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 are used for tracking an object in real-time while the robot keeps regular distance. Object detection distance widens by using ultrasonic sensors and object recognition, and movement of robot is controlled by angle of servo motor and distance of ultrasonic sensors. Not adopting the existing tracking methods: camera, laser-infrared(LRF) and many ultrasonic sensors, the proposed method proves that it is possible to track object using ultrasonic sensor and servo motor. Trajectory of robot is represented and analysed according to movement of object in limited conditions.

Key words: tracking robot; ultrasonic sensor; servo motor; mobile robot

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Recent research on intelligent mobile robots has been actively performed, the robots for various purpose 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 the future. There are robot's two functions for use in everyday life. The first is the estimated position using external information, and the second is the performed function according to people's intention. Along with the development of intelligent robot technique, many methods for humans interaction with robots are proposed, and tracking a target is one of them. Tracking robot is expected to be applied for various purposes like automation of industry, service robot, observation and alert[1].

The sensor commonly used in mobile robot's environmental recognition system is vision sensor, laser sensor, and ultrasonic sensor such as CCD camera. Compared with the 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 the cost increases[2-3]. It is difficult to get the exact information by the laser sensor due to the fact that the sensor is influenced by the surroundings[4-5]. In contrast, the ultrasonic sensor has two advantages. First, the ultrasonic sensor is influenced less than the laser sensor by the surroundings. Secondly, in comparison to the vision, the sensor can have the data accurately and correctly at a reasonable price[6].

There are many methods for recognizing object, but among them, there is a method commonly used by placing a large number of ultrasonic sensors in the system. However, when the robot recognizes object, because the reflection angles of sound waves change with the change in direction of the object, each ultrasonic sensor's data enter another unit depending on the direction change of the object[6-8].

To solve this problem, we propose the method that ultrasonic sensor data and rotation angle of the servo motor are used for tracking object. Section 1 shows ultrasonic sensor, system configuration, characteristics of servo motor and its application. Section 3 describes tracking control method of the robot by means of rotation angle and moving average filter. In section 3, experimental methods and results are shown. A conclusion is drawn finally.

1 System configuration and use of ultrasonic sensor and servo motor

1.1 Ultrasonic sensors

Ultrasonic transmitter and receiver are a pair, Distance data are expressed by controlling a pulse width about coming time in which ultrasonic is reflected from an obstacle and degree of precision is less than 2 cm. Here pulse width is proportional to

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distance from obstacle. The output range is 0.03 – 3 m and the maximum angle is 45 degrees. The measurable mininum time is 36 ms. Fig. 1 shows the range of ultrasonic sensor. Here, angle is 45 degrees in the datasheet, however, the actual measurement value is less than the value of the datasheet.

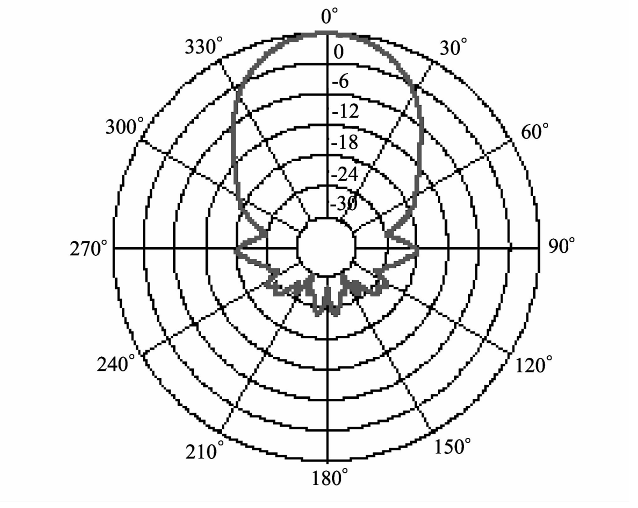

Fig. 1 Characteristics of the measuring range of ultrasonic sensors

1.2 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 5 V.

1.3 Use of ultrasonic sensors and servo motor

Ultrasonic sensor can only represents distance. If you want to know not only movement distance but also direction, DC motor encoder and compass sensor should be used additionally. Rotation angle of mobile robot is output and movement of mobile robot is compensated using this angle[9].

