Presence Sensors: A Comparison Between the Ultrasonic and the Infrared in the Detection of People and Vehicles

Rosana C. B. Rego and Rodrigo S. Semente

Abstract Sensors have become fundamental elements in automation and industrial processes, for updating in a precise and fast way. Among the various types of sensors, there are presence sensors. They are able to perform simple detection tasks more accurately and efficiently than people. This work presented the comparison between two types of sensors: the ultrasonic and the infrared. It is also proposed a method of estimating the length of the vehicle by presence detection. The preliminary results show that the technique is interesting and cheap to distinguish and detect vehicles types.

Keywords Presence sensors · Infrared · Ultrasonic · Vehicles

1 Introduction

The use of sensors is essential in the modern world. Whether it is to control industrial processes, monitor climatic and environmental conditions or simply facilitate everyday life procedures, we can find them in a variety of situations.

The purpose of a sensor is to respond to a stimulus and convert it into an electrical signal compatible with the circuits attached to it. The output signal of the sensor may be in the form of voltage, current, or charge and may be described in terms of amplitude, frequency, phase, or digital code [2, 5].

We can divide the sensors basically into two groups: analog sensors and digital sensors. The analog has as answer an analog signal, that is, assume numerous values. Unlike the digital ones that have a digital signal as its answer, it assumes the values

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0 or 1 [6]. In this work, two types of presence sensors are presented. One has an analog signal on the output, and the other has a digital signal on the output.

An important group of sensors is the proximity sensors or presence sensors. They are used to detect the presence of people or any objects in a monitored area. The presence sensor produces a signal if an object is in its detection zone, whether this object is stationary or not [1, 2, 5]. There are several types of presence sensors, such as ultrasonic, infrared, optics, inductive (used to detect electromagnetic field) [7].

Presence sensors are commonly used in industrial processes, and recently an optimal application of presence sensors is at smart traffic lights. The sensors are typically installed at a mid-block location, which provides accurate measures of vehicle volumes and speeds. The information provided by system sensors can be used to support the following system functions: acquiring traffic flow information to compute signal timing, identifying critical intersection control (CIC), and selecting timing plans [3, 7].

Traffic managers all over the world use a camera or some presence sensor to monitor and manage traffic streams. Be it for monitoring motorists and pedestrians in urban areas, for detecting incidents on highways and in tunnels, or for traffic data collection purposes. However, the video detection by camera requires more data processing, consequently a higher cost. Thinking about this, this work carried out an analysis of two presence senors and how they behave in the detection of people or vehicles.

The aim of this work is to present the principle of operation of two presence sensors, as well as their characteristics, and how they behave in the detection of vehicles and people. It was made a comparison between an ultrasonic sensor and an infrared sensor. And a method for detecting the length of the vehicle is presented. This work is still an initial work in which tests are still being carried out to validate or not the technique.

2 Sensors

2.1 Ultrasonic

The ultrasonic sensor is a distance sensor. It emits sound pulse (transmitted wave) and calculates the time it takes for the pulse to be reflected back to the sensor. Fig. 1 shows the operation of an ultrasonic sensor.

A minimum distance from the sensor is required to promote a time delay, so that the echoes can be interpreted. In the case of the HCSR04 sensor model, which was used in this work, the minimum distance is 2 cm, and the maximum distance is 4 m. This ultrasonic is necessary only to supply a short 10 uS pulse to the trigger input to start the ranging, and then, the module will send out an 8 cycle burst of ultrasound at 40 kHz and raise its echo. An echo is a distance object that is pulse width and the range in proportion.

