GPS/INS Based on Navigation Using Kalman Filter

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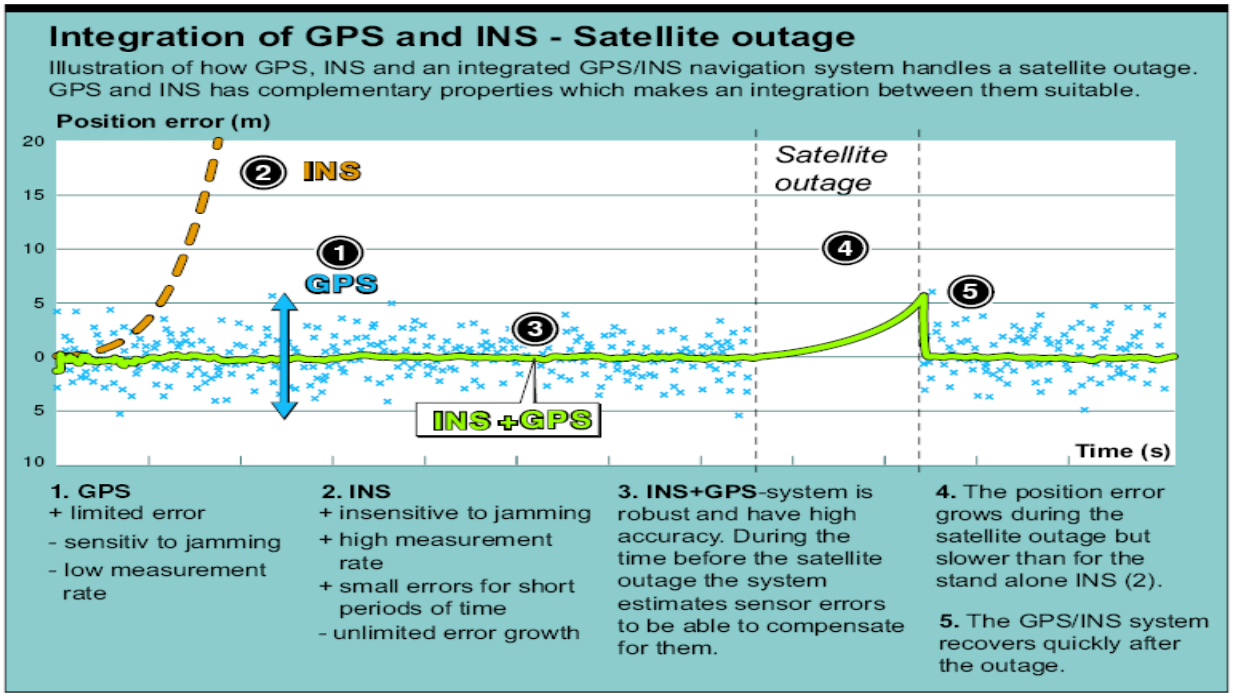
I Introduction

