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Basic Research of Indoor Positioning Method Using Visible Light Communication and Dead Reckoning

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***Abstract*—This study proposes a method for detecting the position of an object indoors using visible light communication and dead reckoning. More specifically, we first obtain positional information using visible light communication and then use dead reckoning. At the start point, where a visible light signal can be received, we detect the absolute position of the object using positional information from the visible light source. Subsequently, the directional information for dead reckoning is detected from a Kalman filter using geomagnetic and gyro sensor output. In this paper, we describe a method for detecting the direction using a Kalman filter and present experiment results.**

Experiments are conducted on the 8th floor of the Information Engineering building in Niigata University, Niigata, Japan. In the experiment, we first move a small robot forward to obtain continuous output from the geomagnetic and gyro sensors installed on the robot and that from the Kalman filter. A personal computer records the results sent from the robot. The maximum direction errors for the geomagnetic sensor, gyro sensor, and Kalman filter are 46.62 degrees, 14.17 degrees, and 5.95 degrees, respectively. The results show that the geomagnetic sensor includes large disturbances and the gyro sensor has accumulated error. However, the output of the Kalman filter did not show any large errors of greater than 6 degrees. In the paper, we also show the relationship between the straight moving distance and the directional error while the robot is moving. For the next step, we will add absolute position information of the start point using visible light communication. Then it will become possible to estimate the exact position in a building.

***Keywords*—Visible Light Communication; Dead Reckoning; Indoor Positioning; Kalman Filter; Geomagnetic Sensor; Gyro Sensor**

I. INTRODUCTION

Generally, the Global Positioning System (GPS) is used for outdoor positioning. This method can be used to detect the position using the arrival time of radio wave signals from satellites. However, it is difficult to use this method for indoor positioning due to wave attenuation and multipath generation. An alternative method for indoor positioning is the dead reckoning method. Dead reckoning is a method that uses directional information and the moving distance to calculate a position. However, this method has some problems if we use only a geomagnetic sensor. (1) This method can be used to obtain only a relative position. (2) Detecting the direction of movement is difficult in an indoor environment with magnetic noise. (3) The error in direction and that in movement are accumulated to the position information. Therefore, we propose a new method that combines visible light communication (VLC) and dead reckoning, and we aim to achieve an indoor navigation system. More specifically, we use VLC to obtain the absolute position. Second, we use the dead reckoning method to detect the relative position from the start point where we can detect the exact position based on VLC. Finally, the current absolute position is estimated using these two procedures. In dead reckoning, since it is very important to obtain accurate direction information, a Kalman filter is prepared using output from a geomagnetic sensor and gyro sensor. The following sections describe the direction detection method and experimental results.

II. METHOD

This experiment aims to reveal the direction sensor errors detected when the robot moves in a straight channel. Fig. 1 shows the configuration for the robot used in the experiment. We use a small robot (LEGO MINDSTORMS NXT) in the experiment as the moving unit, which incorporates a geomagnetic sensor, gyro sensor, and visible light receiver. While the robot is moving, a direction signal is transmitted from these sensors. In addition, we use a rotary encoder mounted on each wheel to detect the movement of the robot.

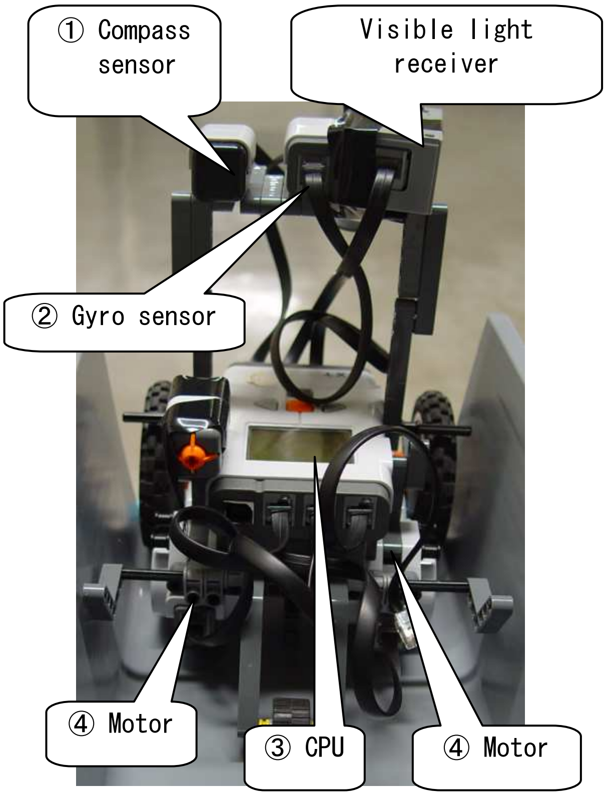
Fig. 2 shows the experimental environment. We conduct the experiment by moving the robot and record the output of the geomagnetic sensor, gyro sensor, and Kalman filter. The channel is made from solid plastic to avoid geomagnetic interference, and the channel width is 150 mm, which is the same as the axel width for the robot. The following is a description of the experimental method.

1) We command the robot to proceed forward along the course (Speed: 0.6 m/s).

