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Guidance system for mobile robots

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Abstract. In this research, we developed a flexible, low cost, easy operation guidance system for mobile robots. A simple route determination system is realized by using a mouse, and the robot was guided by using the image processing of a ceiling camera, and sensor fusion information from a gyro sensor and a geomagnetic sensor merged and mounted on a robot. As a result, it was confirmed that it could move along the route within an error of ±200 mm.

1. Background and purpose

Researchers are developing a construction robot (Figure 1) working immediately after concrete placing, and we would like to realize the guidance system of this robot as soon as possible. It is necessary to easily decide the route at the site and it is necessary to travel freely on the concrete surface avoiding obstacles.

Many of the practical guidance methods for an automatic guided vehicle are the methods of using guide line and reflective tape installed on the floor. However, with these methods there is no flexibility in changing routes, and it is impossible to install lines, reflective tapes, etc. after concrete placing.

In recent years, researches using vision sensors, distance sensors and the like are active, but due to instability and handling complexity, there methods have not spread so much in the practical field. In this research, we have developed a guidance system for a mobile robot using a ceiling camera as a flexible guiding system of a robot with low cost and ease of handling in mind, and its performance were evaluated.

Figure 1. Mobile robot working on a concrete surface

2. Guidance Method

2.1. Experimental environment

Figure 2 shows the entire guidance system of the mobile robot. When a wide-angle camera is attached to the ceiling and the image is displayed on the monitor of the operator's personal computer, the entire mobile environment such as mobile robots and obstacles is displayed in this image. Two lamps are attached to the mobile robot at certain interval, and the position and direction of the robot can be detected by image processing this image. Also, this personal computer and mobile robot can exchange information wirelessly.

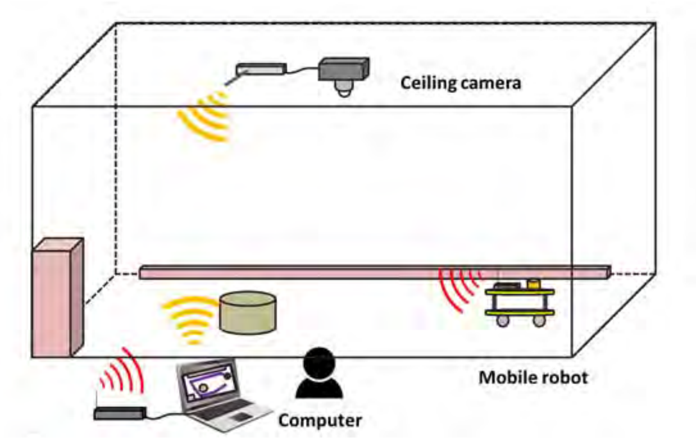

Figure 2. Guidance system(Overall view).

2.2. Routing method

The principle diagram of routing is shown in Fig. 3.

Moving environments such as robots, obstacles, and walls are displayed on the operator's monitor screen. In this screen, plan the guidance route of the robot, approximate the movement route with the line segment, and click the break points of the line segment in the passing order of points as like P1, P2, ...by the mouse. The X, Y coordinates of these points on this screen are saved in the computer.

