Object-tracking robot using ultrasonic sensor and servo motor

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Abstract— **This paper proposes a method that rotation angle of servo motor and distance values of ultrasonic sensor is used for tracking an object in real-time while the robot keeps regular distance. Object detection distance widens using ultrasonic sensors and object recognition, movement of robot is controlled by angle of servo motor and distance of ultrasonic sensors. Not existing tracking method: Camera, LRF, many ultrasonic sensors, for proving that it is possible to track object using ultrasonic and servomotor, trajectory of robot is represented and analysed depending on movement of object in limited conditions.**

Keywords **—** ***Tracking robot, Ultrasonic sensor, Servo motor, Mobile robot***

1 Introduction

Recent research on intelligent mobile robots has been actively performed, various purpose robot in industry and real-life are being developed. Accordingly with a focus on cleaning robots and service robots, robot market is growing rapidly and it is being picked as a new field of future. There are robot's two functions for use in everyday life. First, it is estimated position using external information, second it is performed function according to people's intention. Along with technique development of intelligent robot, many methods for humans interact with robot is being proposed, tracking a target is one method of interaction between human and robot. Tracking robot is expected to apply as various purposes like automation of industry, service robot, observation and alert [1].

The sensor used usually in mobile robot's environmental recognition system is vision sensor, laser sensor, and ultrasonic sensor such as CCD camera. Compared to others, vision can gather the accurate environmental information through the image processing, but there is an amount of data for the process.

When handling the process, it requires high-end system so costs are increased [2][3].

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It is difficult to get the exact information by the laser sensor, due to the fact that the sensor is influenced by the surrounding environment [4][5].

On the other hand, the case of ultrasonic sensor has two advantages.
First of all, the ultrasonic sensor is influenced less than the laser sensor by the surroundings. Second, in comparison to the vision, the sensor can have the data accurately and correctly at a reasonable price [6].
There are many methods for cognizing object, but among them, there is method commonly used by placing a large number of ultrasonic sensors.

However, if the robot recognizes object, because the angle of reflection of sound waves is changed according to change in direction of the object, each ultrasonic sensor data is entered into a another things depending on change of the direction of object [6][7][8].

In this paper, to solve this problem, we propose method that ultrasonic sensor data and rotation angle of the servomotor is used for tracking object. Chapter 2 shows ultrasonic sensor, system configuration, characteristics of servomotor and its application. Chapter 3 describes tracking control method of robot by angle of rotation and moving average filter. In chapter 4, it shows experimental methods and result graph, 5 is conclusion.

2 System configuration and the use of ultrasonic sensor, servomotor

2.1 Ultrasonic sensors

Ultrasonic transmitter and receiver is a pair, Distance data is expressed by controlling a pulse width about coming time that ultrasonic is reflected from an obstacle and degree of precision is less than 2Cm. (Pulse width is proportional to distance from obstacle.) The output range is 0.03~3[m] and the maximum angle is 45 degrees. The measurable time of minimum is 36ms. Fig. 1 shows range of ultrasonic sensor. (Angle is 45 degrees in the datasheet. However, the actual measurement is less than the value of the datasheet.)

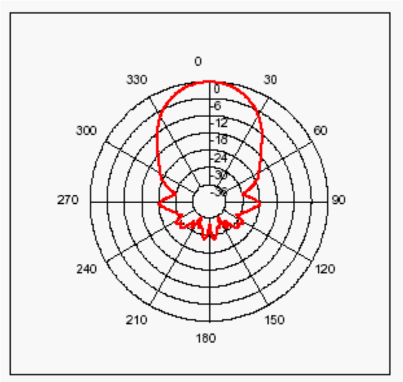

Fig. 1 Characteristics of the measuring range of ultrasonic sensors

2.2 Servo motor

Servo motor points regular direction along with pulse width. Operation angle of servo motor used in this research is maximum 160 degree, the input voltage is 5V.

2.3 The use of ultrasonic sensors and servo motor

Ultrasonic sensor is only represented with distance. If you want to know movement distance and direction, DC motor encoder and compass sensor will be use additionally. Rotation angle of mobile robot is outputted and movement of mobile robot is compensated using this angle [9].

