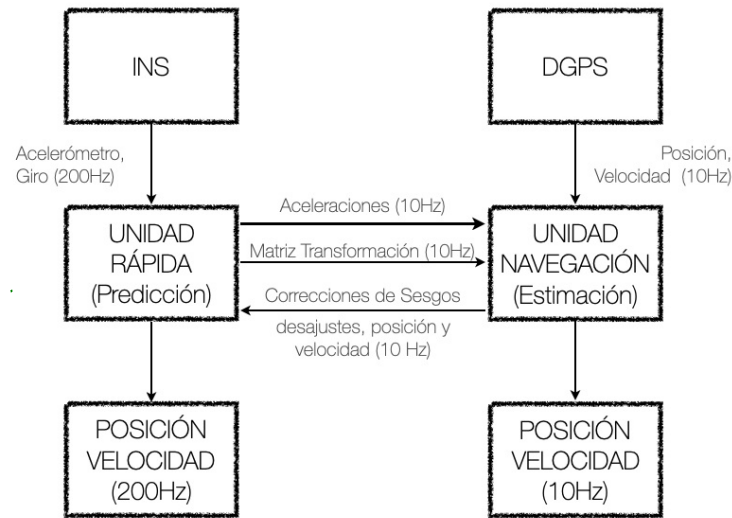
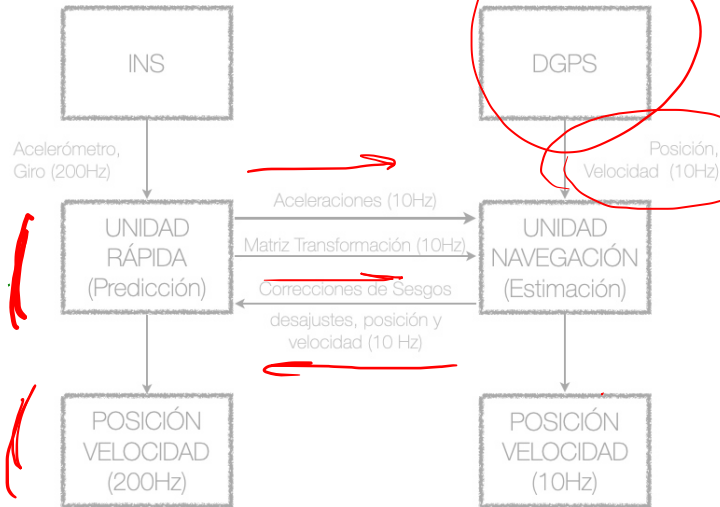


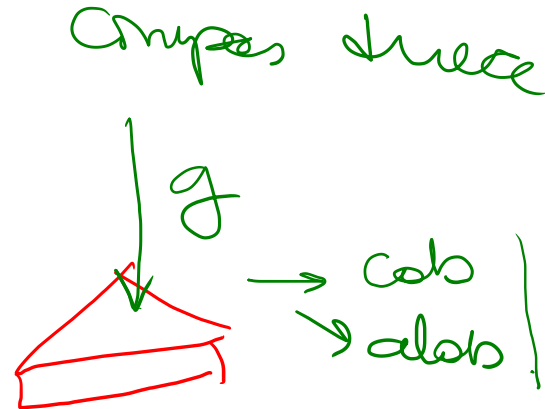
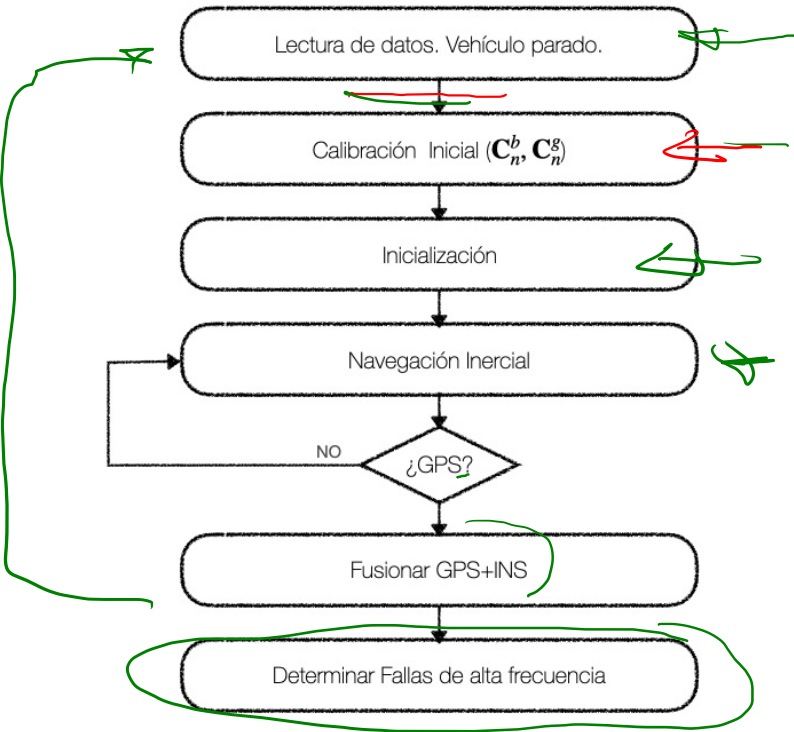
Algoritmo de Integración