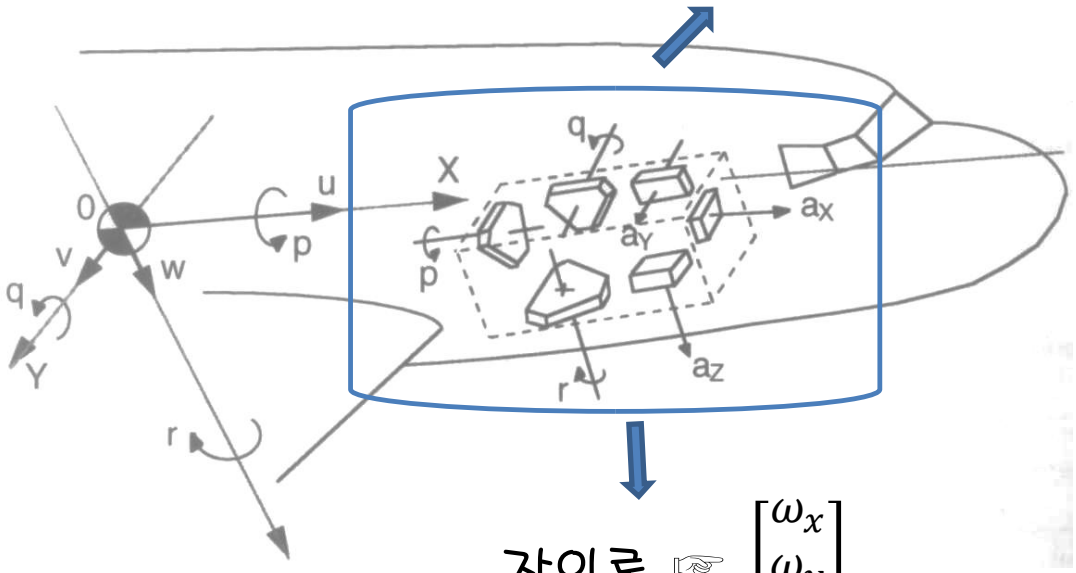
Research purpose

INS(관성항법시스템)의 대표적인 단점은 시간이 지남에 따라 오차가 매우 커진다는 것이고 GPS(위성항법시스템)의 단점은 전파교란을 매우 쉽게 받는다는 것이다. 이러한 단점을 극복하기 위해 이 두 가지 항법시스템을 같이 사용하여 서로의 단점을 보안하고 항법 오차를 줄이는데 그 목적이 있다.



