Development of Autonomous Robot for the Labor-saving Forestry  
- Positioning of the Robot using IMU, GPS and Encoder -

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Abstract  
This paper presents about the positioning of the autonomous robot using IMU, GPS, and encoder devices. Using acceleration and orientation of the IMU sensor that is used to calculate the position of the robot. To locate the position, need to know the distance when the robot moved. Distance is calculated by integrating velocity function and also the velocity is considered by integrating the acceleration function. Results showed distance measurement using only IMU. It shows the difficulty of locating used only IMU. Therefore, GPS and encoder devices need to be combined into the system for position measurements.

Keywords: Positioning system for wheeled robot, IMU, GPS, Encoder.

1. Introduction  
Generally, it takes a lot of time and needs much labor for managing the resources of the forest. In addition, nowadays in Japan, the population of the forestry is getting fewer and getting older. Therefore, our researches have concentrated on developing the autonomous robot for the labor-saving forest, and particularly this research focuses on developing the positioning system of the robot to collect the data in the forest.

The robot is supposed to look around in the forest and collecting the data of the forest. Therefore the robot is modeled based on ATV and some sensors and actuators are installed on it.

To look around automatically at the forest, positioning system is essential to the robot. Our positioning system is going to be composed of IMU, GPS, and Encoder devices. This paper presents about the positioning system using only IMU. The IMU can output 3-axes acceleration, 3-axes angular rate, and 3-axes magnetic field. Integrating the acceleration from IMU, and calculates velocity of the robot and integrates the velocity and calculates the distance the robot moved. Orientation of the robot is decided by the magnetometer of the IMU.

This paper is organized as follows: Section 2 provides the configuration of the robot. Section 3 of the paper explains the way calculating the distance of the robot using IMU and its problem. Section 4 shows the
algorithm for solving the problem. Section 5 shows experimental results with the algorithm. Section 6 concludes the paper.

2. Configuration of the Robot

Our robot developed is shown in Fig.1. KFX®90 (Kawasaki Heavy Industries Motorcycle & Engine Company) is platform of the robot to be able to run in the rugged area (the forest). For avoiding trees, 3D Depth sensor, CCD camera, and RFID antenna are installed. Motors are used for controlling the movement of the robot. IMU for positioning system of the robot. Multi blades for weeding in the forest. And three mini-computers (Intel NUCs) for controlling the all devices.

3. Measuring distance with IMU device

To measure the distance using IMU, fixed the IMU on a cart and move it 10[m] parallel to the IMU’s y-axis and start to measure before cart starts and stop measure when car moves 10 [m] and stops, 10 times conducted. Fig.2 shows the distance calculated by acceleration using IMU. It shows how far it is from 10[m] and how wide its variability, and its standard deviation is 328.04. The distance and velocity are calculated by Equations (1) and (2), where, $\ddot{a}$ is acceleration, $\dot{v}$ is velocity and $x$ is distance.

$$\ddot{v} = \int \ddot{a} dt$$  \hspace{1cm} (1)

$$\dot{x} = \int \dot{v} dt$$  \hspace{1cm} (2)

Fig.3 shows a result of acceleration (blue line) and its approximate line (red points) in this experiment. It shows approximate line is negative ever since about 1.5[s]. It is supposed to be zero except while start moving and stopping. In addition, the value of approximate line is totally different every measurement. Therefore, the calculating approximate curve need for our system.

4. Algorithm for solving the error

To solve the problem we created following system. First, get acceleration data every 0.01 second, and decide whether the cart moves or not. If the cart moves, the acceleration data are accumulated in an array have 100 elements. When the array is full, start calculating the distance and clear all elements of the array and start accumulating from the beginning. Using moving
average of the acceleration, determine the duration of acceleration of the cart. While duration of the acceleration, calculates distance using acceleration revises by offset is determined by average of acceleration before start moving. After the duration of acceleration, calculates approximate curve using the all elements of array, and calculates distance using acceleration subtracted by approximate curve every 0.01 second. The approximate curve is updated every 1 second because the number of elements of array is 100 and get acceleration from IMU every 0.01 second. After calculating distance, decide whether cart moves or not. Fig.4 shows the flowchart.

5. Experimental results

To examine the effect of the system, conducted the experiment the same as it was mentioned in the Section3. Fig.5 shows the experimental results. Results show that accuracy of measurement was improved, and its variability is smaller than before. In fact, its standard deviation is 1.77, before it was 328.04.

Fig.6 shows a result of acceleration (blue line) and its approximate line (red points) in this experiment. It shows that the system started calculating distance after 1 second, because that need to wait accumulating data in the array. After that, duration of acceleration, approximate line is nearly to zero. Now, the effect of this system that revising raw acceleration is verified. However, in this algorithm assume that after duration of acceleration, cart moves in accordance with uniform linear motion. Therefore, when cart motion is not uniform linear motion, this algorithm cannot be used, because revision by the approximate line clear the steep change of acceleration. For example, when cart moves forward and backward in a short term, the change of acceleration is cleared by the approximate line. Because of this, the algorithm cannot be installed with the actual robot.

6. Conclusion

The system improved the accuracy of the measurement, but the system can only be used for the specific situation and application of the system is very limited. Therefore, measuring the distance only using IMU is difficult, because the shape of the approximate
line of the acceleration is completely different every time even cart moves in accordance with the uniform linear motion. Finally, the IMU can also output Euler angle based on angular rate, so it is necessary to use IMU for compensation of the system composed of Encoder and GPS.

References

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