As shown in Fig. 2, ultrasonic sensor is attached to servo motor using fixture for pointing specific height. Detecting range is divided to be 90 degree base on front by arranging it at each two sides. When using a single servomotor, it cannot detect front range of 180 degrees and cause malfunction of the servomotor because of excessive motion. So, we install two servomotors for detecting 180 degree and decreasing detecting time. Also, it is more detect wide location than fixed ultrasonic sensor. So, it shows same effect like multiple ultrasonic sensor used small number of ultrasonic sensor. In this paper, the servo motor describes how to use from now. If mobile robot is moving, ultrasonic sensor recognizes distance between robot and object. Additionally, server motor is stopped and pointing when ultrasonic sensor detect object.

The servo motor's stopped angle is front of mobile robot's rotation angle.

2.4 System configuration

Fig. 2 shows the overall system configuration of the mobile robot. Mobile robot was designed to control for left and right wheels using motor drivers. The overall system was controlled by Coretex-M3-LM8962 based ARM as the main MCU, and motors was controlled by motor drives NT-DC20A. Bluetooth (SD1000) was used to Communication between the mobile robot and PC, and EBIMU-9DOF sensor was used to measure the angle of the direction of movement. EBIMU- 9DOF as IMU sensor was used to measure 3-axis angle values of the Roll, Pitch, Yaw rotation. And using these values, the direction of movement can be seen. Yaw data required for experimental were obtained from the sensor equipped with the mobile robot.

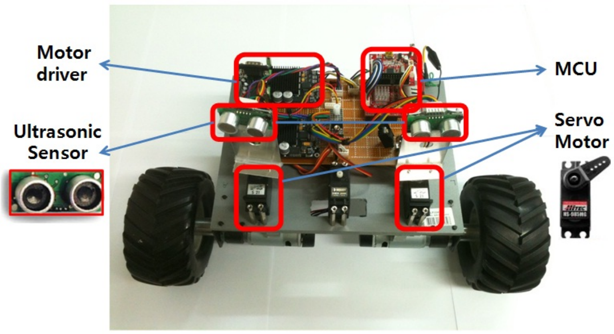

Fig. 2 Servomotor and a mobile robot equipped with ultrasonic sensors configuration

3 Tracking control method

3.1 Tracking controlling for moving object

The mobile robot follows a target keeping a S_d distance. It assumes that the robot chase after the sole thing, which is more close than other mark. In this problem, the given information is the direction angle of servomotor, f_d, and the target's distance, S_d.

The S_d can be got by the ultrasonic sensor. The f_d can be had by servomotor in real time. In Figure 3, the value of l is Eq. (1).

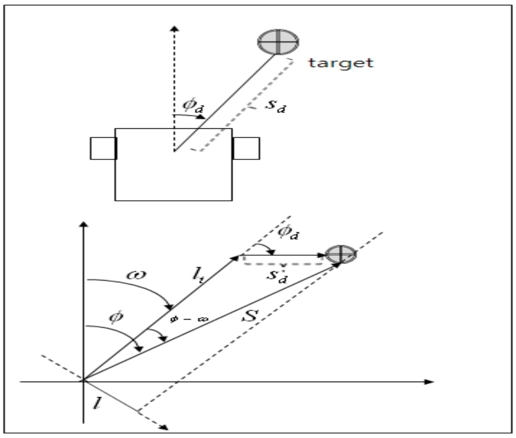

Fig. 3 Motion equations of tracking object

$$l = s \cdot \sin(f - w) \quad \therefore \frac{l}{s} = \sin(f - w) \qquad (1)$$

So w is same as the following one.

$$w = f - \sin^{-1}\left(\frac{l}{s}\right) \qquad (2)$$

In Fig. 3, l_t is the distance that the robot moves to the target, and w denotes the quantity that the robot rotates. The two things are represented as the (3) [1].

$$l_t = s \cdot \cos(f - w) - s_d \cdot \cos f_d \qquad (3)$$

Each driving motor's PWM value is proportionally controlled, according to both sides of ultrasonic sensors' distance and turning angle of servomotor.