Ⅱ GPS / INS

GPS ☞ $\begin{bmatrix} \psi_{GPS} \\ v_{GPS} \\ r_{GPS} \end{bmatrix}$

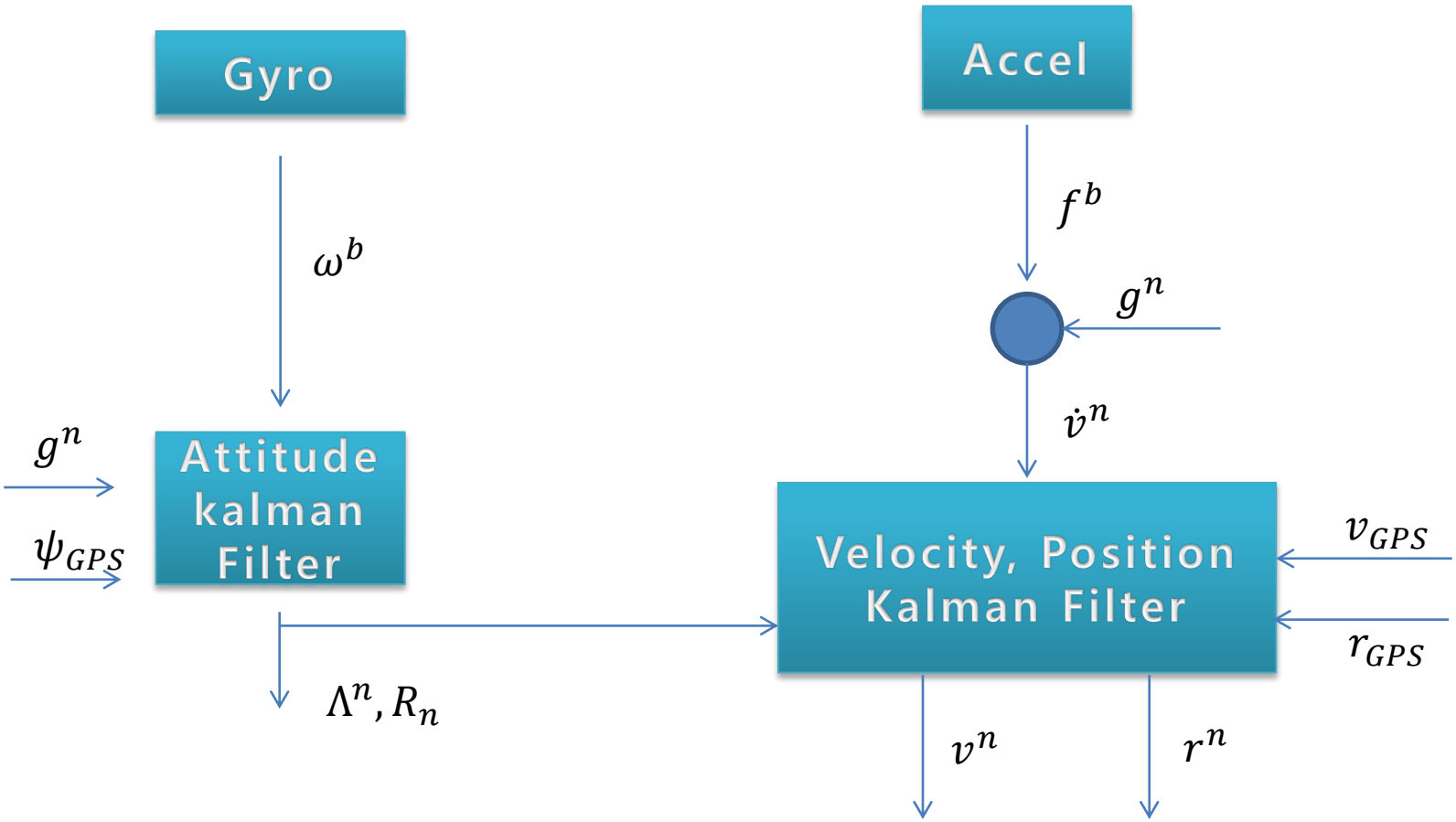


자이로 ☞ $\begin{bmatrix} \omega_x \\ \omega_y \\ \omega_z \end{bmatrix}$

가속도계 ☞ $\begin{bmatrix} a_x \\ a_y \\ a_z \end{bmatrix}$

Ⅱ GPS / INS

INS(관성항법시스템) 알고리즘 구성도



Ⅱ GPS / INS

1. System Model

$$\begin{bmatrix}\omega_x\\ \omega_y\\ \omega_z\end{bmatrix} = \begin{bmatrix}0\\ 0\\ \dot{\psi}\end{bmatrix} + R_z(\psi)\begin{bmatrix}0\\ \dot{\theta}\\ 0\end{bmatrix} + R_z(\psi)\begin{bmatrix}0\\ \dot{\theta}\\ 0\end{bmatrix}$$

$$\Rightarrow \quad \begin{bmatrix}\dot{\phi}\\ \dot{\theta}\\ \dot{\psi}\end{bmatrix} = \begin{bmatrix}1 & sin\phi tan\theta & cos\phi tan\theta\\ 0 & cos\phi & -sin\phi\\ 0 & sin\phi/cos\theta & cos\phi/cos\theta\end{bmatrix}\begin{bmatrix}\omega_x\\ \omega_y\\ \omega_z\end{bmatrix}$$

$$\Rightarrow \quad \begin{bmatrix}\phi\\ \theta\\ \psi\end{bmatrix}_{k+1} = \begin{bmatrix}\phi\\ \theta\\ \psi\end{bmatrix}_{k} + dt\begin{bmatrix}1 & sin\phi tan\theta & cos\phi tan\theta\\ 0 & cos\phi & -sin\phi\\ 0 & sin\phi/cos\theta & cos\phi/cos\theta\end{bmatrix}\begin{bmatrix}\omega_x\\ \omega_y\\ \omega_z\end{bmatrix}$$

II GPS / INS

$$\begin{bmatrix} \dot{q}_1 \\ \dot{q}_2 \\ \dot{q}_3 \\ \dot{q}_4 \end{bmatrix} = \frac{1}{2} \begin{bmatrix} 0 & -\omega_x & -\omega_y & -\omega_z \\ \omega_x & 0 & \omega_z & -\omega_y \\ \omega_y & -\omega_z & 0 & \omega_x \\ \omega_z & \omega_y & -\omega_x & 0 \end{bmatrix} \begin{bmatrix} q_1 \\ q_2 \\ q_3 \\ q_4 \end{bmatrix}$$

$$\begin{bmatrix} q_1 \\ q_2 \\ q_3 \\ q_4 \end{bmatrix}_{k+1} = \begin{bmatrix} q_1 \\ q_2 \\ q_3 \\ q_4 \end{bmatrix}_k + \frac{\Delta t}{2} \begin{bmatrix} 0 & -\omega_x & -\omega_y & -\omega_z \\ \omega_x & 0 & \omega_z & -\omega_y \\ \omega_y & -\omega_z & 0 & \omega_x \\ \omega_z & \omega_y & -\omega_x & 0 \end{bmatrix} \begin{bmatrix} q_1 \\ q_2 \\ q_3 \\ q_4 \end{bmatrix}$$

