

# 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

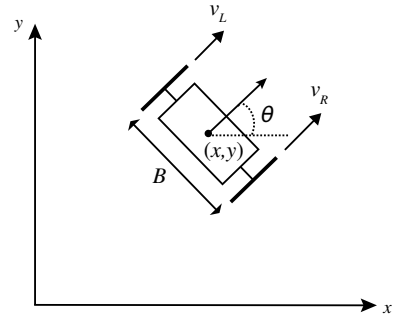


Fig. 1: Robot model

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.

## 2 カルマンフィルタの説明

この章ではカルマンフィルタの説明を行う。アイガモロボットは2次元平面上を移動する。ロボットの中心座標を  $(x, y)$ ,  $x$  軸となす角を  $\theta$  とする。ロボットの状態ベクトル  $x$  は式 1 と表現される。

$$x = \begin{bmatrix} x \\ y \\ \theta \end{bmatrix} \quad (1)$$

ロボットは左右の速度  $v_L, v_R$  によって制御され、制御ベクトル  $u$  は式 2 と表現される。

$$u = \begin{bmatrix} v_L \\ v_R \end{bmatrix} \quad (2)$$

カルマンフィルタの一般式からロボットの推定位置は式 3 のように表現される

$$\hat{x}_t = F\hat{x}_{t-1} + Bu_t + w_t \quad (3)$$

where,  $F = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$ ,  $B = \begin{bmatrix} dt * \cos\theta & 0 \\ dt * \sin\theta & 0 \\ 0 & 1 \end{bmatrix}$ ,  $w$  is process noise.

また、誤差共分散行列の更新は式4のように表現される

$$P_t = F P_{t-1} F^T + Q \quad (4)$$

ただし、 $P$  は誤差共分散行列を表している。 $Q$  はプロセスの共分散行列で、

$$Q = \begin{bmatrix} q_x^2 & 0 & 0 \\ 0 & q_y^2 & 0 \\ 0 & 0 & q_\theta^2 \end{bmatrix}$$

GPS によるロボットの位置  $z$  は式5のように表現される

$$z_t = H x_t + v_t \quad (5)$$

where,  $H = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$ ,  $v$  is observation noise.

カルマンフィルタの更新フェーズでは式6 – 10の式で観測誤差共分散行列  $S$  の更新, カルマンゲイン  $K$  の修正, 推定状態量  $\hat{x}$  の更新を行う。

$$y_t = z_t - H \hat{x}_t \quad (6)$$

$$S_t = R + H P_t H^T \quad (7)$$

$$K_t = P_t H^T S_t^{-1} \quad (8)$$

$$\hat{x}_t = \hat{x}_t + K_t y_t \quad (9)$$

$$P_t = (I - K_t H^T) P_t (I - K_t H^T)^T + K_t R K_t^T \quad (10)$$

ただし、 $R$  は観測の共分散行列で、 $R = \begin{bmatrix} x_x^2 & 0 & 0 \\ 0 & x_y^2 & 0 \\ 0 & 0 & x_\theta^2 \end{bmatrix}$

### 3 カルマンフィルタに用いる分散の取得実験

#### 4 Simulation using Kalman filter

Table 1: Parameters for simulation

Parameter	Value
車輪間距離 $B$	0.35[m]
左車輪速度 $v_L$	0.2[m/s]
右車輪速度 $v_R$	0.3[m/s]
ロボットの制御周波数	100[Hz]
GNSS の更新周波数	5[Hz]

#### 4.1 Result

#### 4.2 Disucussion

### 5 Conclusions

### References

- [1] M. Taku, O. Yoshiaki, O. Jun, N. Keita and N. Keitaro: Mechanism of generating drawbar pull of rod wheel on loose soil, *22rd International Symposium on Artificial Life and Robotics.(AROB)*, Vol.22, No.4, 2017.

