# Exercise 1.

$$x_t = f(x_{t-1}, u_t) + w_t.$$

$$\therefore \; x_t = \begin{pmatrix} x_{t-1} + \delta_{t-1}(\dot{x}_t\cos\phi_t - \dot{y}_t\sin\phi_t) \\ y_{t-1} + \delta_{t-1}(\dot{x}_t\sin\phi_{t-1} + \dot{y}_t\cos\phi_t) \\ \phi_{t-1} + \delta_{t-1}\dot{\phi}_t \\ m_x^1 \\ m_y^1 \\ m_x^2 \\ m_y^2 \\ \vdots \\ m_x^n \\ m_y^n \end{pmatrix} + w_t.$$

$$\begin{pmatrix} \cdots \end{pmatrix} \longrightarrow f(x_{t-1}, u_t)$$

$$\therefore \; F_t = \begin{pmatrix} 1 & 0 & -\delta_{t-1}(\dot{x}_t\sin\phi_t + \dot{y}_t\cos\phi_t) & \overbrace{0 \cdots\cdots 0}^{2n} \\ 0 & 1 & \delta_{t-1}(\dot{x}_t\cos\phi_t - \dot{y}_t\sin\phi_t) & 0 \cdots\cdots 0 \\ 0 & 0 & 1 & 0 \cdots\cdots 0 \\ 0 & 0 & 0 & 1 \cdots\cdots 0 \\ 0 & 0 & 0 & 0 \; 1 \cdots 0 \\ \vdots & \vdots & \vdots & \vdots \;\; \vdots \;\;\;\; \vdots \\ 0 & 0 & 0 & 0 \; 0 \cdots 1 \end{pmatrix}$$

$$F_t \in \mathbb{R}^{(2n+3)\times(2n+3)}$$

$$y_t = \begin{pmatrix} \|m^1 - p_t\| \\ \vdots \\ \|m^n - p_t\| \\ \operatorname{arctan2}(m_y^1 - y_t, m_x^1 - x_t) - \phi_t \\ \vdots \\ \operatorname{arctan2}(m_y^n - y_t, m_x^n - x_t) - \phi_t \end{pmatrix} + v_t$$