3.2 Moving average filter

Moving Average Filter is method that is not only eliminating the noise but also reflecting the system's change of dynamic properly. Moving Average is calculated measurements of a specified number recently, not all measured data. When a new data comes in, it erases the oldest data and calculated the average while it keeps the number of data. In this paper, the noise was calibrated by using a moving average filter at the ultrasonic sensor's measured value. The following expression, the moving average of the n data is subtracted from the previous moving average.

$$\begin{aligned} \bar{x}_k - \bar{x}_{k-1} &= \frac{x_{k-n+1} + x_{k-n+2} + \mathbf{K} + x_{k-1} + x_k}{n} \\ &\quad - \frac{x_{k-n} + x_{k-n+1} + \mathbf{K} + x_{k-1}}{n} \\ &= \frac{x_k - x_{k-n}}{n} \end{aligned} \qquad (4)$$

To summarize about $\bar{x}_k$, the recursive expression of moving average filter is expressed as follows.

$$\bar{x}_k = \bar{x}_{k-1} + \frac{x_k - x_{k-n}}{n} \qquad (5)$$

Where $\bar{x}_k$ is the ($k-n+1$)th data from the (k)th data, a total of n is the average of the data [10].

4 Test and result

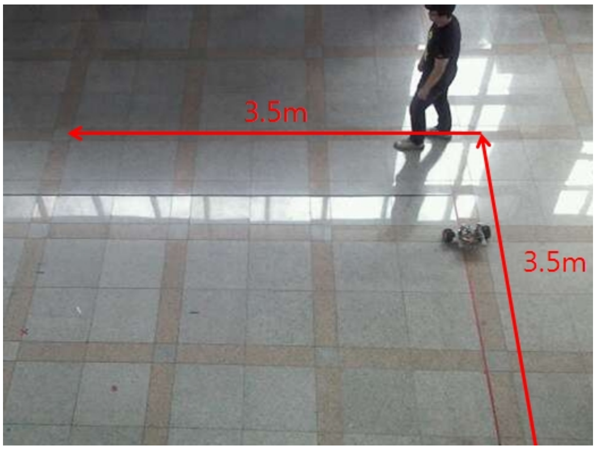

Fig. 4 Doglegged straight line course

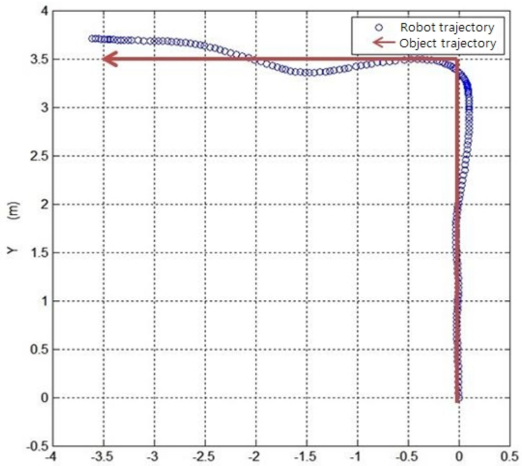

Fig. 5 Mobile robot trajectory of test 1

The first experiment is performed indoor experimental condition like Fig. 4 and mobile robot tracked object while object follows course of 3.5m * 3.5m. Moving trajectory is represented by calculating yaw data of 9DOF and encoder data attached to two DC motor that operates both wheels [11][12][13].

In Fig. 5, object follows along doglegged straight line and it shows that mobile robot tracked along object. In this experimental result, satisfactory result is showed in straight line but 20Cm error occurs in corner because of tracking method and error of motor encoder.