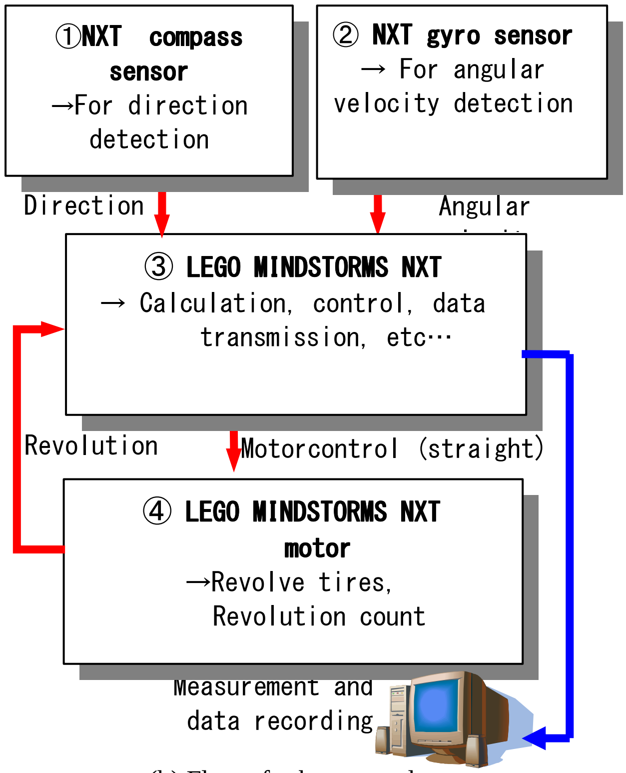
2) When the robot begins to move, the output of geomagnetic and gyro sensors are recorded, as well as the Kalman filter calculation output.

3) The robot sends all recorded information to a personal computer through Bluetooth communications.

We repeat these trials 10 times while moving the robot from east to west, and 10 times while moving the robot from north to south in the corridor.



(a) Robot and sensors



(b) Flow of robot control

Figure 1. Configuration of robot

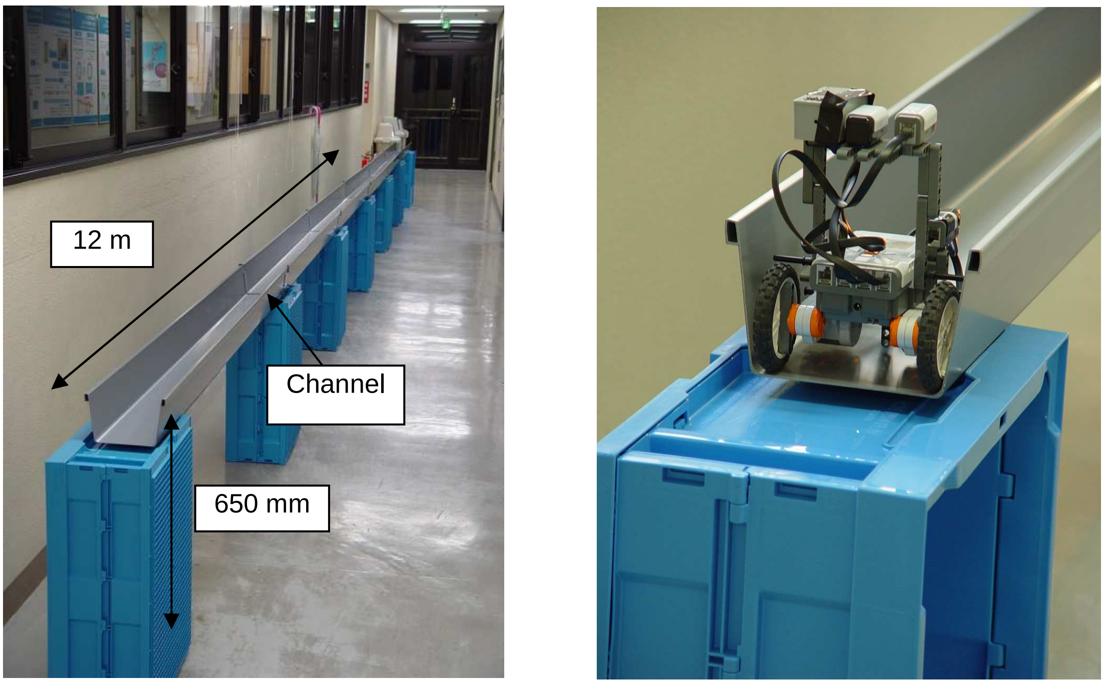
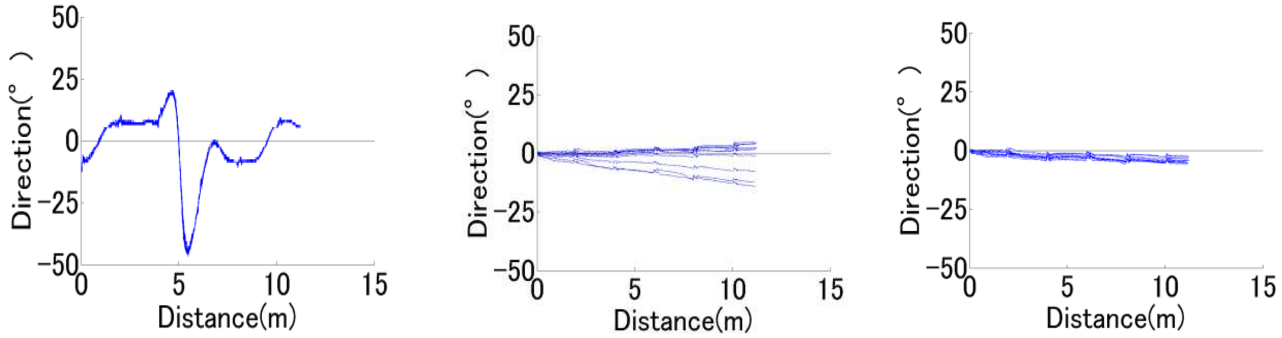


