Point to point Distance Measurement Using Ultrasonic for Excellent Stick

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Abstract\(^1\)

Since sometimes blind people collide against high and moving obstacles, we need obstacle-sensing function in front of the blind people. This paper proposes a method of point-to-point distance measurement using ultrasonic for excellent stick in order to detect moving and high obstacles. In this method, we apply ultrasonic wave technique to measure distance to obstacles, since it does not disturb other people. By setting two ultrasonic sensors on the stick, one for transmission and the other for reception, the moving and high obstacles are detected before colliding. Moreover, embedded systems are employed in the system in order to reduce system size and cost, as well as saving energy. In experiments (with wood, concrete, plastic, etc as obstacles), the results reveal distance measurement accuracy 95 % approximately.

Key Words: point-to-point distance measurement, ultrasonic, blind people, stick

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1. Introduction

Automatic distance measurement plays an important role in many applications such as autonomous robot navigation (Gheorghe et al.), excellent stick for blind people, and so on. Since the number of blind people is not small (Thailand Association of the Blind), and those people need to sense environments in order to live among other normal people, special tools for blind people such as excellent stick are required. To implement the excellent stick that would enable to warn blind people when obstacles are nearby while; for instance, walking along the street, many important issues are under consideration. This includes energy conservation, low cost of system implementation, simplicity of system operation and small size of system. In research and development of distance measurement for excellent stick for blind people, ultrasonic technique is considered as an alternative choice, which provides a low cost solution without any disturbance to other people.

However, for the best of our knowledge, there is no research report for ultrasonic-distance measurement directly applying to develop an excellent stick for blind people. Examples of researches employing ultrasonic techniques are reviewed as follows. Y.Akkaya et al. proposed nondestructive measurement of concrete strength gain by an ultrasonic wave reflection method. Additionally, K.A. Sudduth et al. presented ultrasonic and GPS measurement of combine swath width. K.Imou et al. also applied ultrasonic doppler sensor for measuring vehicle speed in forward and reverse motions including low speed motions. Gheorghe Lazea et al. proposed ultrasonic range finding sensor. From those techniques, it can be seen that the use of ultrasonic wave for point-to-point distance measurement work well in large-scale conditions such as robot, and vehicle. This paper proposes employment of ultrasonic wave for developing excellent stick as an example of small-scale conditions. The system utilizes embedded system based hardware in order to achieve mentioned issues. The organization of this paper is as follows. In section 2, we describe the basic concept of how to measure distance between the stick and an obstacle. Our proposed system is described in Section 3. In addition, section 4 provides some experimental results, and the discussions are presented in section 5. Finally, we conclude our work in session 6.

2. Basic Concept

The basic concept of point-to-point distance measurement system using ultrasonic for excellent stick can be explained as follows. As can be seen from Figure 1, the
system consists of an ultrasonic transmitter and a receiver located with \( d_{tr} \) meters away from each other on a stick. The distance from the stick to the obstacle in perpendicular to middle of range between the transmitter and the receiver denotes \( d_{so} \). By given \( V_T \) as speed of ultrasonic wave propagation at which depends on temperature \( T \) (in Celsius), we can calculate \( d_{so} \) as

\[
d_{so} = V_T \frac{\tau}{2} \cos \theta \tag{1}
\]

where \( \theta_t = \theta_r = \theta \) is, in respective, the angle of the transmitting sensor and the receiving sensor to the x-axis, and \( \tau \) is the time elapsed between the transmitter and receiver.

**Figure 1** Block Diagram of Ultrasonic Speed Sensor

![Figure 1 Block Diagram of Ultrasonic Speed Sensor](image)

\[
V_T = 331 + 0.67^T \tag{2}
\]

**Figure 2** Basic Concept Transmitted and Received Signal

![Figure 2 Basic Concept Transmitted and Received Signal](image)
In case of $d_{sd} \gg d_m$, $\emptyset$ is approximately close to zero and equation (1) can be simplified as

$$d_{sd} = \frac{v_f \tau}{2} \quad (3)$$

3. System design

As already mentioned above that this paper proposes using of ultrasonic wave to enhance ability of stick for blind people with low system cost, simplicity, and low energy utilization criteria, the system must be carefully design. Both hardware and software perspective are discussed in this section as following.

