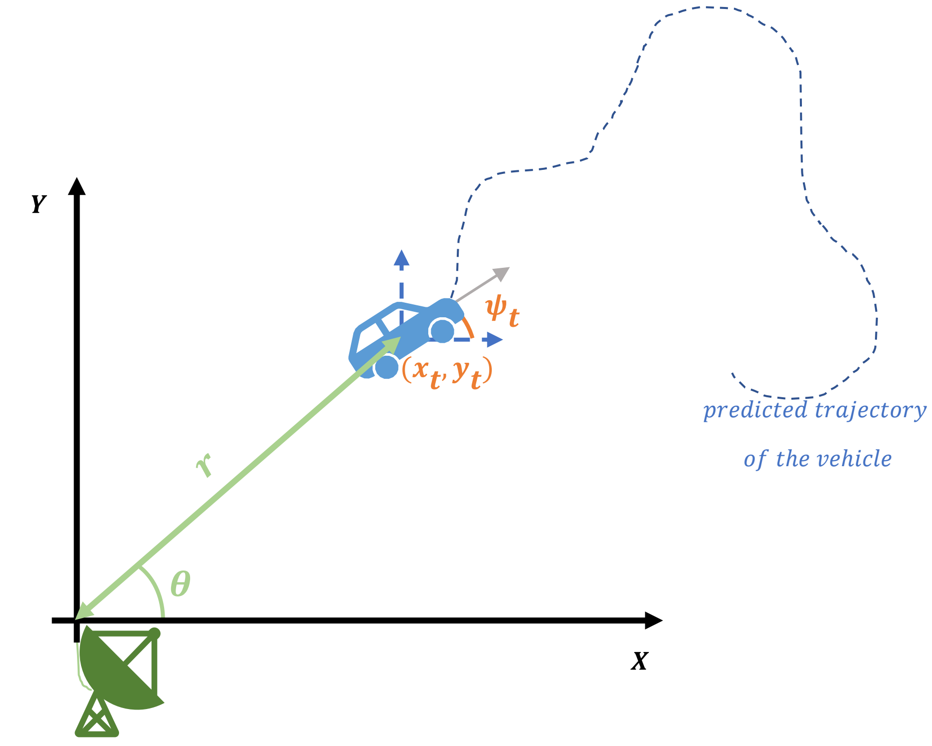
Optimal State Estimation

Practice 7. Particle filter

[Practice 1: True state and measurement simulation for 2D vehicle]

The simulation targets are a dynamic state vector (x, y, ψ*(heading)*) of a vehicle on two-dimension space (*X and Y*), and a bearing sensor located at origin, which can measure the range r between sensor and the vehicle and the angle θ between the vehicle and *X* axis in world coordinate.



A nonlinear discrete vehicle motion model (dead reckoning, DR) with **velocity (V) and yaw rate ($\dot{\psi}$) inputs** can be represented as follow:

$$x_{t+1} = x_t + V \cdot dT \cdot cos(\psi_t)$$

$$y_{t+1} = y_t + V \cdot dT \cdot sin(\psi_t)$$

$$\psi_{t+1} = \psi_t + dT \cdot \dot{\psi}$$

$$(V = \sqrt{v_x^2 + v_y^2})$$

,where x_t is a *X* position of the vehicle at time t, y_t is a *Y* position of the vehicle at time t, ψ_t is the heading of the vehicle at time t, and dT is a sampling time. V is the speed of the vehicle and $\dot{\psi}$ is the yaw rate of the vehicle, which are given inputs of the vehicle model.

The discrete state space description of this system can be written as

$$\begin{bmatrix} x \\ y \\ \psi \end{bmatrix}_{t+1} = \begin{bmatrix} x_t + V \cdot dT \cdot cos(\psi_t) \\ y_t + V \cdot dT \cdot sin(\psi_t) \\ \psi_t + dT \cdot \dot{\psi} \end{bmatrix} = f(x, u, w, t)$$

The measurements are the range between the vehicle and the sensor, direction of the vehicle, therefore the measurement model can be described as follow:

$$y_{t+1} = \begin{bmatrix} r \\ \theta \end{bmatrix}_{t+1} = \begin{bmatrix} \sqrt{{x_t}^2 + {y_t}^2} \\ tan^{-1}(y_t/x_t) \end{bmatrix} = \hbar(x, v, t)$$

We have the sampling time and initial information as below:

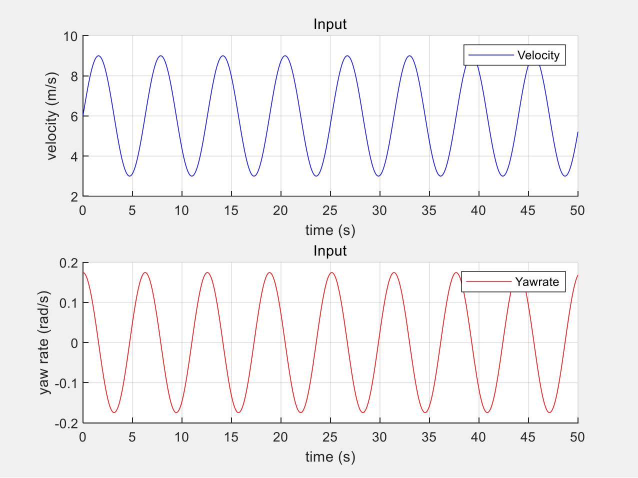
1) $\Delta t = 0.1$
2) initial position $x = 1m, y = 1m$
3) initial heading $\psi = 45$ deg

[Practice 1-1]

Please simulate the x_t, y_t, ψ_t from time $t = 0$ to $t = 50$ using given velocity, yaw rate data:

$$velocity : \begin{cases} period : 2\pi \\ amplitude : 3 \\ vertical\ shift = 6 \end{cases}$$

$$yaw\ rate : \begin{cases} period : 6\pi \\ amplitude : 6\dfrac{\pi}{180} \\ vertical\ shift = 10\dfrac{\pi}{180} \end{cases}$$



Plot the simulation and submit the figure (each state and 2D vehicle position) for the simulation.

[Practice 1-2]

Please simulate the measurement y_t, which is a bearing sensor simulation data. Each standard deviation of the sensor noise is **one meter** and **three degrees**. Plot the simulation results and save to m file. Submit the simulation figure and m. file.

(Hint: using gaussian random variable “normrnd” in Matlab)

[Practice 2: Particle filter with Dead Reckoning Model]

A state of Dead Reckoning model can be written as:

$$\begin{bmatrix} x \\ y \\ \psi \end{bmatrix}_{t+1} = \begin{bmatrix} x_t + V \cdot dT \cdot cos(\psi_t) \\ y_t + V \cdot dT \cdot sin(\psi_t) \\ \psi_t + dT \cdot \dot{\psi} \end{bmatrix}$$

Set the process model of the particle filter (PF) as the Dead Reckoning model (nonlinear model)!

[Practice 2-1]

Plot the estimated state and the error between estimated state and true value (x-axis is time and y-axes are x_t, y_t, ψ_t) for each case. Submit the figures for the estimation for the best *Q, R*.

[Practice 2-2] Get the RMSE between estimated state and true value for each case.

[Practice 3: Evaluation]

[Practice 3-1] Compare the RMSE of {Extended Kalman Filter with Constant Velocity Model}, {Extended Kalman Filter with Dead Reckoning Model} and {Particle Filter with Dead Reckoning Model}.