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Design of Multi Position tracking System using Ultrasonic Sensor Module

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1. Introduction

Ultrasonic sensors enable to track multi position systems to obtain information about obstacles in large environments. This technology is able to apply in a display module including a touch panel configured to be touched so as to input information. The ultrasonic sensors, which are located at fix points in the vertex of the plate, use the received ultrasonic pulse as a trigger to measure the time of flight of ultrasonic signal. The performance and validity of this system are evaluated using 4 pairs of transmitters and receivers located on the 78 cm x 50 cm plate as shown in Fig. 1. The employment of two receivers permits the calculation of the distance and direction of objects. Moreover, Computer simulation has been used to testify the multi position tracking algorithm.

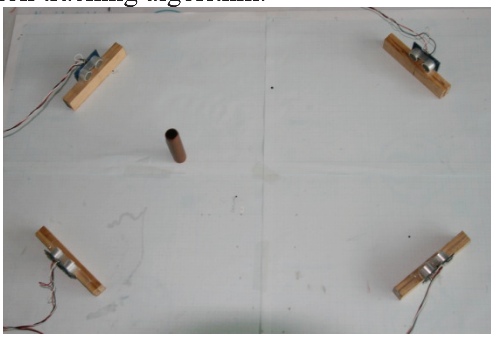

Fig. 1 Position tracking System.

Hardware Platform

In the present work, NT-TS601, which is shown in Fig. 2, ultrasonic sensor modules were employed as ultrasonic transmitter and receiver.

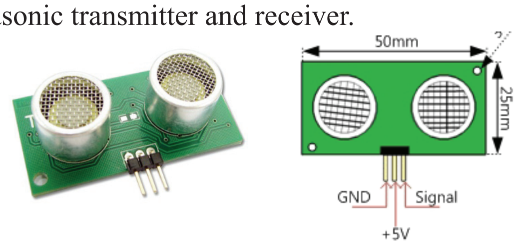

Fig. 2 Ultrasonic sensor module NT-TS601

With the Waveform Generator, trigger pulse for ultrasonic sensor was generated by time interval between transmitted signal and received signals was measured by digital oscilloscope. Each of the four sensors is located to detect the nearest object. The distance from ultrasonic TR to reflector, *d*, can be determined by

$$d = v\frac{t}{2} \quad (1)$$

when *t* is time duration of transmitter-receiver. And v is sound velocity in air which is given by

$$v = 331.5 + 0.60714\,T\ [m/s] \quad (2)$$

where T is temperature in °C. In order to calibrate ultrasonic TR, time delay output from NT-TS601 were measured depending on the reflector distance and shown in **Fig. 3**

Distance-time relationship for pulse-echo system is given by

$$D = (331.5 + 0.60714T) \times (t/2)\ (m) \quad (3)$$

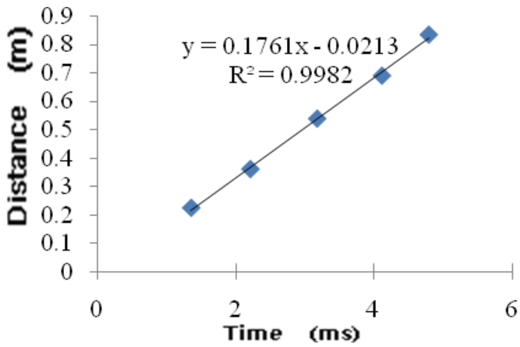

Fig. 3 TR time delay versus distance to reflector

From **Fig. 3,** time-distance equation used in this word obtained a

$$d = 0.174t\ \ (26\,℃) \quad (4)$$

All measurement were carried out at the 26°C of room temperature. Sound velocity will be changed on the change of room temperature. Temperature compensation is essential for precise measurement.

Signal processing

The purpose of the second experiment is making algorithm to detect two objects. At least 4 pairs of TRs are needed to detect the two objects. In the first step, analyze the received signals. Flow chart of basic algorithm of multi position tracking system is shown in Fig. 3.