Algoritmo de Integración



Algoritmo de Integración



Matriz de Cosenos directores

$$C_b^n = \begin{bmatrix} \gamma_c & -\gamma_s & 0 \\ \gamma_s & \gamma_c & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \beta_c & 0 & \beta_s \\ 0 & 1 & 0 \\ -\beta_s & 0 & \beta_c \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & \theta_c & -\theta_s \\ 0 & \theta_s & \theta_c \end{bmatrix}$$

$$= \begin{bmatrix} \beta_c \gamma_c & -\theta_c \gamma_s + \theta_s \beta_s \gamma_c & \theta_s \gamma_s + \theta_c \beta_s \gamma_c \\ \beta_c \gamma_s & \theta_c \gamma_c + \theta_s \beta_s \gamma_s & -\theta_s \gamma_c + \theta_c \beta_s \gamma_s \\ -\beta_s & \theta_s \beta_c & \theta_c \beta_c \end{bmatrix}$$

$\theta \rightarrow$ Balaneo (o alabeo)

$\beta \rightarrow$ Elevación (o cabeceo)

$\gamma \rightarrow$ Dirección (o guiñada)

$$f_n = C f_b$$

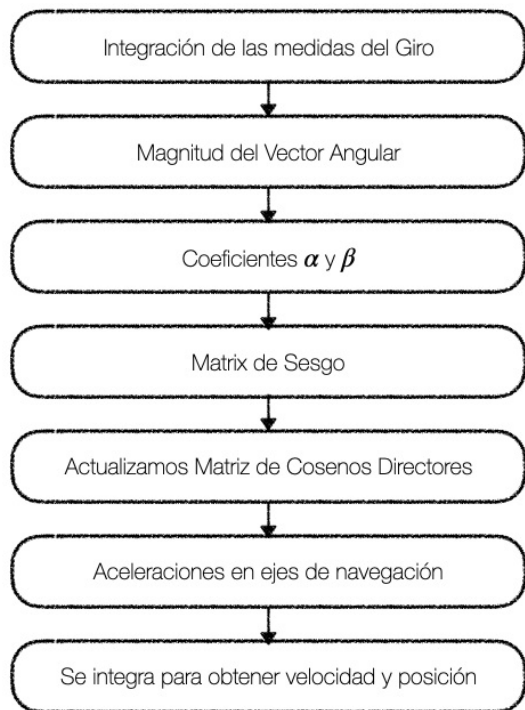
$$f_n = \begin{bmatrix} 0 \\ 0 \\ \theta \end{bmatrix}$$