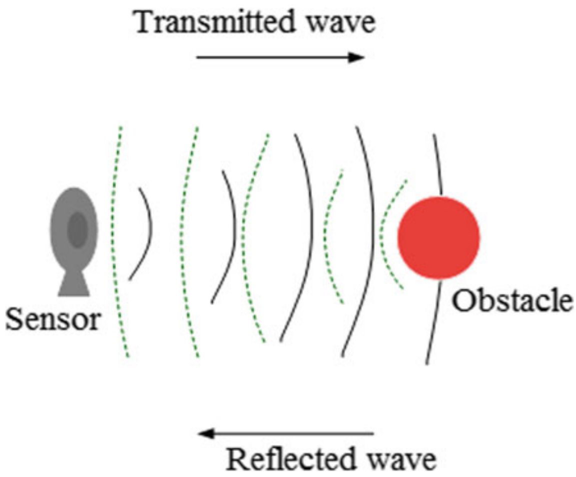


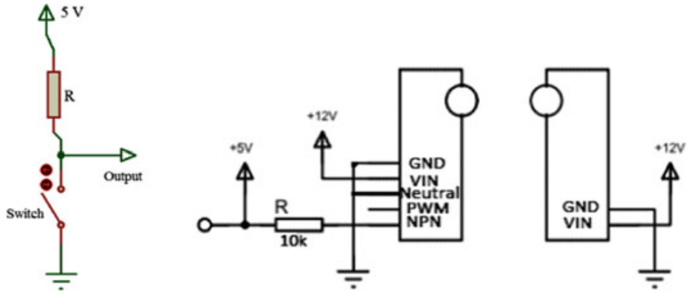
Fig. 1 Ultrasonic operation

Ultrasonic sensors are quite fast for most of the common applications. For example, it can be used for distance measurement of an object in the path of a person, equipment, or a vehicle. These sensors can also be used to detect the driving violations of slower vehicles, and especially large heavy trucks, traveling in an improper lane like the "passing lane," might cause serious negative effects on the highway traffic order, reduce highway traffic efficiency, and become a safety threat for other drivers who have to change lanes more frequently [4].

2.2 Infrared

Infrared sensors can be active or passive. The sensor used here is an active. It has two devices, one that emits (emitter) and another that receives (receiver) the infrared rays. The emitter and receiver form an infrared beam, and when this beam is interrupted, the sensor sends the detection signal to the controller. The sensors consist internally of a switch (transistor) in which they alternate between two levels: high or low. The high state is a voltage of 5 V, and the low state is a voltage of 0 V. This switch can be connected in two ways: with a pull-up resistor or pull-down resistor (Fig. 2a).

The switching of the sensor output is performed by a transistor. When no detection occurs, the sensor is not activated. The infrared output is an NPN output, where the load coupled to the sensor is connected between the positive terminal and the sensor output. When the sensor detects nothing, it remains at a high level, when it detects an object it goes to the low level. Fig. 2b shows the infrared sensor used. These sensors can be used in security applications such as alarms, perimeter protection, automatic lighting, garage doors, and others [6]. Here, it was used to detect vehicles or people.



(a) Switch connected to a resistor pull-up.

(b) The infrared sensor used.

Fig. 2 Infrared sensor

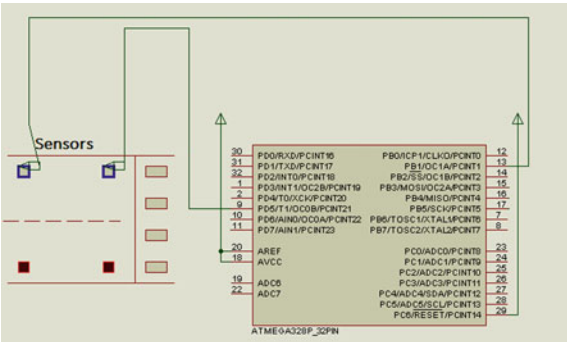


Fig. 3 Circuit diagram

3 Experiment

To get the data, an infrared barrier was created with the infrared receiver and the infrared emitter and the emitter and receiver of the ultrasonic remained in the same encapsulation. It was considered a distance of 300 cm between the infrared pairs. The receivers were at a distance of 400 cm from the emitters.

Figure 3 shows the scheme of the circuit with the microcontroller used. The controller used was an Atmega328. The system would cost approximately $70.00.

An analysis of the effect of one emitter on the other sensor was performed, varying the distance of the two, until the minimum distance to avoid interference between the two was found. The minimum distance found was 50 cm.

To detect the presence of something using the ultrasonic, a maximum distance (350 cm) was defined. If the sensor sends to the controller a distance smaller than the maximum defined, then it detected something.

The measured distance is calculated on the basis of travel time. As shown in Eq. 1.

$$\text{Distance} = \frac{(\text{travel time} \times \text{velocity of sound})}{2} \tag{1}$$

The vehicle speed can bee calculated by Eq. 2.

$$\text{speed} = \frac{\text{SDist}}{T_{i_2} - T_{i_1}}. \tag{2}$$

where SDist is the distance between the two sensors and T_{i_1} and T_{i_2} are, respectively, the initial time of detection of two sensors (Fig. 9). The length of the vehicle can be calculated by Eq. 3.

$$\text{Length} = \text{speed} \cdot \frac{(T_{f_1} - T_{i_1}) + (T_{f_2} - T_{i_2})}{2}. \tag{3}$$

where T_{f_1} and T_{f_2} are the final detection time sensors 1 and 2, respectively. In other words, Eq. 3 is the speed multiplied by the average between the detection time of sensor 1 and sensor 2. However, its measure is not precise, because there are measures imprecision at the detection time of the sensors and the vehicle shape. So, it is proposed that the vehicle signature value (VSV) can be estimated by the integrals of the received signals, S_1 and S_2, by the time, determined by the following Eq. 4,

$$\text{VSV} = \left(\int_{T_{f_1}}^{T_{i_1}} S_1 \mathrm{d}t + \int_{T_{f_2}}^{T_{i_2}} S_2 \mathrm{d}t \right) /2 \tag{4}$$

Two tests were performed in the presence of cars. The first test, a 4 m car (let us reference by car 1) passed through the sensors at speeds of 10, 20, 30 km/h. In the second test, with another car (let us reference by car 2) of 4.232 m passed the sensors at speeds of 14.4, 27 and 39 km/h. The obtained values and results are presented at Table 1. The data were obtained at a sampling rate of 0.2 s.