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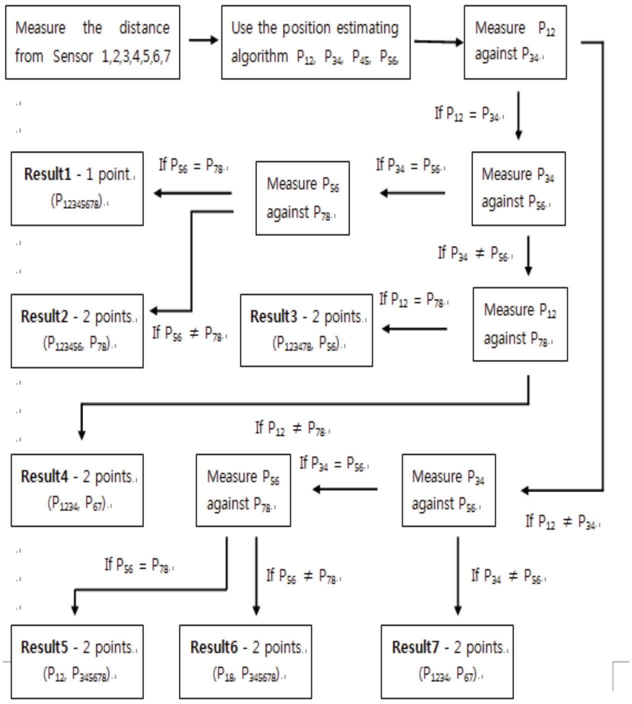

Fig. 3 Algorithm of Multi Position tracking

※ P_{12} = estimated position by using the distance data from ultrasonic module sensor 1 and 2

Mathematical formula of positioning

Steps for mathematical formation for positioning are as follows: [1, 2, 3]

Distance from (s, t) to (x_a, y_a) is d_a

Distance from (s, t) to (x_b, y_b) is d_b

$$d_c = \sqrt{(x_b - x_a)^2 + (y_b - y_a)^2}$$

$$s = \frac{d_a + d_b + d_c}{2}$$

$$D = \frac{d_a^2 - d_b^2 - x_a^2 + x_b^2 - y_a^2 + y_b^2}{2}$$

$$A = \pm 2\sqrt{s(s-d_a)(s-d_b)(s-d_c)} - x_a y_b - x_b y_a$$

Use Heron's formula and inner product to write equation.

$$\sqrt{s(s-d_a)(s-d_b)(s-d_c)} = \pm \frac{1}{2}\{(x_b - x_a)t + (y_b - y_a)s + x_a y_b - x_b y_a\}$$

$$so \quad A = (x_b - x_a)t + (y_a - y_b)s \qquad (5)$$

Use the equation of circle.

$$(s - x_a)^2 + (t - y_a)^2 = d_a^2$$

$$(s - x_b)^2 + (t - y_b)^2 = d_b^2$$

Subtract two equations,

$$d_a^2 - d_b^2 - x_a^2 + x_b^2 - y_a^2 + y_b^2 = 2(-x_a + x_b)s + 2(-y_a + y_b)t$$

$$so \; D = (y_b - y_a)t + (x_b - x_a)s \qquad (6)$$

We now have a simultaneous equation.

$$s = \frac{(-x_a + x_b)D - (-y_a + y_b)A}{(y_a - y_b)^2 + (x_a - x_b)^2}$$

$$t = \frac{(-x_a + x_b)A - (-y_a + y_b)D}{(y_a - y_b)^2 + (x_a - x_b)^2}$$

One solution is a real root and the other is an imaginary root.

Computer simulation

The algorithm and formula was verified by the tracking system shown in **Fig. 3.** In the real system, actual position (10, 10) and (20, 20) was detected (9.67, 10.40) and (20.21, 20.53). Actual Visual C++ is used in the computer simulation. According to the experiment data, error range is ±0.2cm. Through random number generator, random error was given.

Actual Positions (cm)	Measured Positions	Error (%)
(10, 10) and (20, 20)	(10.01,10.17) and (20.04, 19.86)	0.86
(30, 30) and (60, 30)	(30.09, 29.98) and (60.31, 30.40)	0.91
(5, 5) and (5, 70)	(4.96,5.18) and (5.11, 69.67)	0.74
(40, 20) and (40, 40)	(40.11, 20.12) and (39.84, 40.02)	0.42
(10, 40) and (70, 15)	(10.20, 39.81) and (70.48, 15.23)	0.72
(40,50) and (45, 50)	(40.18, 50.08) and (45.21, 49.88)	0.63
(10,5) and (45, 5)	(10.11,4.88) and (44.78, 5.11)	0.54

Table 1 C++ simulation data

According to the simulation data (**Table 1**), error is about 0.63%. With this system, we are able to detect two objects even though they are stick together.

Conclusion

In the first experiment, we testified the ultrasonic sensor's accuracy. Also we are able to track one positioned object with this system. In the second experiment, we use computer simulation to test the multi tracking system. Error was lower than 1 percent. This technology could be used in robot position detecting technology and touch screen, etc.

References

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