As shown in Fig. 2, ultrasonic sensor is fixed to servo motor for pointing specific height with detection range 90 degrees. When using a single servo motor, it cannot detect the front range of 180 degrees and this can cause malfunction of the servo motor because of excessive motion. So, we install two servo motors for detecting 180 degree and this can reduce detection time. In addition, it can detect wider range than the fixed ultrasonic sensor and shows the same effect like multiple ultrasonic sensors. When the mobile robot is moving, the ultrasonic sensor recognizes distance between the robot and the object. When the ultrasonic sensor finds the object, servo motor stops to point it. The servo motor's stopping angle is in front of robot's rotation angle.

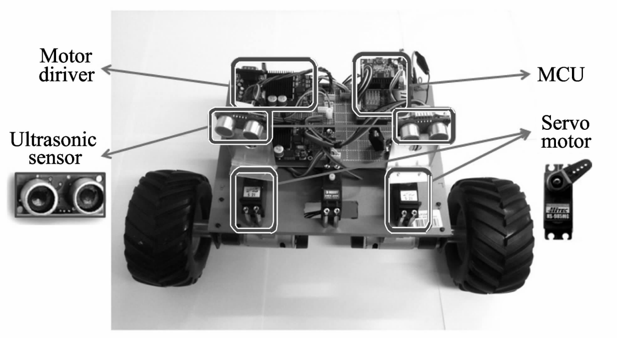

Fig. 2 Servo motor and a mobile robot equipped with ultrasonic sensors

1.4 System configuration

Fig. 2 shows the overall system configuration of the mobile robot. The mobile robot was designed to control 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 drivers 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 and yaw rotation. And using these values, the direction of movement can be seen. Yaw data required for experiments were obtained from the sensors fixed to the mobile robot.

2 Tracking control method

2.1 Tracking control for moving object

The mobile robot follows a target keeping a distance, s_d. It assumes that the robot chases after the sole thing, which is closer than other marks. The given information is the direction angle of servo motor, φ_d, and the target's distance, s_d.

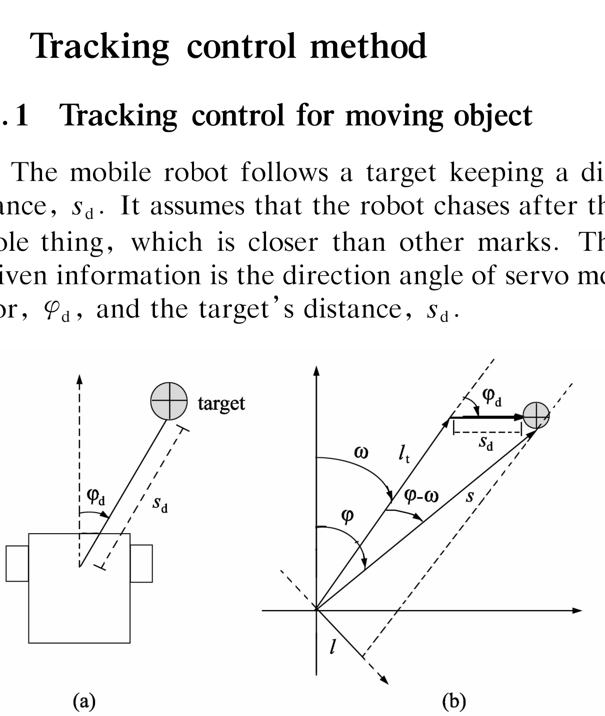

Fig. 3 Motion equations of tracking object

The s_d can be got by the ultrasonic sensor, and φ_d can be had by the servo motor in real time. In

Fig. 3, the value of l is

$$l = s\sin(\varphi - \omega),$$

then
$$l/s = \sin(\varphi - \omega), \quad (1)$$

and ω is the same as

$$\omega = \varphi - \arcsin(l/s). \quad (2)$$

In Fig. 3, l_t is the distance that the robot moves to the target, and ω denotes the quantity that the robot rotates. They can be expressed by[1]

$$l_t = s\cos(\varphi - \omega) - s_d\cos\varphi_d. \quad (3)$$

Each driving motor's pulse-widith modulation (PWM) value is proportionally controlled according to the distance of both sides of the ultrasonic sensors and the turning angle of the servo motor.