$$C^T f_n = f_b = \begin{bmatrix} \theta \\ f_y \\ f_z \end{bmatrix}$$

$$-\sin \beta \theta = f_z$$

$$\sin \theta \cos \beta = f_y$$

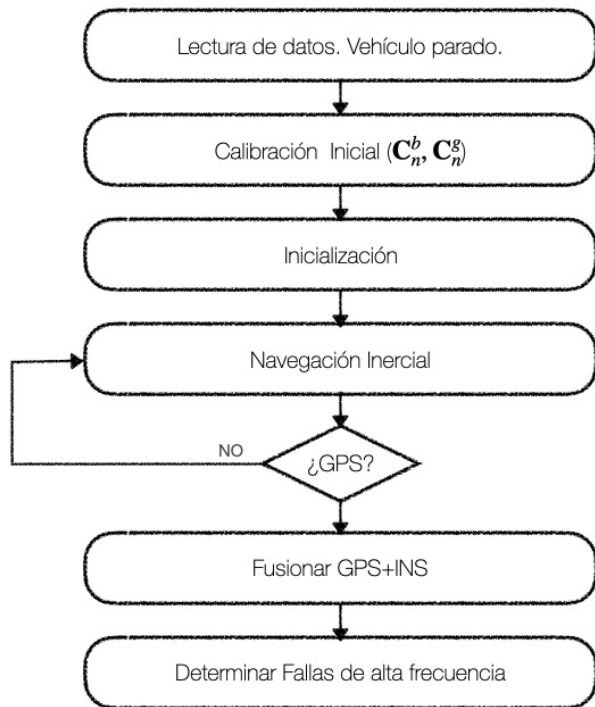
Matriz de Cosenos directores



Matriz de transformación NED

$$\mathbf{C}_n^g = \begin{bmatrix} -\sin \phi \cos \lambda & -\sin \phi \sin \lambda & \cos \phi \\ -\sin \lambda & \cos \lambda & 0 \\ -\cos \phi \cos \lambda & -\cos \phi \sin \lambda & -\sin \phi \end{bmatrix}$$

Repasamos...

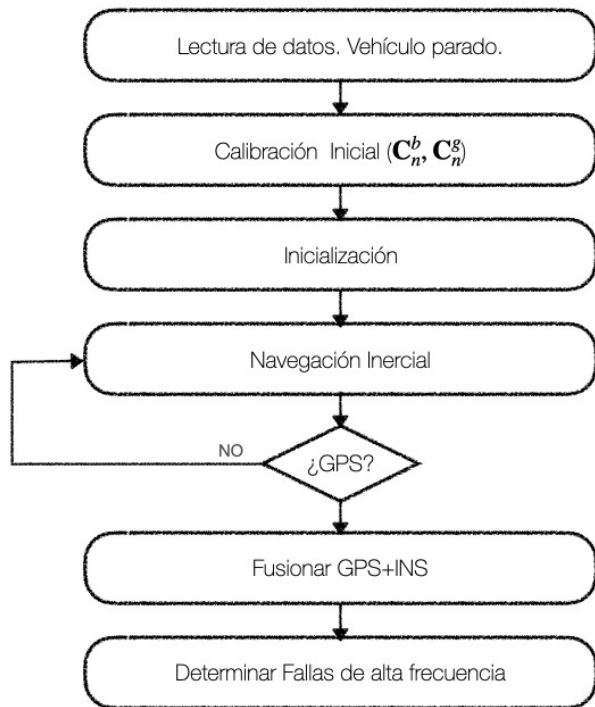


Calibración y Alineación

$$\mathbf{f}_b = (\mathbf{C}_b^n)^{-1} \mathbf{f}_n$$

$$\begin{bmatrix} f_{xT} \\ f_{yT} \\ f_{zT} \end{bmatrix} = \begin{bmatrix} \beta_c \gamma_c & \beta_c \gamma_s & -\beta_s \\ -\theta_c \gamma_s + \theta_s \beta_s \gamma_c & \theta_c \gamma_c + \theta_s \beta_s \gamma_s & \theta_s \beta_c \\ \theta_s \gamma_s + \theta_c \beta_s \gamma_c & -\theta_s \gamma_c + \theta_c \beta_s \gamma_s & \theta_c \beta_c \end{bmatrix} \begin{bmatrix} 0 \\ 0 \\ -g \end{bmatrix}$$

Repasamos...



