Localization method for AGV using magnetic devices and IMU

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Abstract

This paper is a research of the localization method for AGV (Autonomous Guided Vehicle) with a guidance system using magnetic localization devices. For navigation of AGV, an established magnetic guidance AGV detects a magnetic tape and follows the line. However, there are some weaknesses: disturbance and damage. To make up for the weak points, this paper proposes the localization method using two magnetic localization devices, a gyro sensor and encoders. In order to compensate the global position, AGV's location and angle were compensated for a magnet position and gradient information using two magnetic localization devices. Between spot points, a relative position was calculated by kinematics with the devices. To verify the performance of the proposed method, it was compared with the method using a gyro sensor and encoders. As a result, the proposed method is more efficient than the existing one.

Keywords: Autonomous Guided Vehicle, localization method, magnetic device, wireless guidance

1. Introduction

An automation system is a sort of automatic process system widely used in design, control, facility management, quality inspection and distribution.[1-2] One of the representative automation systems is AGV. It can reduce personnel expenses and improve productivity.[3] In industrial field, magnetic guidance AGV is often used because of its high accuracy, stability and lower price sensors.[4] However, there are some weaknesses vulnerable to disturbance and damage. To make up for the weak points, the researches into a sensor fusion are continued about magnetic device and the other sensors.[5-7]

This paper proposes the localization method using two magnetic localization devices, a gyro sensor, encoders and magnet spots. The rest of this research paper is as below. Chapter 2 explains the components of AGV: IMU (Inertial Measurement Unit), magnetic localization devices, a hardware part. Chapter 3 describes the localization system, chapter 4 explains angle compensation, and chapter 5 shows the experimental environment and results. Finally chapter 6 discusses the conclusion.

2. AGV

2.1. *IMU*

IMU is used to calculate an object's location or angle using an object's inertial measurement. In this paper, IMU composes one-axis gyro sensor and encoders included a motor of the wheel. The angle needs to calculate by only one-axis in AGV's case. It is why the one-axis gyro is used in the AGV. Also encoders are substituted for an acceleration sensor.

2.2. *Magnetic localization devices*

With 75mm gap, two magnetic localization devices are attached to front of the AGV. These devices are located at intervals of 20mm in the same level from the floor. Figure 1 is shown magnetic localization devices used in the experiment.[8-10]

2.3. *Hardware of AGV*

AGV is made of frames, two driving wheels and two caster wheels. DSP (Digital Signal Processor) carries out communication with sensors and laptop. The total system configuration of designed AGV is same as Figure 2.

3. Localization System

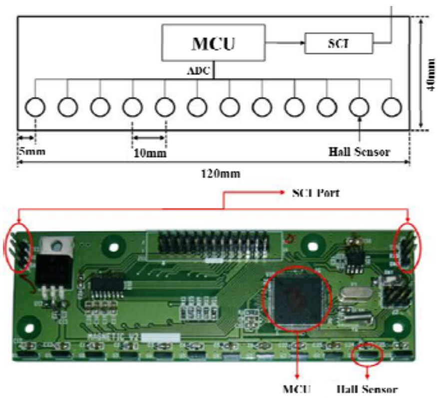

Fig. 1. Magnetic localization devices

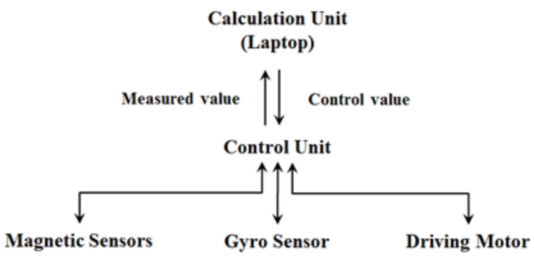

Fig. 2. System configuration

After AGV with a wireless guidance type decides a goal position, it makes a virtual path from the current position to the next position and follows that line. As AGV follows a virtual path, it finds its position using sensors. In case of the proposed method, the absolute coordinate value is not obtained. Therefore, the coordinate must be updated after an initial position is decided arbitrarily.

3.1. *Calculation of AGV's position*

By encoders' values, *LWD* and *RWD* are calculated. *LWD* is a moving distance of AGV's left wheel. And *RWD* is a moving distance of AGV's right wheel. *L* is a distance between wheels. An angle $\theta_{Encoder}$ made by a gap between *LWD* and *RWD* is obtained by Eq. (1).

$$\theta_{Encoder}\,(\text{radian}) = \tan^{-1}\left(\frac{LWD - RWD}{L}\right). \quad (1)$$

As $\theta_{Encoder}$ is accumulated, we can calculate AGV's body angle. Also X-axis variation and Y-axis variation are obtained by Eq. (2).

$$\begin{aligned} \theta &= \frac{\theta_{Encoder} + \theta_{Gyro}}{2}. \\ dv &= \frac{(LWD + RWD)}{2}. \\ dx &= \sin\theta \cdot dv. \\ dy &= \cos\theta \cdot dv. \end{aligned} \quad (2)$$

θ_{Gyro} is an angle calculated by a gyro output value. *dv* is constant needed a coordinate calculation, *dx* is X-axis variation, *dy* is Y-axis variation. AGV's position is calculated by accumulating X-axis variation and Y-axis variation.

