ORB-SLAM based Sensor Fusion Algorithm for Real-Time Precision Driving

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Abstract

In this paper, we propose a position correction method through SLAM (Simultaneous Localization And Mapping)-based sensor fusion for precise driving in the indoor. There was a problem that it was not possible to determine the exact posture and position with a single image alone. To compensate for this, additional IMU (Inertial Measurement Unit) sensor and encoder sensor should be installed and calibrated. At this time, the encoder sensor acquires information about the distance traveled and the attitude of the mobile robot. The IMU sensor measures the attitude error caused by the sliding and friction of the mobile robot and acquires the slope information of the current terrain. As a result, by combining the location information acquired by using the SLAM and the complex location information of the IMU sensor and the encoder sensor, precise position control is possible even in a space without many feature points.

Keywords: SLAM, Indoor Localization, Mobile Robot

1. Introduction

Recently, with the development of various image processing-related technologies, SLAM technology is in the spotlight as an algorithm for autonomous driving, which is a key keyword of the fourth industrial revolution. SLAM is a technology that maps the surrounding environment and estimates its relative position simultaneously based on sensors attached to the robot. Sensors used are Mono Camera, Stereo Camera, RGB-D Camera, IMU, LiDAR (Light Imaging Detection and Ranging), etc., and are used in various spaces such as AGV (Automated Guided Vehicle) in factory environments, vehicles and drones in outdoor environments, and service robots in indoor environments. Becomes Various algorithms [1-3] have been studied according to the number of cameras and the sensor used, and the advantage of using LiDAR, which enables precise environmental measurement, has the advantage of high algorithm accuracy, but it is difficult to commercialize due to the high price of LiDAR. Has a big disadvantage. Therefore, the need for an alternative technology to replace the LiDAR-based SLAM is highlighted. Therefore, through this research, IMU and Encoder intend to develop algorithm that can measure and control precise position in the environment where there are not many feature points.

2. Mobile Robot Location Estimation

Dead Reckoning is a method of obtaining the position and direction of a mobile robot using only the amount of wheel movement. If there is no sliding of the mobile robot and there are no structural errors such as wheel size and rotation angle, dead reckoning can be used to estimate the position of the robot. Due to the error of the wheel, the sliding of the wheel during movement, and the structural error of the mobile robot, it is difficult to estimate the exact position only by the odometry information through the encoder. Because of this, the odometry information should be corrected and used. At this time, the correction acquires the posture information (Roll, Pitch, Yaw) of the mobile robot by using the IMU sensor and corrects the posture error of the mobile robot based on this.

2.1. *Position Estimation Using Encoder Values*

The robot used in the paper is shown in Fig. 1. The driving method of the mobile robot is driven without a separate steering device and determines the moving direction of the robot by the sum of the forces of four wheels, respectively. In order to calculate the forward and angular velocities of the mobile robot, each wheel rotation must be measured. In order to measure the angular velocity of the robot, each motor was equipped with an incremental encoder, and the angular velocity was measured by calculating the RPM value as a pulse is input every time the motor rotates. The robot is equipped with four encoders and uses the average of the left and right encoders.

$$E_L = \frac{E_{FL} + E_{BL}}{2} \qquad E_R = \frac{E_{FR} + E_{BR}}{2} \tag{1}$$

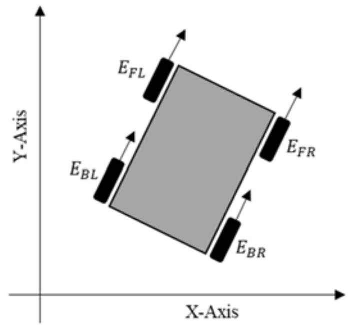

Fig. 1. 4-Wheel mobile robot.