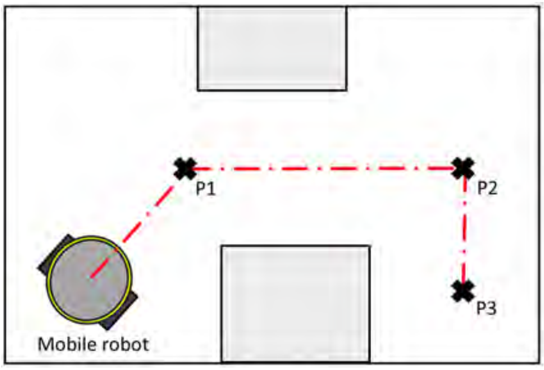

Figure 3. Principle diagram of Routing

2.3 Method of sensor fusion

This robot follows the route based on position and direction information obtained from the ceiling camera, but there is a time lag in image processing, and a real time sensor is necessary. As a real-time angle sensor, there are a gyro sensor and a geomagnetic sensor. However, the geomagnetic sensor is influenced by the disturbance magnetism at the traveling place, and the gyro sensor is not affected by the disturbance magnetism, but the influence of the drift can not be avoided. Therefore, it is decided to suppress the measurement error of the robot's direction angle by sensor fusion taking advantage of the gyro sensor and geomagnetic sensor. In this method, the detection angle of the geomagnetic sensor is adopted as a basis, but the detection angle of the gyro sensor is adopted while it is disturbed by the disturbance magnetic field. A method of discriminating that the geomagnetic sensor is disturbed by a disturbance magnetic field will be described with reference to FIG.4. In FIG. 4, the horizontal axis represents the measurement position and the vertical axis represents the detection angle of each sensor. The green line shows the detection angle of the gyro sensor drifting, and the red broken line shows the detection angle of magnetism sensor disturbed under the disturbance magnetic field. When the difference between the angular change $\Delta\delta$ g of the gyro sensor and the angular change $\Delta\delta$ c of the geomagnetic sensor over the sampling time ΔT exceeds the threshold value nc as in the expression (1), it is judged that there is a disturbance magnetic field, and use the detection angle of gyro sensor.

$$|\Delta\delta c - \Delta\delta g|/\Delta T \geq nc \qquad (1)$$

Also, while judging that there is no disturbance magnetic field, use the detection angle of the geomagnetic sensor and cancel the drift of the gyro sensor.

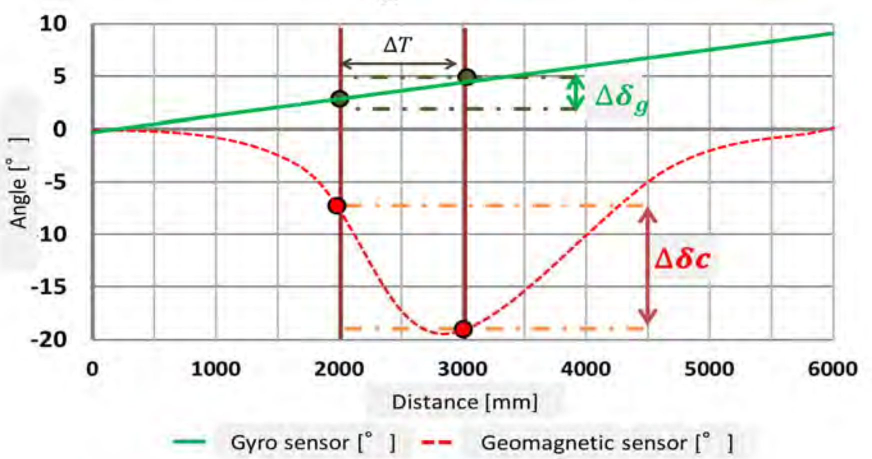

Figure 4. Fusion principle diagram of gyro sensor and geomagnetic sensor

2.4 Method of robot guidance

The guidance method is shown in Fig.5. The angle difference θ between the line a connecting the current position of the robot and the next passing point P 1 obtained from the ceiling camera and the direction b detected from the ramp of the robot is transmitted from the personal computer to the robot. The movement of the robot is controlled in real time so that the deviation angle θ between the direction angle obtained by sensor fusion and the direction of the line a can become zero. Then, when the center O of the robot reaches the area D, it is determined that it has reached the arrival point P 1 and heads toward the next target point P 2. When arriving at all target points, the guidance of the mobile robot is ended.

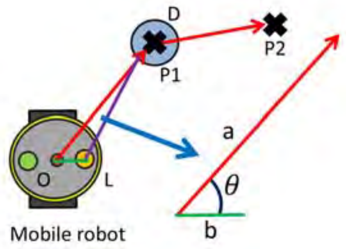

Figure 5. Guidance method

3. Guidance system

3.1 System and specification of robot

The entire guidance environment is shown in Fig.6. The position, direction of the robot and obstacles in the moving environment are displayed on the monitor of the personal computer by the wide angle camera installed on the ceiling. On the screen of the personal computer, the operator instructs the route of the mobile robot. The mobile robot used in this research is shown in Fig.7. This mobile robot is controlled by an independent left and right wheel driving system, and it can move forward and backward, rightward, leftward, large curvature, and ultra-pivotal turn (see Table 1).