3.2. *Control with driving error angle*

A driving error angle control AGV's direction using the measured values of a gyro sensor, a body angle and a path angle. AGV's path angle is calculated by the current position and the next position. AGV's body angle is calculated by Eq. (3).

$$\begin{aligned} \alpha &= \frac{\theta_{Encoder} + \theta_{Gyro}}{2}. \\ \beta &= \tan^{-1}\left(\frac{X_2 - X_1}{Y_2 - Y_1}\right). \end{aligned} \quad (3)$$

α is a body angle and β is a path angle. Finally, we obtain an error angle θ_{Error} by Eq. (4).

$$\theta_{Error} = \beta - \alpha. \quad (4)$$

4. Angle Compensation

Hall sensor measures Gauss of magnet and outputs proportional voltages to measured Gauss.

4.1. *Central value calculation*

To calculate the central value of magnetic localization devices, an initial reference value is established. A reference value is measured by the experiment. Threshold is used for determining the ON/OFF of each of the hall sensors. To determine the threshold, we make Eq. (5) using heuristic method.

$$Th = M_{NM} + (M_M - M_{NM}) \times \frac{2}{3}. \quad (5)$$

Th is Threshold. M_{NM} is an average value of each of hall sensors' measured values about 100 times when there is no magnet. M_M is an average value of each of hall sensors' measured values about 100times when there is a magnet. If a measured value exceeds threshold, it means there is a magnet and hall sensor turns ON. We calculate the central value of magnet by Eq. (6).

$$C = \frac{\sum H_{ONPOS}}{\sum H_{ONCNT}}. \quad (6)$$

H_{ONPOS} is the position value of hall sensor turned ON, and H_{ONCNT} is the number of hall sensor turned ON. And C is the central value of magnet.

4.2. *Angle calculation*

Because of the sensor's accumulative errors, a body angle has always errors. To make up for this weak point, AGV's body angle needs to be compensated and updated. First, we calculate central values of two magnetic localization devices. Second, we calculate a body angle by Eq. (7) when AGV passes through magnet.

$$\alpha = \tan^{-1}\left(\frac{C_2 - C_1}{L}\right) \quad (7)$$

C_1 is a central value of first magnet device and C_2 is second one.

4.3. *Angle compensation*

A point angle is a required angle to change from AGV's current direction to the direction toward next point. When AGV changes the path, an angle is compensated with a point angle and AGV's angle.

5. Experiments & Results

5.1. Experiment environment

AGV's size is 760 x 490 x 480mm. A driving path is straight-line section. There are 2 spot points on a driving path. To compensate a driving error angle, there is magnet spot in each point and its size is 80 x 80mm.

5.2. *Localization using IMU*

In the localization experiment using IMU, AGV drives by an angle calculation of encoders and a gyro sensor. If AGV arrives a spot point using a position calculation, a point angle is updated towards next point and AGV starts to drive.

5.3. *Localization using magnetic devices and IMU*

To reduce accumulative errors, a body angle is calculated by magnetic localization devices on each point and angles of encoders and a gyro sensor are updated. For comparison of errors in two experiments, mean error, root mean square error and maximum error are calculated. Table 1 is shown for a comparison of the proposed method with an established IMU.

Table 1. Result of the position measurement

Unit: mm

IMU			Magnetic device & IMU		
Mean Error	RMSE	Max Error	Mean Error	RMSE	Max Error
226.96	329.74	1089.40	70.24	91.41	186.48

In case of only IMU, error values are immense. On the other hand, error values decrease in case of magnet devices and IMU. Maximum error is six times less. As an angle is compensated using magnetic localization devices, we can measure more accurate position and reduce error value.

6. Conclusion

In this paper, we proposed the localization method for AGV with a guidance system using magnetic localization devices and IMU. AGV is designed by us and magnetic localization devices made for advanced research are attached. Using encoders and a gyro sensor, AGV's position is calculated and a body angle is controlled. When AGV arrives at each point, a body angle is calculated by values of two magnetic localization devices and compensated. As a result, the proposed method is more efficient than an existing one.

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