Where E_L and E_R are the average of the left and right encoder rotations. And the velocity and angular velocity can be obtained by using the encoder rotation values obtained above.

$$v = \frac{r(\Delta E_R + \Delta E_L)}{2} \qquad \omega = \frac{r(\Delta E_R - \Delta E_L)}{d} \tag{2}$$

Where r is the diameter of the wheel and d is the width between the left and right wheels. For the time [t_i, t_{i+1}], when the robot is given a constant speed input v, ω and knows p_i as the position of the robot at the current time, the method to calculate the position p_{i+1} of the robot at the next time is as follows.

$$\begin{aligned} x_{i+1} &= x_i + v_i \Delta t \cos\theta_i \\ y_{i+1} &= y_i + v_i \Delta t \sin\theta_i \\ \theta_{i+1} &= \theta_i + \omega_i \Delta t \\ \Delta t &= t_{i+1} - t_i \end{aligned} \tag{3}$$

Eq. (3) can be used to find the position p_{i+1} at time t_{i+1}.

2.2. *IMU-based pose measurement*

Fig. 2. shows the IMU sensor coordinate system used in the paper. The gyroscope sensor needs an integration process to find the rotation angle. At this time, an integration error occurs, and as the number of rotation angle calculations increases, rotation angle drift due to error accumulation occurs. The accelerometer sensor extracts abnormal values for fast rotation and fast

direction changes. However, instead of these drawbacks, the gyroscope showed a relatively stable value change during the movement, and the accelerometer has a characteristic that maintains a constant value at the beginning and the end, so the merits of the two should be fused through the complementary filter.

Accelerometer is a sensor that shows the derivative value of velocity for unit time in the linear direction. It should be converted into Roll and Pitch angle values as follows.

$$\rho = \arctan\left(\frac{A_x}{\sqrt{A_y^2 + A_z^2}}\right)$$
$$\phi = \arctan\left(\frac{A_y}{\sqrt{A_x^2 + A_z^2}}\right) \quad (4)$$

The accelerometer passes the low pass filter and the gyro sensor passes the high pass filter and adds up the result to get the corrected angle. Fig. 3. shows the complementary filter.

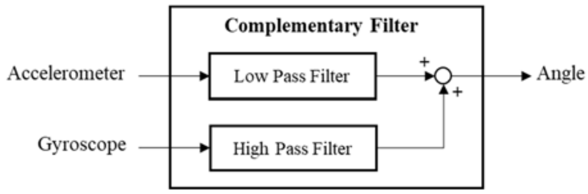

Fig. 3. Block diagram of the complementary filter.

The corrected angle value in Fig. 3. can be expressed as the following equation.

$$\rho_i = \alpha * (\rho_{i-1} + gyro\_x * dt) + (1-\alpha) * (acc\_x)$$
$$\phi_i = \alpha * (\phi_{i-1} + gyro\_y * dt) + (1-\alpha) * (acc\_y) \quad (4)$$

α is the filter constant, ρ_{i-1} is the previous roll angle and ϕ_{i-1} is the previous pitch angle. $gyro$ is the angular velocity measured by the gyro sensor, dt is the sampling time of the gyro sensor, and acc is the x-axis measurement of the acceleration sensor.

Yaw angle can be obtained by using a geomagnetic field sensor, and correction according to tilt change should be applied. The equation can be expressed as follows.

$$X' = X\cos(\phi) + Y\sin(\rho) - Z\cos(\rho)\sin(\phi)$$
$$Y' = Y\cos(\rho) + Z\sin(\phi) \quad (5)$$
$$\theta = \arctan\left(\frac{Y'}{X'}\right)$$

3. ORB-SLAM Calibration

Fig. 4. shows the flow chart for the ORB-SLAM [4-5] calibration. According to the procedure, the incremental encoder is used before correction to collect information on the moving distance and the current driving direction by changing the encoder value according to the movement. And using the IMU sensor to acquire the attitude information (Roll, Pitch, Yaw) of the mobile robot. Finally, the posture information and the position information in the image acquired by ORB-SLAM are compared with the information obtained from each sensor and corrected to improve the accuracy.