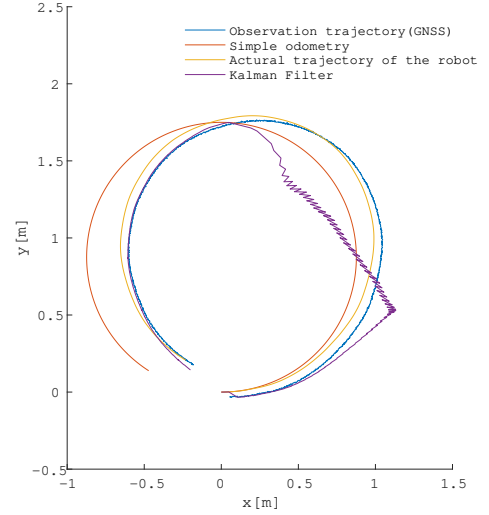


Fig. 2: Small process noise

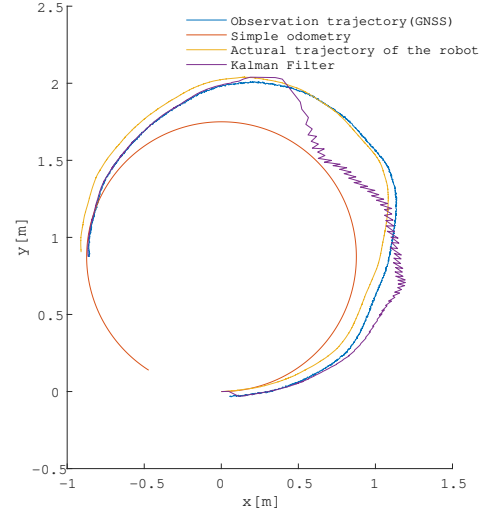


Fig. 3: Middle process noise

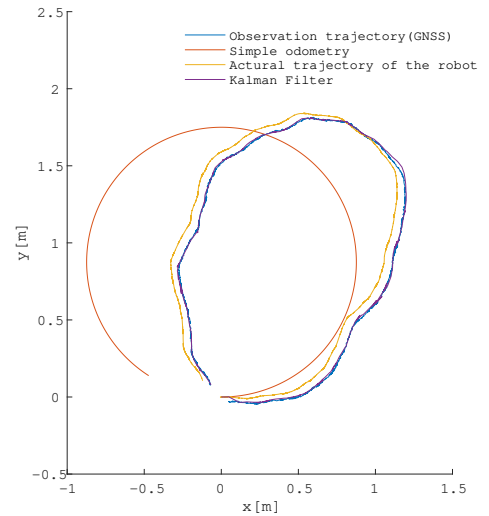


Fig. 4: Large process noise

- [2] S. Shotaro, H. Zhencheng and F. Thomas: Tracking offFeature Points for VisualSLAM with MultipleCameras *The Institute of Image Information and Television Engineers*
- [3] Z. Fang, L. Deng, Y. Ou and X. Wu: A tracking robot based on wireless beacon *International Conference on Intelligent Robotics and Applications*, pp.191-202, 2010.
- [4] H. J. Christopher and C. Eric: Evolution of the global navigation satellite system (gnss), *Proceedings of the IEEE*, Vol.96, No.12, pp.1902-1917, 2008.
- [5] K. Michio, N. Noboru, I. Kazunobu and T. Hideo: Field Mobile Robot navigated by RTK-GPS and FOG, *Journal of the Japanese Society of Agricultural Machinery*, Vol.63, No.5, pp.74-79, 2001.(in Japanese)
- [6] S. Masahiro, N. Yoshisada, T. Katsuhiko and K. Kyou: *Journal of the Japanese Society of Agricultural Machinery*, Vol.72, No.3, pp.276-282, 2010.(in Japanese)
- [7] Emlid Reach RS, <https://docs.emlid.com/eachrs/>
- [8] Emlid Reach, <https://docs.emlid.com/each/>