Direction Control of Moving Vehicle using Dual RTK-GNSS and Kalman Filter

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Abstract

We have been investing a weeding robot. The robot estimates its position with Global Navigation Satellite System(GNSS) but includes errors, which are around a few meters, when it does single positioning. The direction of the robot deviates a lot as it is based on location information. Hence by using the more accurate Real Time Kinematic GNSS (RTK-GNSS), the positional accuracy improved. However, since the direction of the robot was estimated from the difference with the position of the previous robot, it was difficult to estimate the direction while posing. Therefore, we presumed self-position with two single frequency RTK-GNSS receivers which become to be available recently and are economically friendly. By setting the normal vector calculated from the left and right position information with two modules as the direction of the robot, it made it possible to estimate the direction not only while running but also posing. Moreover, we will tackle construction of position estimation system with Kalman filter.

1 Introduction

Our research group has been developed a small weeding robot[1]. This robot weeds automatically in paddy fields. It is important for the robot to know the self-position because it moves in a vast environment. To know the self-position, some researchers use camera[2] or beacon[3]. However, these devices easily affected by disturbance such as weather, so it is difficult to apply to our robot. Therefore, we adopt Global Navigation Satellite System(GNSS) to obtain self-position of the robot. Conventionally, robots obtain self-position by single-positioning method. However, position errors and orientation errors are greatly increase. Therefore, we adopt Real Time Kinematic-GNSS (RTK-GNSS) for higher accuracy.

GNSS modules mainly receive two kinds of carries. Dual frequency receivers are expensive and large, so we can not mount our robot. On the other hand, the number of satellites has increased by multi-GNSS technology in recent years. As a result, cheap and compact modules that can acquire one frequency carrier have been on the market. Therefore, we adopt these modules. We installed two modules on the both side of the robot because it is difficult to estimate the orientation of the robot using only one module. In this research, we propose a more accurate self-localization system by introducing the Kalman filter into our positioning system. We verify our proposed method by Matlab.

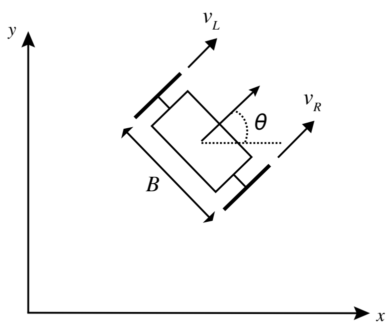

Fig. 1: Robot model

2 Kalman filter

この章では提案するカルマンフィルタのモデルを説明をする．本研究ではアイガモロボットを対象としており，このロボットは２次元平面上を移動する．
カルマンフィルタの予測フェーズ

$$\begin{aligned}\hat{x}_{t+\Delta t|t} &= F_t\hat{x}_t + B_t u_t \\ &= \hat{x}_t + B_t u_t \end{aligned} \tag{1}$$

$$\begin{aligned}P_{t+\Delta t|t} &= F_t P_{t|t} F_t^T + Q \\ &= P_{t|t} + Q \end{aligned} \tag{2}$$

$$\begin{bmatrix}\hat{x}_{t+\Delta t|t}\\ \hat{y}_{t+\Delta t|t}\\ \hat{\theta}_{t+\Delta t|t}\end{bmatrix} = \begin{bmatrix}\hat{x}_{t|t}\\ \hat{y}_{t|t}\\ \hat{\theta}_{t|t}\end{bmatrix} + \begin{bmatrix}\Delta t cos\hat{\theta}_{t|t} & 0\\ \Delta t sin\hat{\theta}_{t|t} & 0\\ 0 & \Delta t\end{bmatrix}\begin{bmatrix}v_t\\ \omega_t\end{bmatrix} \tag{3}$$

$$e_t = \hat{x}_t - x_t = \begin{bmatrix}\hat{x}_t - x_t\\ \hat{y}_t - y_t\\ \hat{\theta}_t - \theta_t\end{bmatrix} \tag{4}$$