Figure 6. Guiding environment

Figure 7. Mobile robot

The robot mounts a gyro sensor, a geomagnetic sensor, a wireless module, and a microcomputer, and two LED lamps for detecting the position and direction of the robot are installed with a ceiling camera (see Table 2).

Table 1. spec. of robot

Item	Full length	Width	Total height	Weight
Value	0.45[m]	0.45[m]	0.36[m]	8.0[kg]

Table 2. spec. of camera, gyro, geomagnetic sensor

Kind	Camera	Gyro sensor	Geomagnetic sensor
Model number	BSW200MBK	MPU6050	HMC5883L
Characteristic	Viewing angle : 120[°] Number of pixel : 200 million pixels Maximum resolution : 1920×1080	Measurement range : ±250[° /sec] Scale factor : 131[LSB/(° /sec)]	Measurement range : ±8.1Gauss Resolution : 12bit

3.2 Routing system

We created software to designate the route to guide the mobile robot. As the operation method, while watching the image of the wide angle camera on the ceiling, click the mouse at the passing points P1, P2, ... of the mobile robot on the monitor. After inputting the route, when the START button is clicked, guidance of the mobile robot is started. The purple line in the camera image represents the indicated route. Figure 8 shows the display screen of the route designation software. The image on the left screen is the image viewed from the ceiling camera, the route, and the movement trajectory of the robot are displayed. The right screen shows passing point coordinates inputting with a mouse. A routing flowchart is shown in Figure 9.

Figure 8. Routing software

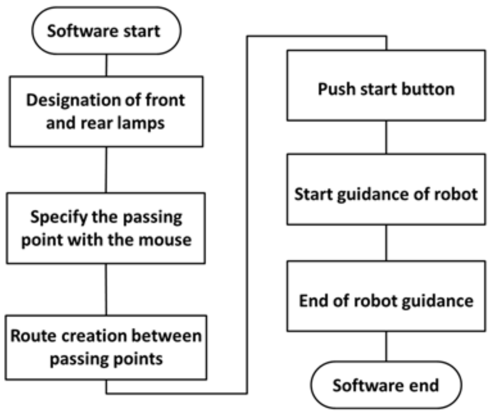

Figure 9. Routing flowchart

3.3 Sensor fusion

3.3.1 Gyro sensor and its characteristics

The characteristics of the gyro sensor are not affected by disturbance magnetism, but drift can not be ignored. The detection angle of the gyro sensor is shown in FIG.10. The horizontal axis represents time and the vertical axis represents angle. There is a drift of 2500 degrees in 30 minutes.