Table 1 Data obtained with the ultrasonic sensor response for the car 1 detection

	Detection 1	Detection 2	Detection 3
Speed (km/h)	10	20	30
Length (m)	3.34	3.34	4.16
VSV	8.78	4.36	6.58

4 Results and Analysis

In Fig. 4, it is possible to observe the behavior of the ultrasonic sensor in the detection of presence, in case of detection of people. And in Fig. 5, it is possible to observe the transient response of the infrared sensor (when detecting the person).

The ultrasonic sensor has a response rate slightly higher than the infrared sensor; however, the infrared is more stable than the ultrasonic. The model of the ultrasonic sensor used here has an accuracy of 2 cm. Because the ultrasonic output signal is an analog signal, it is more sensitive to noise as shown in Fig. 4. To improve the output signal, it is advisable to use a filter.

Fig. 6 shows the response of the infrared sensor in the presence of car 1. And Fig. 7 shows the response of the ultrasonic sensor for the same case. The car passed three times through the sensors at different speeds as you can see in Fig. 7. The response of both sensors was similar; however, the infrared sensor did not detect the car when it passed at a speed greater than 20 km/h. As can see in Fig. 6 in the time 112 s, it did not detect anything.

Comparing the two responses (infrared and ultrasonic), the use of infrared is suitable for presence detection of moving objects with low speed only. Since the ultrasonic, it detects the presence and still provides the distance, despite the oscillations in the response. Therefore, to detect only people, the infrared is recommended. However, if you want to detect the distance of the object or a very fast object, then the ultrasonic is recommended.