2.2 Moving average filter

Moving average filter is the method that can not only eliminate the noise but also reflect the system's change of dynamic property. Moving average is the calculated measurements of a specified number recently, not all the measured data. When new data come in, the oldest data are erased and the average are calculated while the number of data keeps constant. The noise was calibrated by using a moving average filter at the ultrasonic sensor's measured value. In Eq. (4), the moving average of the n data is subtracted from the previous moving average.

$$\bar{x}_k - \bar{x}_{k-1} = \frac{x_{k-n+1} + x_{k-n+2} + \cdots + x_{k-1} + x_k}{n} - \frac{x_{k-n} + x_{k-n+1} + \cdots + x_{k-1}}{n} = \frac{x_k - x_{k-n}}{n}. \quad (4)$$

To summarize about $\bar{x}_k$, the recursive expression of moving average filter is given by

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

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

3 Test and result

The first experiment is conducted indoors as Fig. 4 shows. The mobile robot tracks the object while object follows the course of 3.5 m × 3.5 m. Moving trajectory is represented by calculating yaw data of 9DOF and encoder data attached to two DC motors that operate both wheels[11-13].

In Fig. 5, the object follows along the doglegged straight line. It can be seen that mobile robot tracks along the object and satisfactory result is shown in straight line but 20 cm error occurs in the corner resulting from the tracking method and the errors of motor encoder.

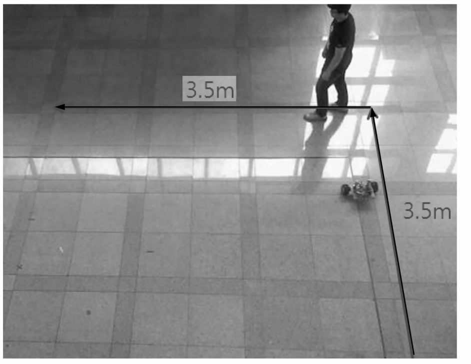

Fig. 4 Doglegged straight line course

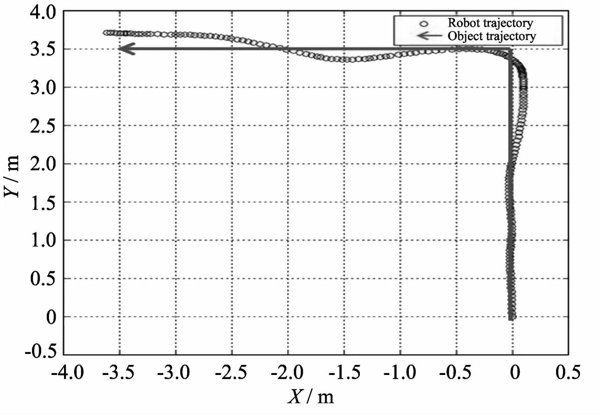

Fig. 5 Mobile robot trajectory of test 1

The second experiment is performed indoors as Fig. 6 shows. The mobile robot tracks the object while the object follows the course of 3 m × 6 m size and S-shape.

Fig. 6 S-shape course

In Fig. 7, the object follows along S-shape course and the results shows that the mobile robot tracks along the object. Max error is 40 – 50 cm which occurs in curve point because accurate measurement is difficult due to slip of the wheels.

