GPS+IMU Fusion, Yao Ge FAD

A: Measurement Model

For GPS measurement, only position in longitude-latitude-altitude (LLA) is available.

Here use Error-State Kalman Filter

1. Define state $X = [\delta P^T, \delta V^T, \phi^T, \varepsilon^T, \nabla^T]^T$

2. For GPS measurement,

$$Y_{GPS} = G_{GPS} X + C_{GPS} N$$

in which: $Y_{GPS} = \delta P \in R^3$, $G_{GPS} = [I_3, 0, 0, 0, 0] \in R^{3\times 15}$

$$C_{GPS} = I_3 \in R^{3\times 3},$$

$$N = [n_{PE}, n_{PN}, n_{PU}]^T$$

δP can be attained from the diff:

$$\delta P = trans^n_{IMU} - trans^n_{GPS}$$

B: Observability & Observability Degree

For ESKF, its process equation F

$$F = \begin{bmatrix} O_3 & I_3 & O_3 & O_3 & O_3 \\ O_3 & O_3 & F_{23}^{wa} & O_3 & F_{25}^{w} \\ O_3 & O_3 & F_{33}^{g} & F_{34}^{w} & O_3 \\ & & O_{6\times 15} & & \end{bmatrix}$$

In which:

$\because V$:

$$F_{23}^{wa} = f^{n\times} = F(\text{orientation, gyro, accel})$$

$$F_{25}^{w} = C_b^n = F(\text{orientation, gyro})$$

$$F_{33}^{g} = -w_{ie}^{n\times} = F(\text{latitude})$$

$\because \phi$:

$$F_{34}^{w} = -C_b^n = F(\text{orientation, gyro})$$

$\therefore$ For ESKF its observability will be influenced by:

1. Current Orientation
2. Gyro Measurement
3. Accel Measurement
4. Latitude

$\therefore$ Ego vehicle's motion state will influence ESKF observability the most.