Figure 2. Experimental environment

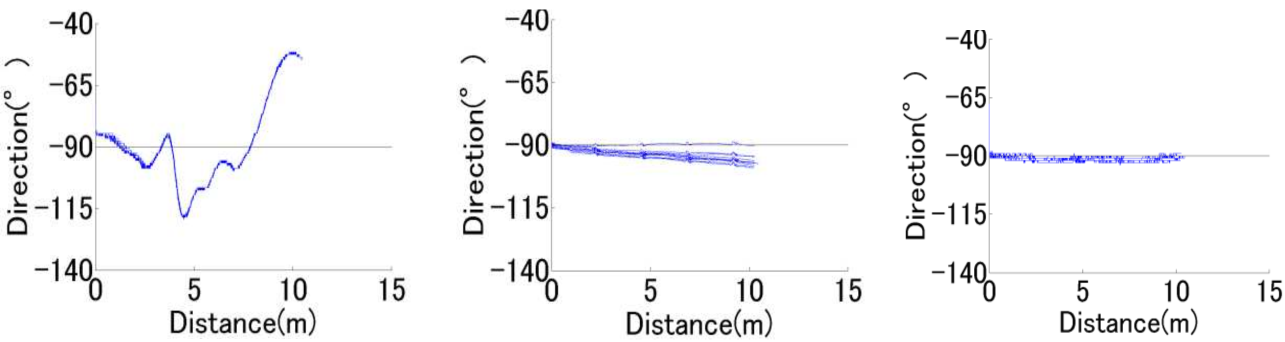
III. RESULTS

Fig. 3 shows the results from the (a) geomagnetic sensor, (b) gyro sensor, and (c) Kalman filter when the robot moved from east to west. The maximum error for the geomagnetic sensor was 46.62 degrees in Fig. 3(a). The calculated directional offset for the gyro sensor can be seen in Fig. 3(b). The maximum directional offset was 14.17 degrees. However, the maximum error of the Kalman filter output was 5.95 degrees, and it was less than those of the other two sensors. Fig. 4 shows the results when the robot moved from north to south. In this case, the maximum error for the geomagnetic sensor, gyro sensor, and Kalman filter were 38.38 degrees, 9.33 degrees, and 4.00 degrees, respectively. Therefore, the geomagnetic sensor included the largest errors while the gyro sensor also contained offset. The Kalman filter had the lowest error of the three.



(a) Geomagnetic sensor (b) Gyro sensor (c) Kalman filter

Figure 3. Results of sensor output while robot is moved from east to west



(a) Geomagnetic sensor (b) Gyro sensor (c) Kalman filter

Figure 4. Results of sensor output while robot is moved from north to south

IV. DISCUSSION

In the experiment, the directional error is minimized to ±6 degrees using the Kalman filter. If the robot moves while retaining the 6 degree error, the positioning error is 10.5 cm. The shape of the visible light receiving area is determined from the shape of the light source, the height between the VLC sensor and ceiling, and the receiving angle of the VLC sensor. For example, if the visible light source is a point light source, height = 2.25 m, with the receiving angle of θ = 15 degrees, the shape of the receiving area will become a circle with the radius of 603 mm. If the robot starting position is a point 3 m away from the light source, it will be necessary to suppress the error to less than 11.3 degrees to reach the light source area. In this experiment, we confirmed that the robot can reach to the visible light receiving area because the maximum directional error of the Kalman filter was kept to less than 6 degrees. Under this condition, we can update the direction using the moving distance of the robot and the actual distance of the visible light source.

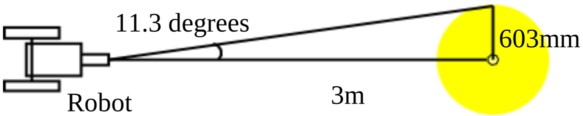


Figure 5. Robot direction and visible light receiving area

V. CONCLUSION

We proposed a new method that combines visible light communication and dead reckoning for indoor positioning. In addition, we conducted an experiment to detect the direction information using a Kalman filter. The results show that we succeeded in maintaining a directional error of less than 6 degrees. For the next step, we will add the absolute position at the start point using visible light communication to detect exact position in a building.

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