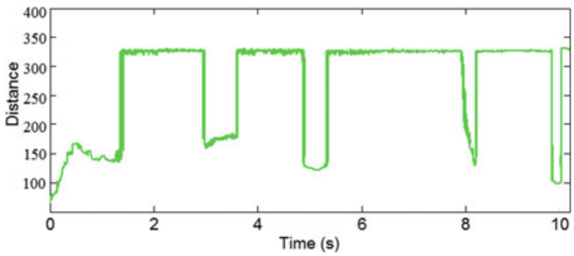


Fig. 4 Ultrasonic sensor curve

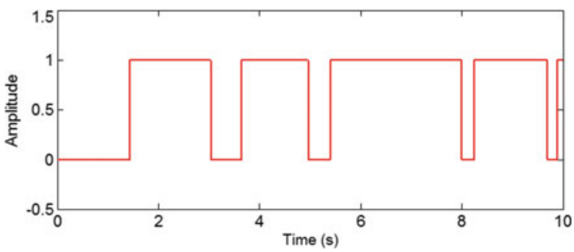


Fig. 5 Infrared sensor curve

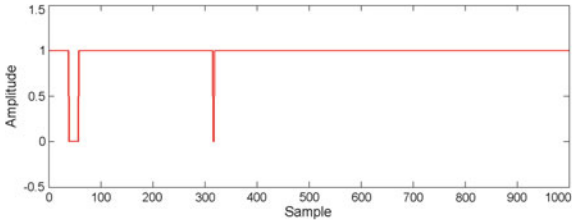


Fig. 6 Infrared sensor response for the car 1 detection

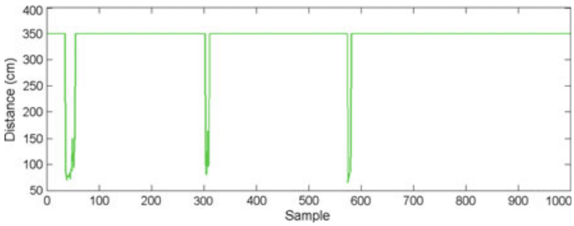


Fig. 7 Ultrasonic sensor response for the car 1 detection

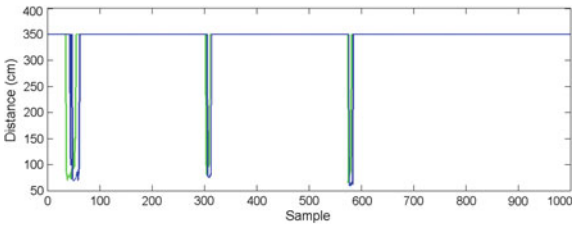


Fig. 8 Data obtained with the ultrasonics sensors for the car 1 detection

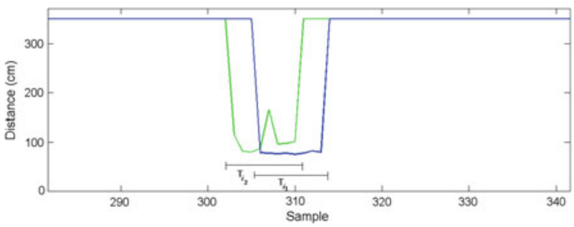


Fig. 9 Data obtained with the ultrasonic sensors in car 1 detection

The infrared sensor behaved properly when the vehicle passed at low speeds as shown in Fig. 6 on the first detection when the signal change from 1 to 0. Therefore, the analysis of the results obtained will be performed with the data coming from the ultrasonics sensors (Fig. 8).

Figure 8 shows the response of the sensors in the detection of the car 1.

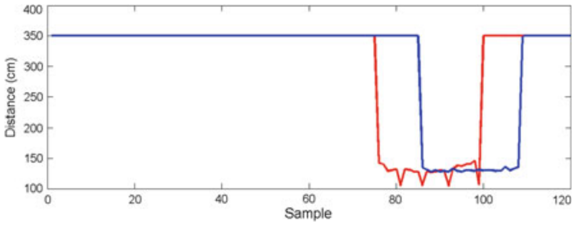


Fig. 10 Ultrasonic sensor response for the car 2 detection with a speed of 14.4 km/h

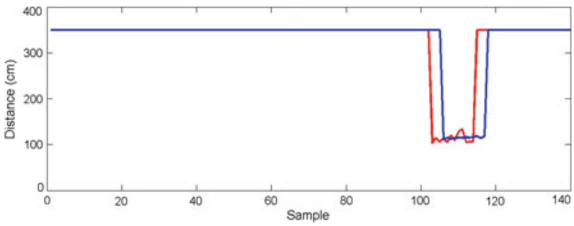


Fig. 11 Ultrasonic sensor response for the car 2 detection with a speed of 27 km/h

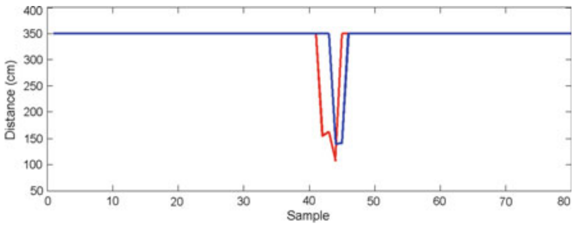


Fig. 12 Ultrasonic sensor response for the car 2 detection with a speed of 39 km/h

Table 2 Data obtained with the ultrasonic sensor response for the car 2 detection

	Detection 1	Detection 2	Detection 3
Speed (km/h)	14.4	27	39
Length (m)	4.9	4.875	4.873
VSV	6.41	7.03	8.34

Figures 10, 11, and 12 show the response of the ultrasonic sensors in the detection of the car 2 with different speeds. From the data obtained (Fig. 8), consider the following speeds 10, 20, and 30 km/h. The calculations of the estimated length of the vehicle are given in Table 1.

According to Table 1, the estimated average length was 3.5 m. The original length of the car 1 is 4 m. So there is an error of 12.50%.

According to Table 2, the estimated average length was 4.88 m. The original length of the car 2 is 4.23 m. So there is an error of 15.31%. It is necessary to calibrate the sensors beforehand, but these results suggest the feasibility of the technique used.

The VSV for Table 1 has a variation coefficient of 33.55%. And for Table 2, the variation coefficient is 13.85%

The VSV should be compared with others vehicles VSV to calibrate and used to identify the vehicle. It was observed that the energy of the system suffered little variation with the speed and could be used for the detection of the vehicle type. More testing with other vehicle types will be needed to validate the technique.

5 Conclusion

To choose the sensor to be used, you need to know what you want to detect. If it is only the presence of an object, the infrared is more appropriate. However, if it is necessary, know the distance that this object is, then the ultrasonic is more appropriate. Also, it is necessary to take into consideration the environmental factors, this is, the conditions of the environment in which the sensor will be installed are of extreme importance for your choice. For example, if it is an environment where it has a lot of light, the infrared sensor is no a good choice.

How it was seen, the infrared is more precise, but, it is necessary voltage power source (12 V), and it was not sensitive to the detection of cars.

As discussed previously to validate the technique of estimating the length of the vehicle, it is necessary to carry out more measurements with different types of vehicles with different sizes.

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