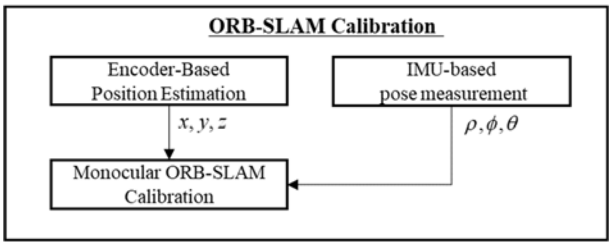

Fig. 4. Block diagram of the ORB-SLAM calibration

4. Experiment

Experiments were performed to verify the ORB-SLAM calibration method using the Encoder and IMU sensors. In this experiment, the camera uses a webcam with 1280 * 720 resolution for the robot's position estimation, and is equipped with four encoders, an IMU including an acceleration sensor, a gyro sensor, and a geomagnetic sensor. Fig. 5. shows the mobile robot used in the actual experiment. In the mobile robot, sensor values and images acquired in real time are transmitted to the host PC using TCP / IP communication based wireless communication, and the host PC estimates the position of the mobile robot with improved accuracy by correcting the ORB-SLAM based on the acquired information.

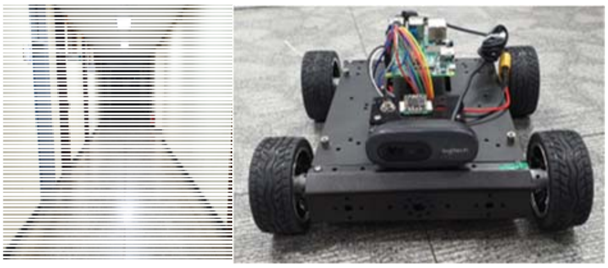

Fig.5. Experiment Environment and Mobile Robot

Fig. 6. is a graph comparing the difference between before and after applying the algorithm when driving indoors at 9m width and 14m height.

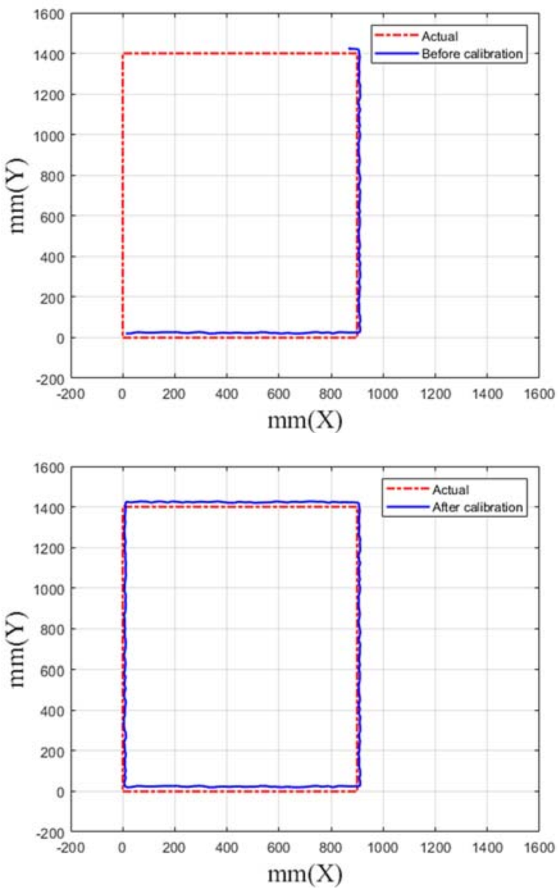

Fig.6. Results before and after calibration

5. Conclusion

In this paper, we proposed an algorithm to correct the position by acquiring the position and posture information of encoder and IMU sensor to solve the problem of position error when driving indoors with less feature points when using Monocular ORB-SLAM. As a result of the experiment, it was able to recognize the path not recognized by the existing algorithm and create a path similar to the experimental environment.

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