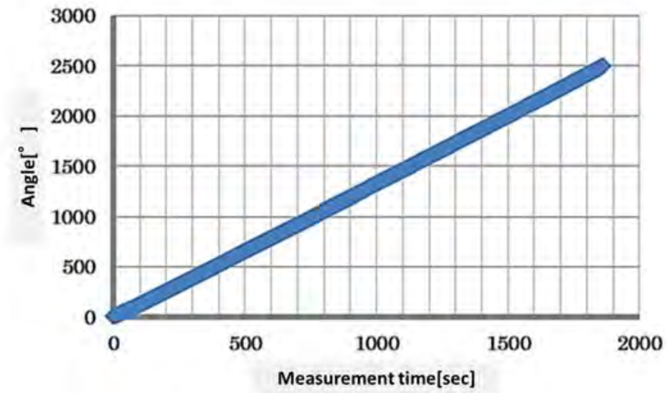

Figure 10. Drift of gyro sensor

3.3.2 Geomagnetic sensor and its characteristics

The geomagnetic sensor detects the direction angle of the robot by utilizing the earth's magnetism. Although the geomagnetic sensor is less likely to drift, it is easily affected by the disturbance. By running the robot on a straight line in the laboratory, the detection angles of the geomagnetic sensor were recorded and shown in FIG.11. The horizontal axis is the measurement position and the vertical axis is the detection angle. An error of 20 degrees was detected at the position around 1.5 m between 6m. In this figure, offset correction to be described later is performed. In general, the geomagnetic sensor has individual differences, so it is necessary to perform offset correction. Rotating the robot on the spot in a fixed magnetic field, Fig. 12 shows the horizontal X and Y output of the geomagnetic sensor. As a result, since the offsets of the geomagnetic sensor on the X axis and the Y axis were -120 mG and -140 mG, offset correction was performed.

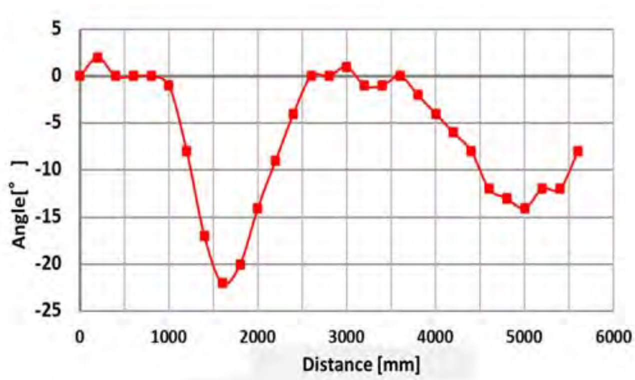

Figure 11. Magnetic effect of geomagnetic

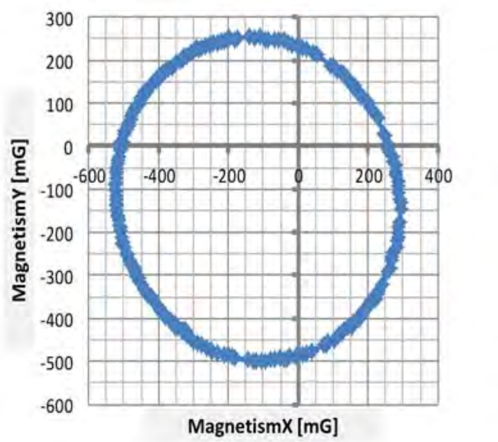

Figure 12. Offset correction

3.3.3 Sensor fusion

By utilizing the gyro sensor and the geomagnetic sensor, we compensate for the shortcomings of a single sensor and obtain more accurate angle. We decided to use a gyro sensor when the magnetism is disturbed, and to use the geomagnetic sensor when not disturbed. Using the equation (1) with the threshold nc = 6.0, it was judged whether or not the magnetism was disturbed. The sensor fusion result is shown in Fig.13. In the figure, a disturbing magnetic field is intentionally applied to the geomagnetic sensor. This drift was compensated because the gyro sensor drift is always about 1 deg / sec. However, it still has about 1 degree of drift in 50 seconds. The error of the geomagnetic sensor is about ± 10 degrees (cut above ± 5 degrees on the graph). However, from the result of sensor fusion, it was confirmed that the detection angle was suppressed to 1 degree or less, and the effect of sensor fusion was large.