$$\begin{pmatrix} \cdots \end{pmatrix} \longrightarrow h(x_t).$$

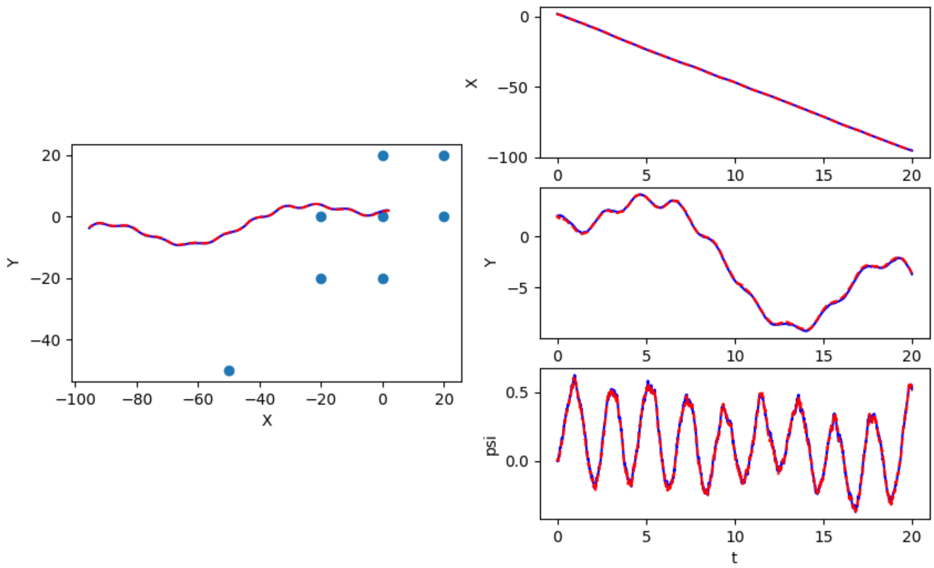
$H_t =$

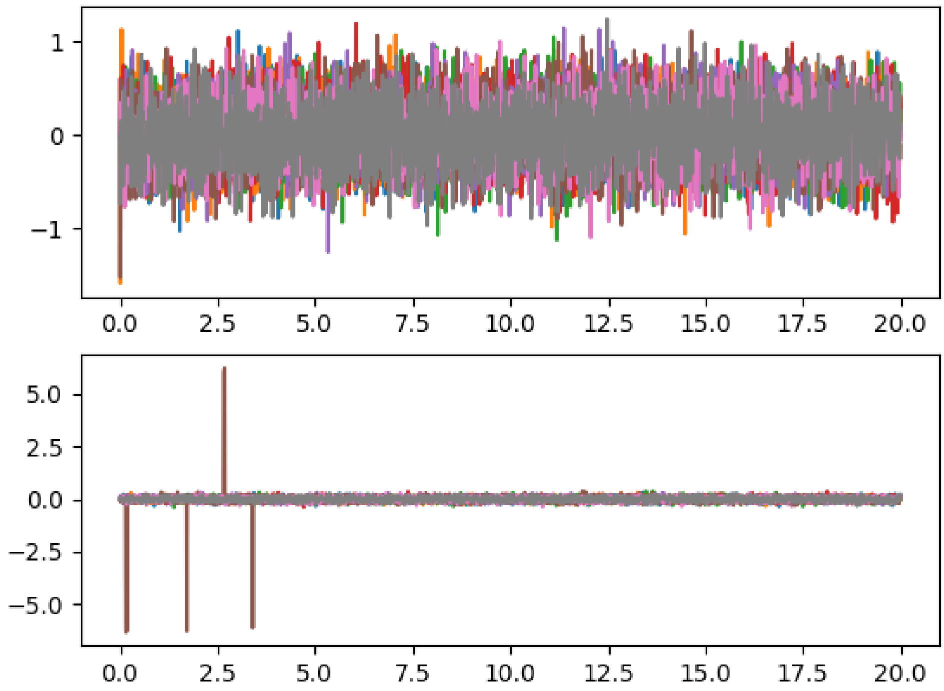
$$
\begin{bmatrix}
\frac{-(m_x^1 - X_t)}{\sqrt{(m_x^1-X_t)^2+(m_y^1-Y_t)^2}}, & \frac{-(m_y^1 - Y_t)}{\sqrt{(m_x^1-X_t)^2+(m_y^1-Y_t)^2}}, & 0, & \frac{m_x^1 - X_t}{\sqrt{(m_x^1-X_t)^2+(m_y^1-Y_t)^2}}, & \frac{m_y^1 - Y_t}{\sqrt{(m_x^1-X_t)^2+(m_y^1-Y_t)^2}}, & 0 \cdots 0 \\
\vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\
\frac{-(m_x^n - X_t)}{\sqrt{(m_x^n-X_t)^2+(m_y^n-Y_t)^2}}, & \frac{-(m_y^n - Y_t)}{\sqrt{(m_x^n-X_t)^2+(m_y^n-Y_t)^2}}, & 0, & 0 & \cdots & \frac{m_x^n - X_t}{\sqrt{\cdots}}, \quad \frac{m_y^n - Y_t}{\sqrt{\cdots}} \\
\frac{m_y^1 - Y_t}{(m_x^1-X_t)^2+(m_y^1-Y_t)^2}, & \frac{-(m_x^1 - X_t)}{(m_x^1-X_t)^2+(m_y^1-Y_t)^2}, & -1, & \frac{-(m_y^1 - Y_t)}{(m_x^1-X_t)^2+(m_{y_1}-Y_t)^2}, & \frac{m_x^1 - X_t}{(m_x^1-X_t)^2+(m_{y_1}-Y_t)^2}, & 0, \cdots, 0 \\
\vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\
\frac{m_y^n - Y_t}{(m_x^n-X_t)^2+(m_y^n-Y_t)^2}, & \frac{-(m_x^n - X_t)}{(m_x^n-X_t)^2+(m_y^n-Y_t)^2} & -1, & 0, & 0, & \frac{-(m_y^n - Y_t)}{(m_x^n-X_t)^2+(m_y^n-Y_t)^2} \quad \frac{m_x^n - X_t}{(m_x^n-X_t)^2+(m_y^n-Y_t)^2}
\end{bmatrix}
$$

$H \in R^{2n \times (2n+3)}$

Then we can use EKF to solve this problem.

This is the test plot of my ekf_slam:



# Exercise 2:

This is the final plot of my model.