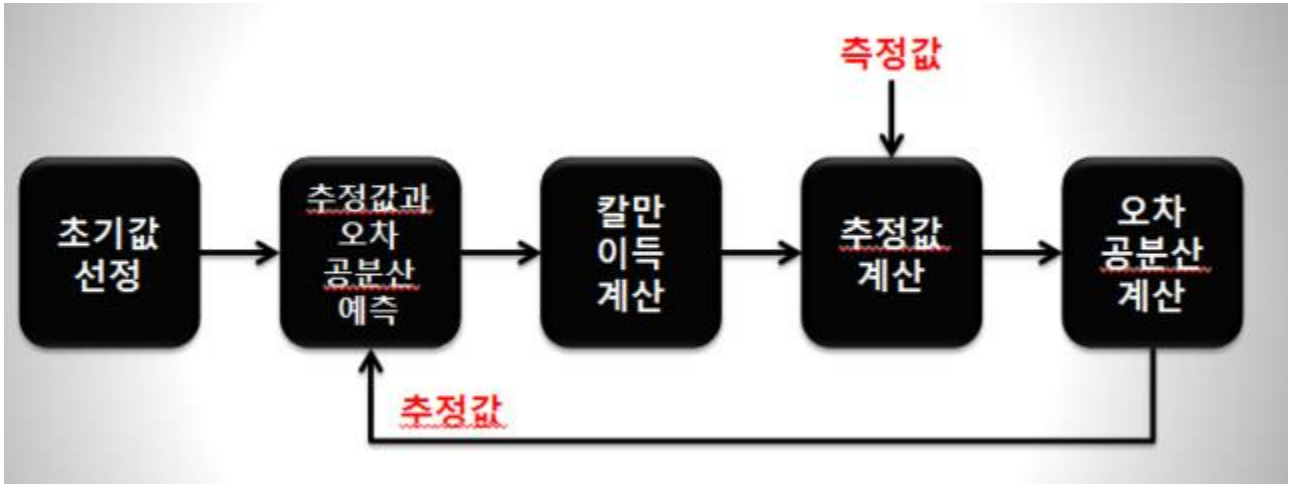
$$\Rightarrow \quad q_{k+1} = \left(I + \frac{\Delta t}{2} \omega^X \right) q_k$$

Ⅱ GPS / INS

일반적인 선형 시스템 모델

$$x_{k+1} = Ax_k + w_k$$
$$z_k = Hx_k + v_k$$

$$A = I + \frac{\Delta t}{2}\omega^x$$
$$H = I$$



Ⅱ GPS / INS

초기값 선정

$\hat{x}_0, \hat{P}_0$

추정값과 오차 공분산 예측

$$\hat{x}_k^- = A\hat{x}_{k-1}$$
$$P_k^- = AP_{k-1}A^T + Q$$

칼만 이득 계산

$$K_k = P_k^- H^T [HP_k^- H^T + R]^{-1}$$

추정값 계산

$$\hat{x}_k = \hat{x}_k + K_k(z_k - H\hat{x}_k^-)$$

오차 공분산 계산

$$P_k = P_k^- - K_k H P_k^-$$

Ⅱ GPS / INS

칼만 이득 계산

$$K_k = P_k^- H^T [H P_k^- H^T + R]^{-1}$$

추정값 계산

$$\hat{x}_k = \hat{x}_k + K_k (z_k - H\hat{x}_k^-)$$

Attitude Update by GPS

Attitude Update by Gravity

Ⅱ GPS / INS

Attitude Update by Gravity

$$\mathbf{a} = \dot{\mathbf{v}} + \mathbf{v} \times \boldsymbol{\omega} + \mathbf{R}^T \mathbf{g} \qquad (\because \mathbf{R}^T = \mathbf{R}^{-1})$$