The third experiment is performed indoors as

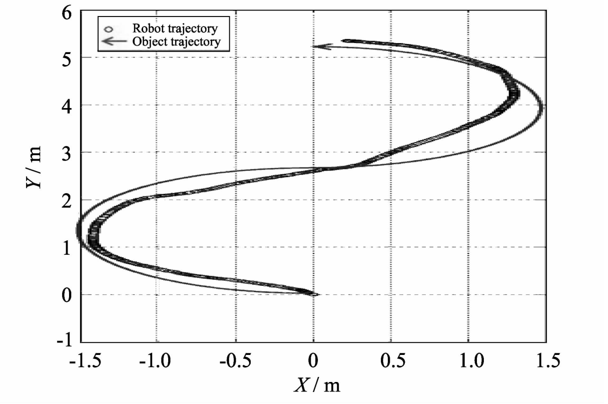

Fig. 7 Mobile robot trajectory of test 2

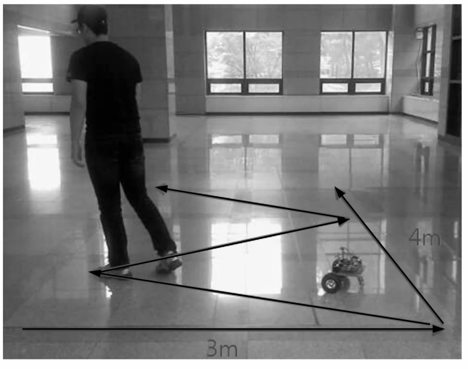

Fig. 8 Zigzag-shape course

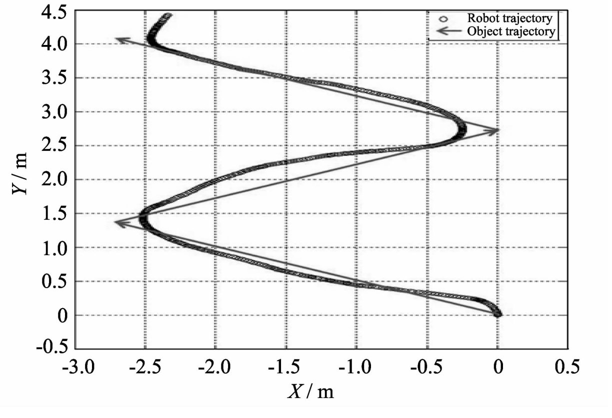

Fig. 9 Mobile robot trajectory of test 3

Fig. 8 shows. The mobile robot tracks the object while the object follows the course of 3 m×4 m size and zigzag-shape.

In Fig. 9, the object follows along zigzag-shape course and the results show that the mobile robot tracks along the object. In zigzag course, Max error is 30 − 40 cm which occurs since mobile robot reaches a vertex. Both wheels of the robot are controlled according to rotation angle of servo motor and the errors occur due to detection time of ultrasonic sensor after robot turning at the corner.

4 Conclusion

By means of distance data of ultrasonic sensor and rotation angle of servo motor, the proposed method solve ultrasonic interference that occurs in a large number of ultrasonic sensors and the mobile robot can track the object successfully.

Max error, 50 cm, occurs as shown in Figs. But it can be seen that the mobile robot can track the object. Gurther research on tracking robot in experimental condition with obstacles will be made.

References

[1] Ko N Y, Seo D J, Moon Y S. A method for real time target following of a mobile robot using heading and distance information. Journal of Korea Intelligent Information System Society, 2008, 18(5): 624-631.

[2] Kwon H J, Bae S K, Kim B G. 3D position tracking for moving objects using stereo CCD cameras. The Journal of GIS Association of Korea, 2005, 13(2): 129-138.

[3] Lee D S, Lee D W, Kim S D, et al. Real-time moving object tracking and distance measurement system using stereo camera. Journal of the Korean Society Of Broadcast Engineers, 2009, 14(3): 271-385.

[4] Kim D Y, Ryoo Y J. Human-following system of mobile robot using IR range sensor and photo sensor. Proc. of KIIS Spring Conference 2010, 2010, 20(1): 473-482.

[5] Ko N Y, Seo D J, Kim K J, et al. A method for a robot to track a moving object using laser range finder. Journal of the Institute Electronics Engineers of Korea, 2007, 20 (2): 258-875.

[6] Han S B, Lee S G, Lim J K, et al. The study on map building algorithm and traveling algorithm of the mobile robot with the ultrasonic sensor. Journal of the Korean Society of Marine Engineering, 2006, 11: 1-292.

[7] Lee S J, Lim J H, Cho D W. A complete feature map building method of sonar sensors for mobile robots. Korean Society for Precision Engineering, 2010, 27(1): 11.

[8] Kim B S, Lee P J. Recognition of geometric elements and the configuration of multi ultrasonic sensors for mobile robot. The Korean Institutute Electrical Engineers, 2003: 1999-2899.

[9] Park S S, Kim K K, Ko N Y, et al. Position estimation of a mobile robot using electronic compass and encoder. Korean Institute of Information Technology, 2007: 1-256.

[10] Kim S P. Understanding the Kalman filter. A-jin publishing, 2009.

[11] Yea M J, Ko K E, Sim K B. Development of algorithm and simulator for mobile robot SLAM by using scan matching method and electronic compass. Proc. of KIIS Fall Conference 2010, 2010, 20(2): 1-5.

[12] Kim H D, Seo S W, Jang I H, et al. Simultaneous localization and mapping of mobile robot using digital magnetic compass and ultrasonic sensors. International Journal of Fuzzy Logic and Intelligent Systems, 2007, 17(4): 435-581.

[13] Ko N Y, Kim K J, Seo D J. Pose estimation of a mobile robot using electric compass. The Korean Society of Mechanical Engineers, 2006, 11: 1-209.