$$P_{t|t} = E\left(e_t e_t^T\right) \tag{5}$$

$$
\begin{bmatrix}
\sigma_{xx,t|t+\Delta t} & \sigma_{xy,t|t+\Delta t} & \sigma_{x\theta,t|t+\Delta t} \\
\sigma_{yx,t|t+\Delta t} & \sigma_{yy,t|t+\Delta t} & \sigma_{y\theta,t|t+\Delta t} \\
\sigma_{\theta x,t|t+\Delta t} & \sigma_{\theta y,t|t+\Delta t} & \sigma_{\theta\theta,t|t+\Delta t}
\end{bmatrix}
= \begin{bmatrix}
\sigma_{xx,t|t} & \sigma_{xy,t|t} & \sigma_{x\theta,t|t} \\
\sigma_{yx,t|t} & \sigma_{yy,t|t} & \sigma_{y\theta,t|t} \\
\sigma_{\theta x,t|t} & \sigma_{\theta y,t|t} & \sigma_{\theta\theta,t|t}
\end{bmatrix}
+ \begin{bmatrix}
q_x^2 & 0 & 0 \\
0 & q_y^2 & 0 \\
0 & 0 & q_\theta^2
\end{bmatrix} \tag{6}
$$

カルマンフィルタの更新フェーズ

$$y_t = z_t - H_t \hat{x}_{t+\Delta t|t} \tag{7}$$

$$S_t = R + H_t P_{t+\Delta t|t} H_t^T \tag{8}$$

$$\hat{x}_{t+\Delta t|t+\Delta t} = x_{t+\Delta t|t+\Delta t} \tag{9}$$

3 Experiments on acquisition of covariance matrix for Kalman filter

We investigated the error distribution used for the Kalman filter in the previous study.

3.1 Experimental device

RTK-GNSS requires at least GNSS modules, base station and rover. In this experiment, we use one Reach RS[7] from Emlid as a base station and two Reach[8] from Emlid as a rover. As shown in Figure 2, the base station is installed at a position of 1.5m above the ground with a quaint triangle with a clear view. Rover uses an experimental apparatus as shown in Figure 3. Under the antennas of the base station and the mobile station, an aluminum plate of 10 cm x 10 cm is laid down to prevent multipass from the ground.

Fig. 2: Small process noise

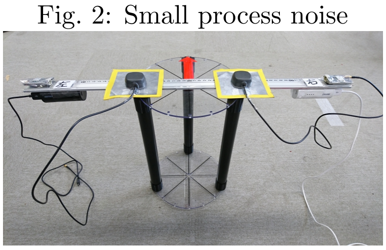

Fig. 3: Small process noise

3.2 Investigation method

In the previous study, the following data set was measured in order to investigate the position error, the orientation error, the influence of the module distance and orientation, when two modules were used for a rover.

(i) Ground height 30cm/Distance between modules 20cm

(ii) Ground height 30cm/Distance between modules 30cm

(iii) Ground height 30cm/Distance between modules 40cm

(iv) Ground height 150cm/Distance between modules 20cm

(v) Ground height 150cm/Distance between modules 30cm

(vi) Ground height 150cm/Distance between modules 40cm

Figures 4 and 5 show the results of (ii) which is closest to the real environment.

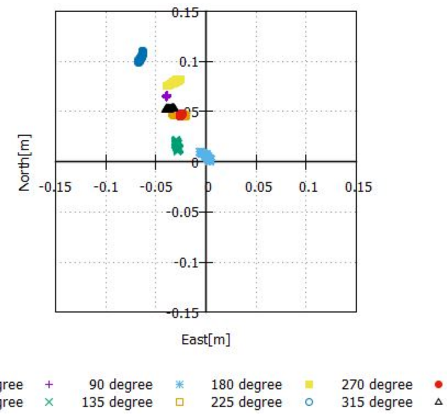

Fig. 4: aaa

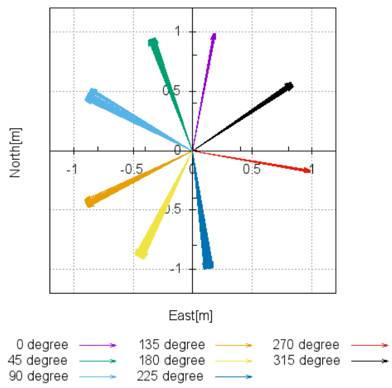

Fig. 5: aaa

A variance covariance matrix is calculated from the error data obtained from this experiment. The multivariate normal distribution of only the position is shown in figure 6.