$$= \begin{bmatrix} \dot{v}_x \\ \dot{v}_y \\ \dot{v}_z \end{bmatrix} + \begin{bmatrix} 0 & v_z & -v_y \\ -v_z & 0 & v_x \\ v_y & -v_x & 0 \end{bmatrix} \begin{bmatrix} \omega_x \\ \omega_y \\ \omega_z \end{bmatrix} + g_z \begin{bmatrix} -\sin\theta \\ \cos\theta\sin\phi \\ \cos\theta\cos\phi \end{bmatrix}$$

$$\begin{bmatrix} a_x \\ a_y \\ a_z \end{bmatrix} = g_z \begin{bmatrix} -\sin\theta \\ \cos\theta\sin\phi \\ \cos\theta\cos\phi \end{bmatrix}$$

선가속도와 각속도가 0이라 가정하면

$$\tan\phi = \frac{a_y}{a_z}, \quad \sin\theta = -\frac{a_x}{g_z}.$$

$$\boldsymbol{\Lambda}^n \leftarrow \boldsymbol{\Lambda}^n + \mathbf{C}_0^{-1} \begin{bmatrix} \tilde{\phi} \\ \tilde{\theta} \\ 0 \end{bmatrix}$$

$$\mathbf{C}_0^{-1} = \begin{bmatrix} \cos\psi / \cos\theta & \sin\psi / \cos\theta & 0 \\ -\sin\psi & \cos\psi & 0 \\ \cos\psi\tan\theta & \sin\psi\tan\theta & 1 \end{bmatrix}$$

II GPS / INS

Attitude Update by GPS

1. $\psi_{GPS} \quad v_{GPS}$

2. $\psi_v = \tan^{-1}\left(\frac{a_{21}}{a_{11}}\right)$

3. $\tilde{\psi} \triangleq \psi_{GPS} - \psi$

4. $\mathbf{\Lambda}^n \leftarrow \mathbf{\Lambda}^n + \mathbf{C}_0^{-1}\begin{bmatrix} 0 \\ 0 \\ \tilde{\psi} \end{bmatrix}$

Ⅱ GPS / INS

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$$\hat{x}_k^- = A\hat{x}_{k-1}$$
$$P_k^- = AP_{k-1}A^T + Q$$