In hardware perspective, the system can be divided into two parts: transmitting part, and receiving part. In transmitting part, the system composes of an ultrasonic transmitter of number 4000ST160, a microcontroller, and an alarm. In receiving part, the sensor number 4000RT is employed as a receiver, which is connected to an amplifier, a rectifier, and a trigger in series. In addition, the output of the trigger is connected to a microcontroller number PIC12F675 in order to send a signal to activate the alarm in case of receiving reflection signal. Figure 3(a) and 3(b) show block diagram of the system and its circuit implementation.

![Figure 3 (a) Block Diagram of System](image)

![Figure 3 (b) System Circuit Implementation](image)
In software perspective, the program is operated as follows. The program starts with initiating all the operating ports and timer. Then, the timer is set to zero in order to count the propagation time from the transmitter to the receiver. After that, the program drives the transmitter to generate a signal with 40 kHz for 50 cycles and send them along the air. Then, the program waits for reflection signal which will reach the receiver. If the input of the receiver is 1, it displays value at port C, and if the input of the receiver is 0 it will check whether the time is overflow. In case of overflow, it sends data to set time again. In case of time 0 is not overflow, it will send data to re-check the input at the receiver. Figure 4 shows software flowchart of system operation.

Figure 4 Software Flowchart of System Operation

4. Experimental Results

There are basically three parts of testing for implementing excellent stick as follows:
- Testing for transmitted signal waveform and its transmitted power requirement
- Testing for positioning of ultrasonic sensors
- Static testing for system operation
The following subsections discuss all these in details.

4.1. Testing for Transmitted Signal Waveform and Its Transmitted Power Requirement

Excellent stick utilizes principle of signal reflection in order to detect obstacle and warn the blind people when they are nearby. In order to get best or at least detectable reflected signal, two issues are of interests: shape of transmitting, and transmitted power requirements. In the first issue, the shape of transmitting signal is examined. This can be done by generating three general but different types of signal, i.e., square waveform, sine waveform, and sawtooth waveform from a signal generator to the transmitter and detecting received signal at the receiver from an oscilloscope as shown in Figure 5. By measuring amplitudes of received signals, it can be seen that the received signal from a square wave source has higher amplitude. It can also be seen from the result as shown in Figure 6 that the received signal is in form of sine wave though the transmitted signal is in any waveform.

4.2. Testing for positioning of ultrasonic sensor

The distance between the transmitter and receiver is determined by the same method as above. The distance from two sensors is tested by varying it from as low as 2 cm to 6 cm and the strength of the received signal is measured. From the result as tabulated in Table 1, it is seen that at distance from transmitter to receiver of 4 cm, the percentage of attenuation of received signal when distance from sensors to obstacle increases from 10 to 20 and 30 cm is smallest. Thus, four-centimeter length between the transmitter and receiver will be used for this experiment.

![Figure 5 Test Model for Signal Strength and Distance between the Transmitter and Receiver](image)
Figure 6 Output from Oscilloscope when Difference Type of Transmitted Signal is Input

Table 1 Effect of Length between Transmitter and Receiver to the Power of Received Signal

<table>
<thead>
<tr>
<th>Distance from sensors to obstacle</th>
<th>10 cm</th>
<th>20 cm</th>
<th>30 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 cm</td>
<td>150 mV</td>
<td>22 mV</td>
<td>22 mV</td>
</tr>
<tr>
<td>3 cm</td>
<td>120 mV</td>
<td>20 mV</td>
<td>10 mV</td>
</tr>
<tr>
<td>4 cm</td>
<td>120 mV</td>
<td>20 mV</td>
<td>20 mV</td>
</tr>
<tr>
<td>5 cm</td>
<td>100 mV</td>
<td>10 mV</td>
<td>10 mV</td>
</tr>
<tr>
<td>6 cm</td>
<td>70 mV</td>
<td>50 mV</td>
<td>10 mV</td>
</tr>
</tbody>
</table>