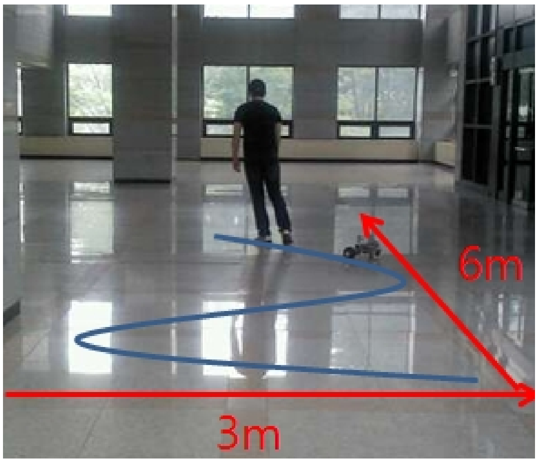

Fig. 6 S-shape course

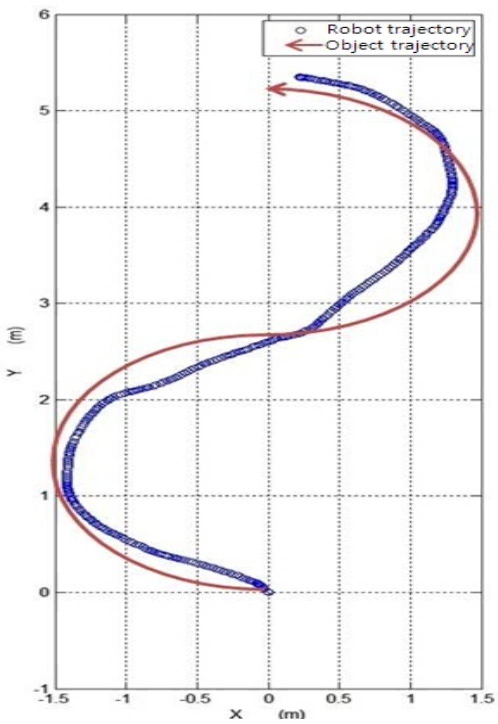

Fig. 7 mobile robot trajectory of test 2

The second experiment is performed in door experimental condition like Fig. 6 and mobile robot tracked object while object follows course of 3m*6m size and S-shape.

In Fig. 7, object follows along S-shape course and it shows that mobile robot tracked along object. Maximum 40~50Cm error occurs in curve point because it is difficult to accurately measure due to slip of wheels.

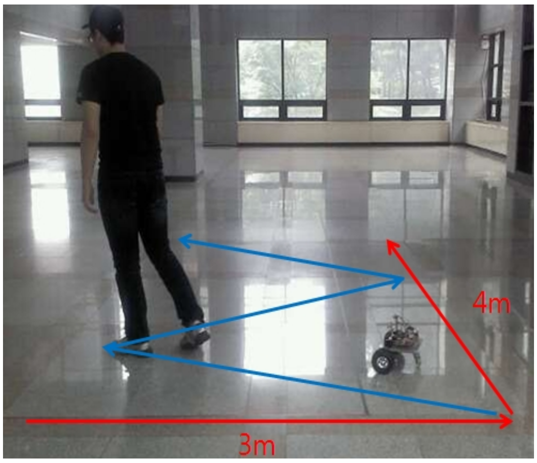

Fig. 8 Zigzag-shape course

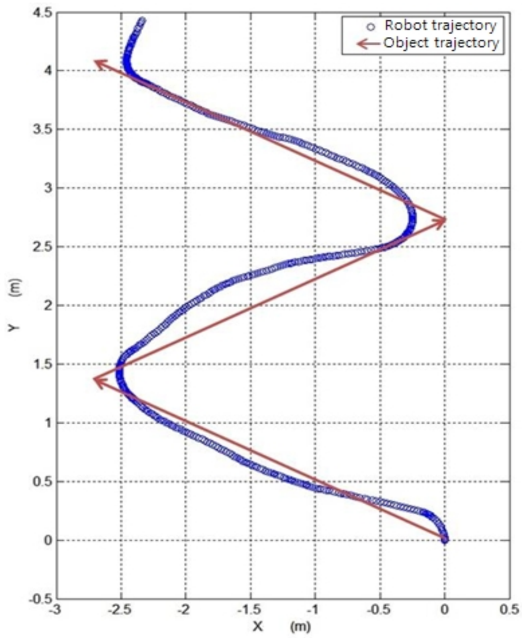

Fig. 9 mobile robot trajectory of test 3

The third experiment is performed in door experimental condition like Fig. 8 and mobile robot tracked object while object follows course of 3m * 4m size and zigzag-shape.

In Fig. 9, object follows along zigzag-shape course and it shows that mobile robot tracked along object. In zigzag course, Maximum 30~40Cm error occurs since mobile robot reached a vertex.

Both wheels of robot are controlled according to rotation angle of servo motor and error occurs due to detection time of ultrasonic sensor after robot turns on corner.

5 Conclusion

Proposed method that uses distance data of ultrasonic sensor and rotation angle of servo motor solve ultrasonic interference that occurs in a large number of ultrasonic sensors as well as it tracked object successfully.

Maximum error of 50Cm occurs like shown graph but it can see that mobile robot tracked object. We plan to research into tracking robot in experimental condition that has obstacles.

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