Fusión INS/GNSS

$$\mathbf{x} = [\delta p_N, \delta p_E, \delta p_D, \delta v_N, \delta v_E, \delta v_D, \delta \phi_N, \delta \phi_E, \delta \phi_D]^T$$

$$\mathbf{F}_g = \begin{bmatrix} 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & -f_D & f_E \\ 0 & 0 & 0 & 0 & 0 & 0 & f_D & 0 & -f_N \\ 0 & 0 & 0 & 0 & 0 & 0 & -f_E & f_N & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Fusión INS/GNSS... incluyendo sesgos

$$\mathbf{x} = [p, v, \phi, f_g, \omega_{ib}]^T$$

$$\mathbf{F} = \begin{bmatrix} & & 0 & 0 \\ & \mathbf{F}_g & \mathbf{C}_b^n & 0 \\ & & 0 & \mathbf{C}_b^n \\ 0 & 0 & 0 & \mathbf{T}_a & 0 \\ 0 & 0 & 0 & 0 & \mathbf{T}_g \end{bmatrix}$$

$$\mathbf{G} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ 0 & \mathbf{C}_b^n & 0 & 0 & 0 \\ 0 & 0 & \mathbf{C}_b^n & 0 & 0 \\ 0 & 0 & 0 & \mathbf{I} & 0 \\ 0 & 0 & 0 & 0 & \mathbf{I} \end{bmatrix}$$

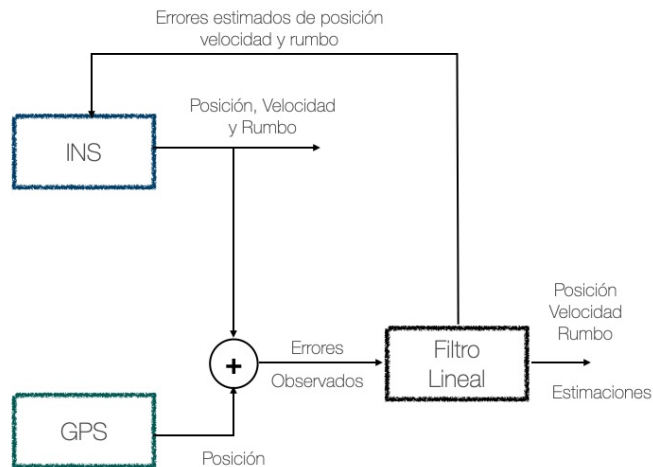
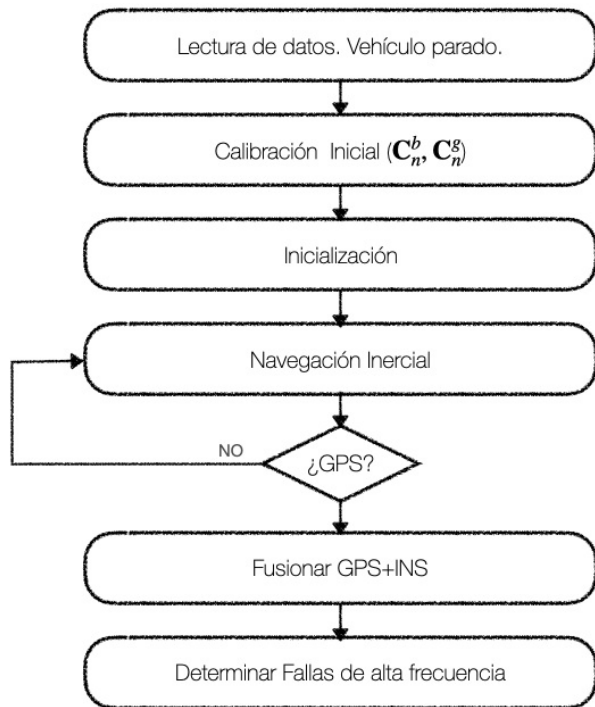
Fusión INS/GNSS discreto

$$\hat{\mathbf{x}}(k|k-1) = \mathbf{F}(k)\hat{\mathbf{x}}(k-1|k-1)$$

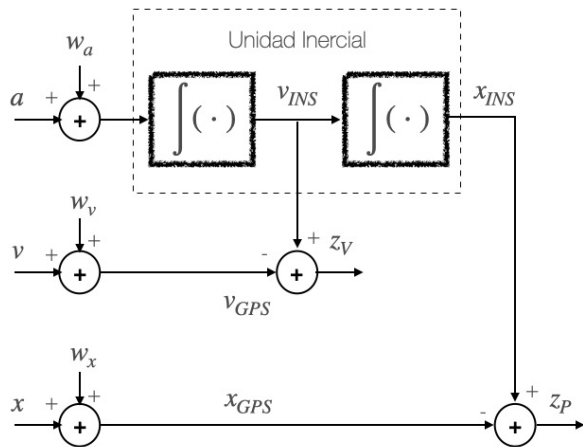
$$\mathbf{P}_{k|k-1} = \mathbf{F}(k)\mathbf{P}_{k-1|k-1}\mathbf{F}^T(k) + \mathbf{Q}(k)$$