4.3. Static testing for system operation

The system is constructed as shown in Figure 3 (a) and 3 (b). To evaluate how effective the ultrasonic wave be employed to enhance stick for blind people, both dynamic and static test are possible. The dynamic test may be of more practical, but some significant variables cannot be set up, so that the results are difficult to analyze. In the static test, on the other hand, several variables are set up, hence performance of the system can be evaluated under some certain scenarios. In this paper, only the static test is of interests, and the test is conducted under the following variables and assumptions:

- Length between the transmitting sensor and the receiving sensor is 4 cm.
- Six types of material are tested: iron, concrete ceramic, wood, glass, plastic, and assuming that human or living thing are aware of blind people so that they are not including in the experiment.
- Tested temperature is at 22 Celsius.
- Transmitted power is 10 Vp-p.
- Frequency of transmitting signal is 40 kHz.
- Distance from the obstacles to the stick varies from 0.1 to 2.0 meters by 10 centimeters.

The method of testing is as follows. Firstly, generating signal, the transmitter generates 50 cycles of 10 Vp-p pulse signal, by sending logic “1” and logic “0” at period of 12.5 microseconds alternately. Then the receiver waits for some maximum of 12 milliseconds (two meters in distance of propagation) for arrival of reflected signal. If there is no reflected signal arrived, it means that there is no obstacle within two meters length from the stick. Then, the transmitter send new 50 cycles signal and wait repeatedly until the system is turned off. If the receiver detect reflected signal, arrival time is recorded, and the distance from the stick to the obstacle is determined by means of equation (3). Next, the above method is repeated for different value of distance from the obstacle to the stick, and types of obstacle. The results are tabulated in Table 2. Percentages of error are also provided. In addition, Figure 7 shows how the experiment has been set up.

Table 2 Distance Measurement for Six Types of Obstacles and Its Percentage of Error

<table>
<thead>
<tr>
<th>Distance (meters)</th>
<th>Distance calculated from equation (3) (meters) at 22 Celsius</th>
<th>Time measurement from oscilloscope</th>
<th>Percentage Error (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>iron</td>
<td>wood</td>
<td>concrete</td>
</tr>
<tr>
<td>0.1</td>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
</tr>
<tr>
<td>0.2</td>
<td>0.21</td>
<td>0.21</td>
<td>0.21</td>
</tr>
<tr>
<td>0.3</td>
<td>0.31</td>
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<tr>
<td>0.4</td>
<td>0.42</td>
<td>0.42</td>
<td>0.42</td>
</tr>
<tr>
<td>0.5</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>0.6</td>
<td>0.62</td>
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<tr>
<td>0.7</td>
<td>0.73</td>
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<tr>
<td>0.9</td>
<td>0.95</td>
<td>0.95</td>
<td>0.95</td>
</tr>
<tr>
<td>1.0</td>
<td>1.05</td>
<td>1.05</td>
<td>1.07</td>
</tr>
<tr>
<td>1.1</td>
<td>1.16</td>
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<td>1.2</td>
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</tr>
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<td>1.3</td>
<td>1.38</td>
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<td>2.0</td>
<td>2.05</td>
<td>2.07</td>
<td>2.07</td>
</tr>
</tbody>
</table>
5. Discussion

From the results tabulated in Table 2, it can be seen that the excellent stick enables to detect all type of obstacles within determined two meters length, with some error. However, those error is not significant and can be ignored because the key objective of this work is to extend ability of the stick for blind people to be able to operate at longer length. Position of the sensors are very close together (4 cm), thus the system can be stick together and is very small in size as can be seen in Figure 8. This is very useful in the sense that the system can be located any where, e.g., in the stick, or on the human (blind people) body. This system, in addition, can be applied by putting it on the head of the blind people so that they can detect high level of obstacles, protecting obstacles, such as branches of tree, hitting their head.

![Figure 7 Experimental Environment](image)

6. Conclusion

In conclusion, this paper proposes small-scale condition of point-to-point distance measurement using ultrasonic for excellent stick. The results reveal that, by using this technique, operational length of a conventional stick for blind people can be extended from the original position of the sensors. Within the operational length of two
meters, the system provides distance measurement accuracy of 95 percentages on average. The measurement system can be applied for detecting high-level of obstacles.

Acknowledgement

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