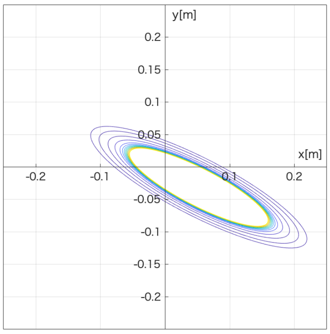

Fig. 6: aaa

The mean and variance covariance matrix with the orientation of the robot also added are shown in equations 10 and 11.

$$\mu = \begin{bmatrix} \mu_x \\ \mu_y \\ \mu_\theta \end{bmatrix} = \begin{bmatrix} 0.0523096875 \\ -0.0315079375 \\ -0.0287904375 \end{bmatrix} \tag{10}$$

$$R = \begin{bmatrix} \sigma_{xx} & \sigma_{xy} & \sigma_{x\theta} \\ \sigma_{yx} & \sigma_{yy} & \sigma_{y\theta} \\ \sigma_{\theta x} & \sigma_{\theta y} & \sigma_{\theta\theta} \end{bmatrix}$$
$$= \begin{bmatrix} 0.0000041093 & -0.0000001684 & -0.0000053749 \\ -0.0000001684 & 0.0000058535 & 0.0000322863 \\ -0.0000053749 & 0.0000322863 & 0.0003444646 \end{bmatrix} \tag{11}$$

4 Simulation using Kalman filter

Table 1: Parameters for simulation

Parameter	Value
Wheel distance B	$0.35[m]$
Left wheel speed v_L	$0.2[m/s]$
Right wheel speed v_R	$0.3[m/s]$
Robot control frequency	$100[Hz]$
Update frequency of GNSS	$5[Hz]$

4.1 Result

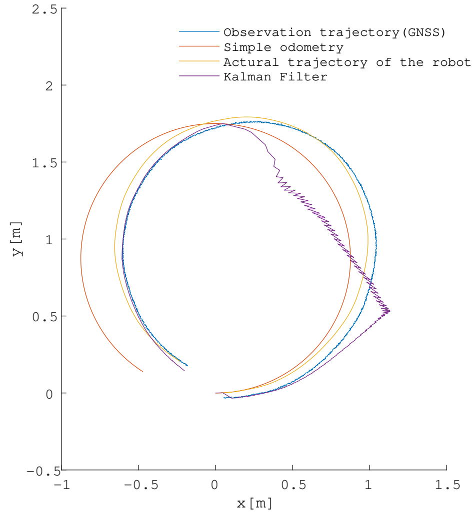

Fig. 7: Small process noise

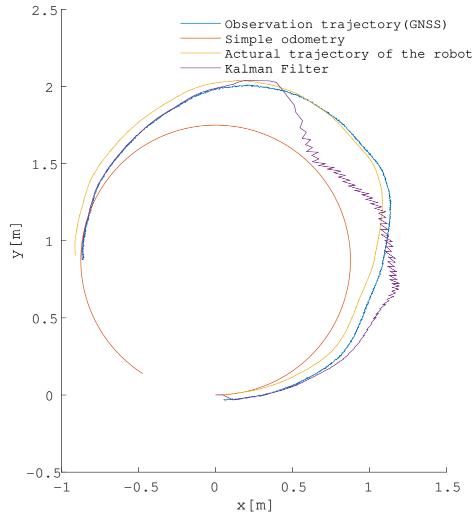

Fig. 8: Middle process noise

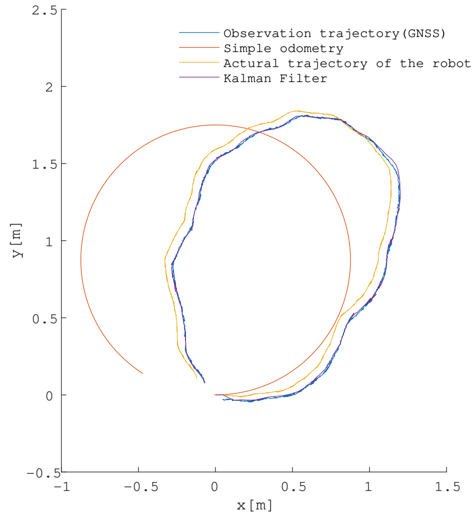

Fig. 9: Large process noise

4.2 Disucussion

5 Conclusions

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