$$\mathbf{Q}(k) = \frac{1}{2}[\mathbf{F}(k)\mathbf{G}(k)\mathbf{Q}_c(k)\mathbf{G}^T(k)\mathbf{F}^T(k) + \mathbf{G}(k)\mathbf{Q}_c(k)\mathbf{G}^T(k)]\Delta t$$

Repasamos...

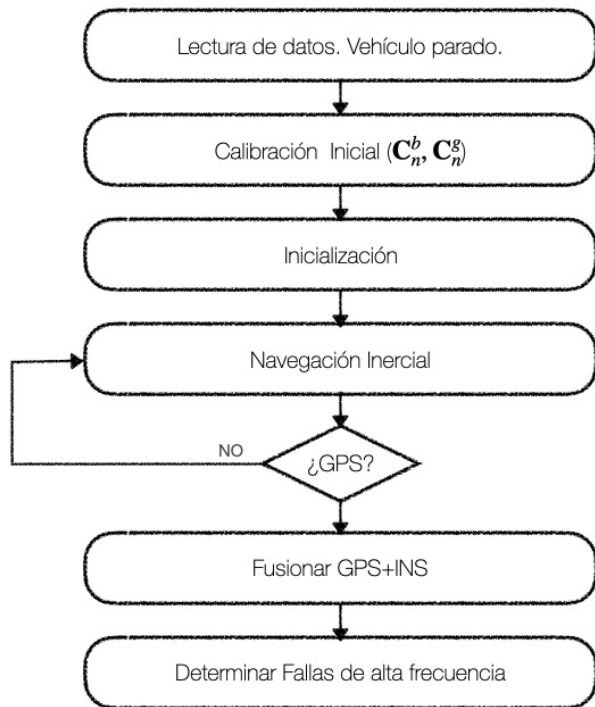


Fusión INS/GNSS, realimentación directa



$$\mathbf{z}(k) = \begin{bmatrix} \mathbf{z}_p(k) \\ \mathbf{z}_v(k) \end{bmatrix} = \begin{bmatrix} \mathbf{P}_{inercial}(k) - \mathbf{P}_{GPS}(k) \\ \mathbf{V}_{inercial}(k) - \mathbf{V}_{GPS}(k) \end{bmatrix}$$

Repasamos...



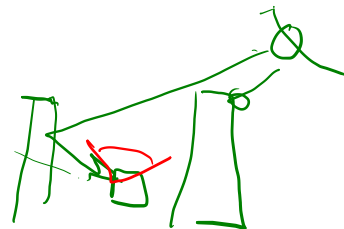
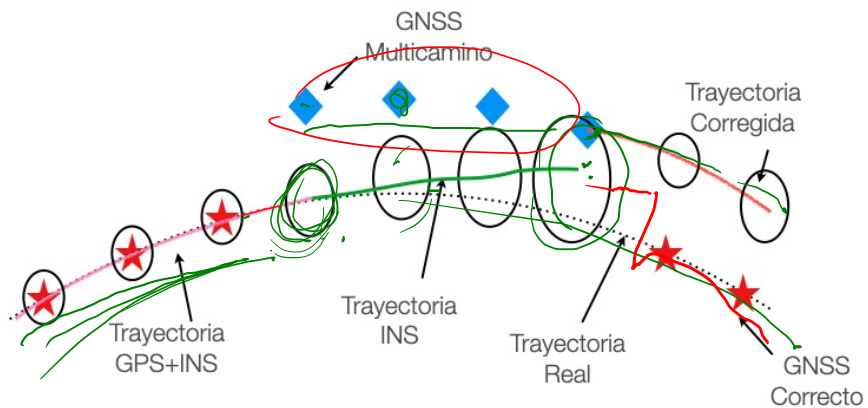
Implementación: Consistencia del Filtro

$$\gamma = \mathbf{v}^T \mathbf{S}^{-1} \mathbf{v}$$

Implementación: Multicamino



Implementación: Sintonía



Implementación

