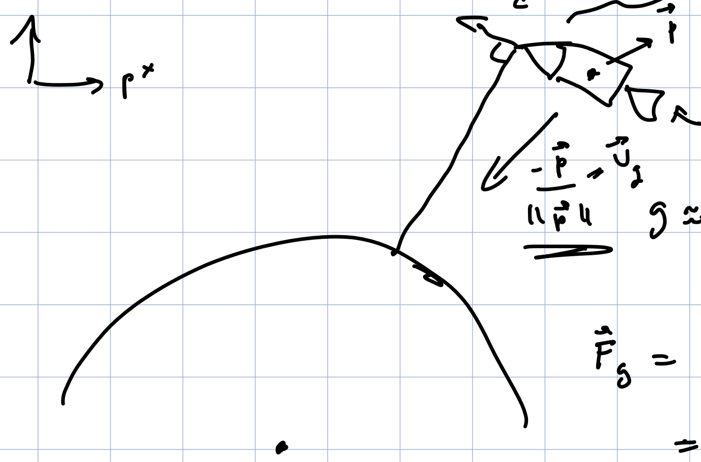


$$\vec{u}_p = \frac{1}{\|\vec p\|}\begin{pmatrix}-p^y\\ p^x\end{pmatrix}$$

$$\frac{-\vec p}{\|\vec p\|} = \vec u_g$$

$$g \approx g_0 \cdot \left(\frac{r_e}{\|\vec p\|^2}\right)$$

$$\vec F_g = m\cdot g_0 \left(\frac{r_e}{\|\vec p\|^2}\right)\vec u_g$$

$$= m\cdot g_0\left(-\frac{r_e\cdot\vec p}{\|\vec p\|^3}\right)$$

$$\vec F_p = F_p\cdot \vec u_p = F_p \frac{1}{\|\vec p\|}\begin{pmatrix}-p^y\\ p^x\end{pmatrix}$$

$$m\cdot\vec a = \vec F_g + \vec F_p$$

$$m\cdot \vec a = -m\cdot g_0\cdot r_e^2 \frac{\vec p}{\|\vec p\|^3} + F_p\cdot\frac{1}{\|p\|}\underbrace{\begin{pmatrix}-p^y\\ p^x\end{pmatrix}}_{\begin{pmatrix}0&-1\\ 1&0\end{pmatrix}\vec p}$$

input: $u(t)$

$$p = \begin{pmatrix}p^x\\ p^y\end{pmatrix}$$

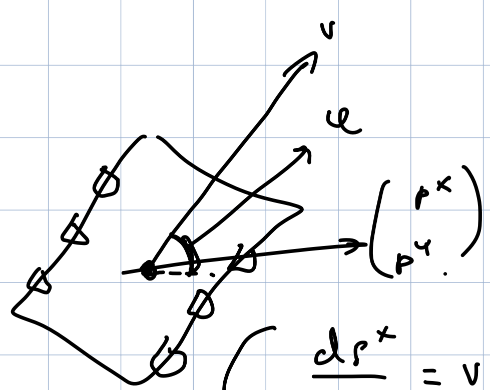
$$\begin{cases}
\dfrac{dp^x}{dt} = \dfrac{dp^x}{dt} \\[2mm]
\dfrac{dp^y}{dt} = \dfrac{dp^y}{dt} \\[2mm]
\dfrac{d^2p^x}{dt^2} = -g_0\cdot r_e^2\dfrac{p^x}{\|p\|^3} - u\cdot\dfrac{p^y}{\|p\|}\cdot\dfrac{1}{m} \\[2mm]
\dfrac{d^2p^y}{dt^2} = -g_0\cdot r_e^2\dfrac{p^y}{\|p\|^3} + u\cdot\dfrac{p^x}{\|p\|}\cdot\dfrac{1}{m}
\end{cases}$$

$$\begin{pmatrix}p^x\\ p^y\\ \vdots\end{pmatrix}$$

$$\dot{\vec{x}} = \begin{pmatrix} dp^x/dt \\ dp^y/dt \end{pmatrix}$$

$$\frac{d\vec{x}}{dt} = \underbrace{\begin{pmatrix} x_3 \\ x_4 \\ -g_0 \cdot r_e^2 \dfrac{x_1}{\sqrt{x_1^2+x_2^2}^{\,3}} \\ -\text{''}- \; x_2 \end{pmatrix}}_{\vec{f}(\vec{x}) \,\neq\, A\vec{x}} + \underbrace{\begin{pmatrix} 0 \\ 0 \\ -\dfrac{x_2/r}{\sqrt{x_1^2+x_2^2}} \\ \dfrac{x_1/r}{\sqrt{x_1^2+x_2^2}} \end{pmatrix}}_{B_u(\vec{x})} \underbrace{u}_{\vec{U}}$$

$$\frac{d\vec{x}}{dt} = \vec{f}(\vec{x}) + B_u(\vec{x})\vec{U}$$



$$\vec{v} = V \cdot \begin{pmatrix} \cos\varphi \\ \sin\varphi \end{pmatrix}$$

$$\frac{dp^x}{dt} = v \cos\varphi$$

$$\frac{dp^y}{dt} = v \cdot \sin\varphi$$

$$\frac{dv}{dt} = w_1$$

$$\Big\{ \quad \frac{d\varphi}{dt} = w_2$$

$$\vec{x} = \begin{pmatrix} p^x \\ p^y \\ v \\ \varphi \end{pmatrix}, \quad \frac{d\vec{x}}{dt} = \begin{pmatrix} x_3 \cos x_4 \\ x_3 \sin x_4 \\ 0 \\ 0 \end{pmatrix} + \begin{pmatrix} 0 & 0 \\ 0 & 0 \\ 1 & 0 \\ 0 & 1 \end{pmatrix} \begin{pmatrix} w_1 \\ w_2 \end{pmatrix}$$

$$\vec{y} = \text{position} + \text{noise} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{pmatrix} \vec{x} + \vec{\sigma}$$

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wheel sensors

$$\begin{cases} \dfrac{dp^x(t)}{dt} = v(t) \cos \varphi(t) + w_1 \\[2ex] \dfrac{dp^y(t)}{dt} = v(t) \sin \varphi(t) + w_2 \\[2ex] \dfrac{d\varphi(t)}{dt} = \omega_{gyro}(t) + w_3 \end{cases}$$

gyro

$$\vec{x} = \begin{pmatrix} p^x \\ p^y \\ \varphi \end{pmatrix}$$

$$\vec{f}(\vec{x}, t) = \begin{pmatrix} v(t) \cos x_3 \\ v(t) \cdot \sin x_3 \\ \omega_{gyro}(t) \end{pmatrix}$$