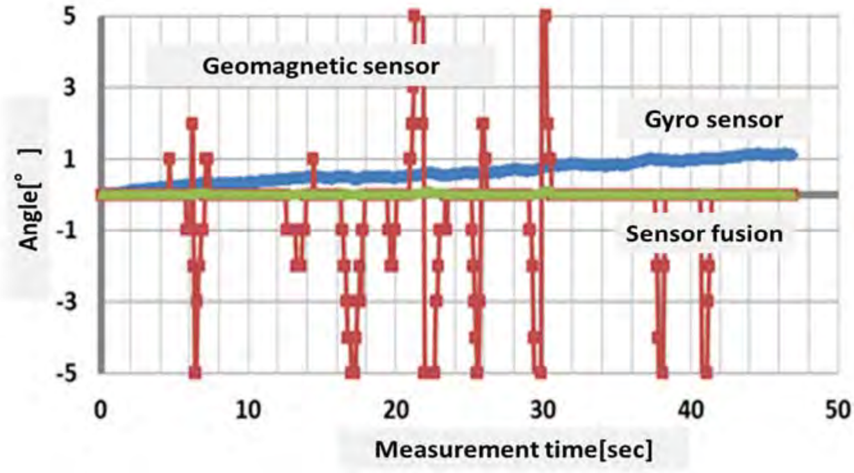

Figure 13. Sensor fusion result

3. 4 Route guidance system

FIG. 14 shows a guidance flowchart. When it starts, it first receives the position, direction of the robot and the direction of the passing point from the ceiling camera. Then, it moves while controlling to match the detection angle obtained from sensor fusion in the direction of the target passing point.

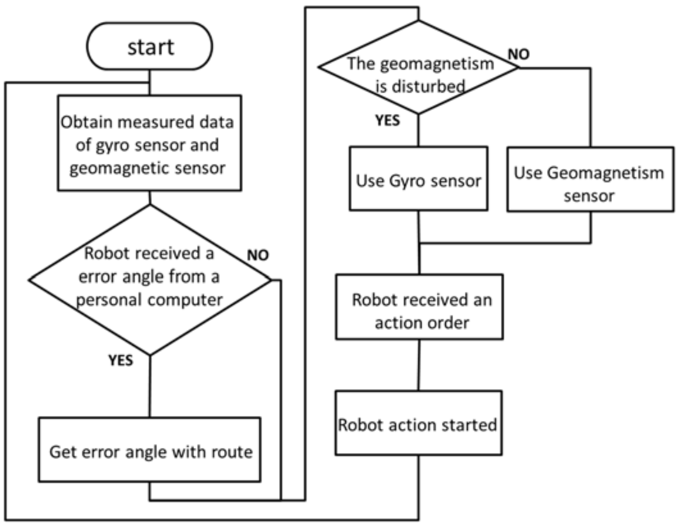

Figure 14. Route guidance flowchart

3.5 Route guidance experiment results

As shown in Fig. 15, in the laboratory, the mobile robot was guided by instructing routes of approximately 1 m east, north 1 m, east 2 m and south 1 m. In the figure, the blue line shows the instructing path and the orange line shows the moving locus of the robot. It is roughly moving along the route. Although the instructed passing point certainly passes, there are cases in which it travels by about ± 200 mm from the route. The main cause of the deviation from this path is instability of the robot's own direction control.

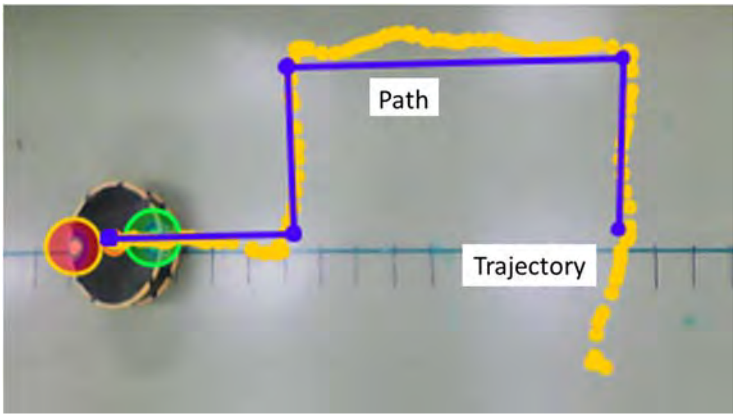

Figure 15. Route tracking experiment result

4. Conclusion
Within the image of the ceiling camera, we could easily decide the route using the mouse, and we made software to make the robot follow the route and carried out the experiment. As a result, it was confirmed that routes can be easily determined and changed. We also confirmed the effect of the simple sensor fusion method of the gyro sensor and the compass sensor. As a result of the guidance experiment of the robot, it was confirmed that it surely passed through the instructed passing point.

References

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