distance between the ultrasonic sensor and the obstruction will increase. To find out the time needed to measure the distance with 4 sensors, it can be calculated using equation (5).

\[ \sum_{i=1}^{n} t(i) \] (5)

Where \( t(i) \) is the time required to detect obstructions on the ultrasonic sensor.
2.2. Filter
The filter is a method for refining incoming data. Where the incoming data does not only come from sensor readings, but the readings can be obtained by the noise that can come from the sensor or ultrasonic module. Filter methods to overcome noise can use a low-pass filter (LPF), moving average filter, Kalman filter, and others [13]. On paper only based on the use of a moving average filter and compared with the Kalman filter. This is done for the comparison of the moving average filter and the Kalman filter.

2.2.1 Moving average filter
Equation (6) is a method of using a moving average filter.

\[
MAF = \frac{(A_1 + A_2 + \cdots + A_n)}{n}
\]  

Where MAF is the result of the filter output calculation, A is the reading data, n is the amount of data to be averaged.

2.2.2 Kalman filter
Equations (7) and (8) show the solution of the filter Kalman applied to the ultrasonic filter.

\[
x_k = F_k x_{k-1} + B_k u_k + w_k
\]  

\[
z_k = H_k x_k + v_k
\]  

Where \(F_k\) is the state transition model which is applied to the previous state \(x_{k-1}\), \(B_k\) is the control-input model which is applied to the control vector \(u_k\), \(w_k\) is the process noise which is assumed to be drawn from a zero-mean multivariate normal distribution, \(H_k\) is the observation model which maps the true state space into the observed space, \(v_k\) is the observation noise which is assumed to be zero-mean Gaussian white noise with covariance.

3 Method
3.1. Design
Figure 1 shows a schematic of the electronic design for 4 ultrasonic sensor triggers. Where all the trigger pins (Tr) on the ultrasonic sensor are connected to a buffer. Where the buffer function is to maintain electric current. The use of buffers maintains the condition of the signal from the microcontroller in order to transmit ultrasonic waves to the sensor.

![Figure 1. Schematic of 4 Ultrasonic Sensors](image)

The ultrasonic sensor output flows from the Echo (Ec) pin. The ultrasonic sensor output is connected to the microcontroller input pin. The microcontroller used in this research is
STM32F103C8T6 using the ARM32 architecture. Whereas in Figure 2 shows the filter design for reading 4 ultrasonic sensors on the microcontroller.

Where when the ultrasonic sensor sends a signal to the microcontroller [11], [14], [15]. The digital signal is converted by a timer to get the value $t$. Thus, when the $t$ value is calculated by calculation, the value $d$ is obtained. The calculated data is filtered using a moving average filter or Kalman filter. After going through the filter stage, the data is used for monitoring or control purposes via a multiplexer. Filter computation is carried out by a number of sensors used.

3.2. Study case
The case study carried out in this research consists of 3 stages of testing, namely testing in steady state, ramp up, ramp down, and step. Each test is carried out by adjusting the ultrasonic sensor distance from the barrier. The ultrasonic sensor is on the machine that operates during the testing process. So that the noise comes from the vibration of the combustion engine.

3.2.1 Steady state
The steady state test is done by determining the measurement distance. Then measure the distance at rest and the distance reading is carried out continuously.

3.2.2 Ramp Test
Ramp testing is carried out in 2 stages, namely, ramp up and ramp down. When the ramp goes up, the distance of the barrier with the ultrasonic sensor is kept away. The farther the ultrasonic sensor is from the barrier, the greater the $d$ value. When the ramp descends, the ultrasonic distance of the barrier is brought closer.

3.2.3 Step Test
Step testing is done by gradually bringing the ultrasonic sensor closer to the barrier.

4 Result and Discussion
Figures 3 and 4 show the test results during steady-state conditions and the maximum value step.
In Figure 3, the reading results have quite a large deviation. This is because the ultrasonic sensor is located on a vibrating machine. This is certainly a big problem. This is because when the sensor measures the distance when the combustion engine vibrates, there will be a fairly large deviation in the distance measurement. By using a moving average filter, the deviation can be suppressed to reach the setpoint value. In Figure 4, when taking a step from the minimum point to the maximum, the use of the Kalman filter is better but the use of a moving average filter experiences a very slow response.

Figures 5 and 6 show the ramp up and down tests carried out from the closest point to the farthest point. The ramp test results show the response of the moving average filter is slower. It can be seen that during ramp up and ramp down, there is a large difference between the setpoint and the result of the moving average filter.

Whereas in Figure 7 shows a step test on an ultrasonic sensor. Where the response generated by the moving average filter is very slow. So that when the condition is at rest, then an increase occurs, the response to the filter condition does not immediately respond well.
Figures 8 and 9 show the results of a comparison of the steady-state condition and the maximum value step using a moving average $n = 5$ and $n = 10$. Figure 8 shows the test results at a steady state using a mean of 5 and 10 data. Where the bigger the average data, the closer the setpoint value. Figure 9 shows the maximum step test using a mean of 5 and 10 data. Where the greater the mean value, the slower the response to the result.

5 Conclusion
Based on the test results and analysis of the acquisition of test data, the moving average filter for ultrasonic sensor applications is very suitable for use in steady-state conditions. When the value fluctuates above and below the setpoint, the use of a moving average filter is better with a fairly large average value.

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7 References
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