칼만 이득 계산

$$K_k = P_k^- H^T [HP_k^- H^T + R]^{-1}$$

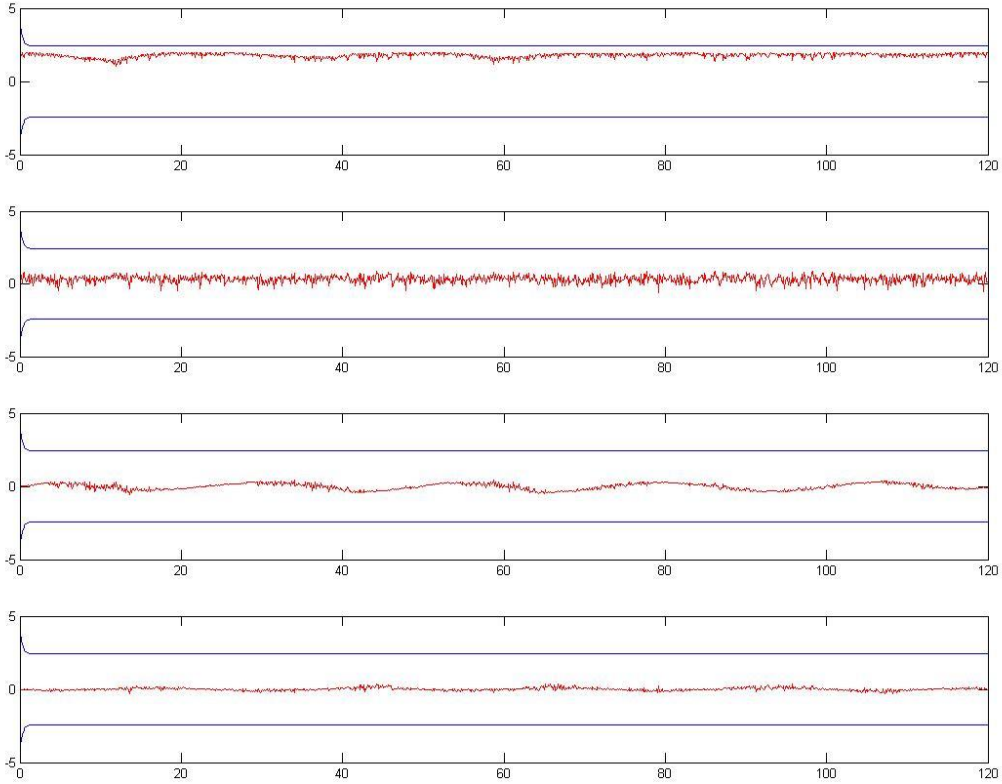
추정값 계산

$$\hat{x}_k = \hat{x}_k + K_k(z_k - H\hat{x}_k^-)$$

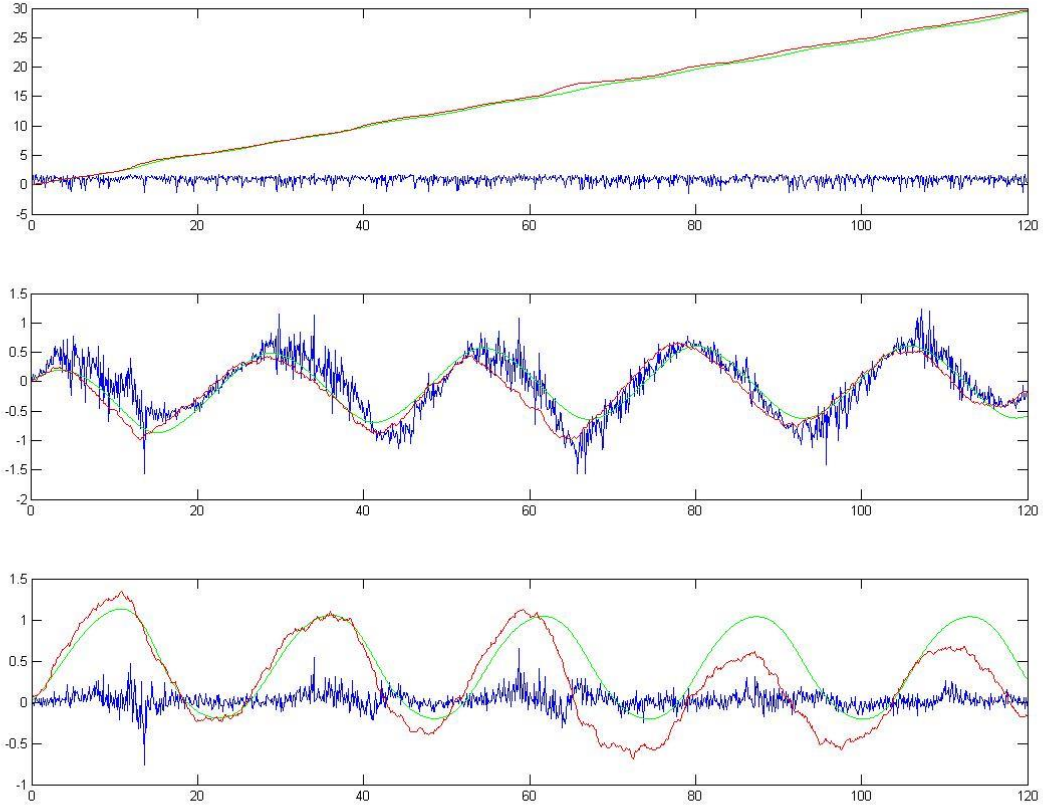
오차 공분산 계산

$$P_k = P_k^- - K_k H P_k^-$$

Ⅲ Simulation & Result



Ⅲ Simulation & Result



IV Future Plan

1. GPS/INS 시뮬레이션

2. 1번과 Stereo vision 을 활용한 위치 추정

Q&A