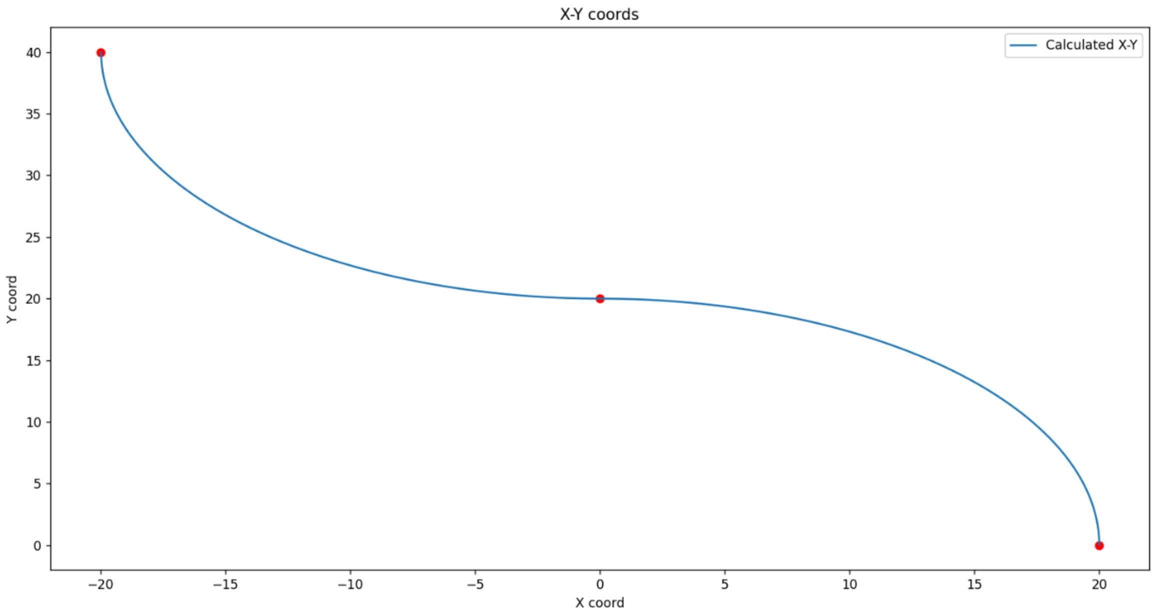
Autonomous Mobile Robotics

HW4

Walid Shaker

Path Planning:

The trajectory is defined using two circles as shown below. The code is attached.



Point B (starting point) is selected as (-20, 40)

Point A (final point) is (20,0)

Point C (midpoint) is (0,20)

Since $r \ = \ 20$, so if we set $v = 0.5$, then $\omega = 0.025$

The simulation time from B to C $(t) \ = \frac{\pi/2}{\omega} = 62.83 \ sec$

So, the total time (t_f) that the vehicle takes from B to A is $125.6 \ sec$

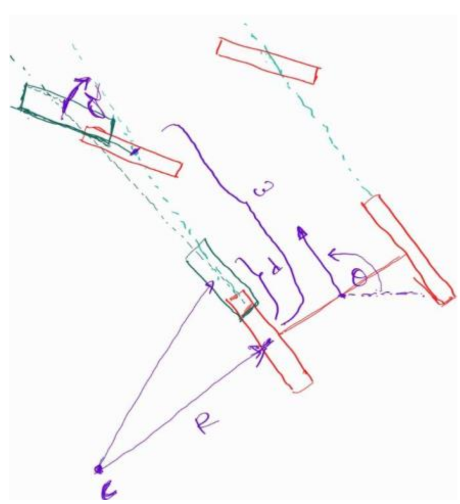
Let the sampling time $dt = 0.05$, so the number of iterations to reach final point $N = \frac{t_f}{dt} = 2512$

Motion Model: kinematics

I used the same bicycle model explained in the lecture.

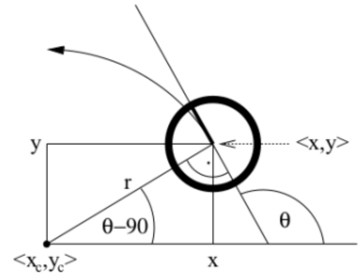
Robot pose $[x, y, \theta]^T$

A robot can be control through linear and angular velocities $u \ = \ [v, \omega]^T$



The center of the circle is at

$$\begin{bmatrix} x_c \\ y_c \end{bmatrix} = \begin{bmatrix} x - \frac{v}{\omega}\sin(\theta) \\ y + \frac{v}{\omega}\cos(\theta) \end{bmatrix}$$



After δt time, ideal robot will be at $\mathbf{x}_{t+1} = \begin{bmatrix} x_{t+1} & y_{t+1} & \theta_{t+1} \end{bmatrix}$

$$= \begin{bmatrix} x_c + \frac{v}{\omega}\sin(\theta_t + \omega\delta t) \\ y_c - \frac{v}{\omega}\cos(\theta_t + \omega\delta t) \\ \theta_t + \omega\delta t \end{bmatrix} = \begin{bmatrix} x_t \\ y_t \\ \theta_t \end{bmatrix} + \begin{bmatrix} -\frac{v}{\omega}\sin(\theta_t) + \frac{v}{\omega}\sin(\theta_t + \omega\delta t) \\ \frac{v}{\omega}\cos(\theta_t) - \frac{v}{\omega}\cos(\theta_t + \omega\delta t) \\ \omega\delta t \end{bmatrix}$$

Real motion model

$$\underbrace{\begin{pmatrix} x_{t+1} \\ y_{t+1} \\ \theta_{t+1} \end{pmatrix}}_{\mathbf{x}_{t+1}} = \underbrace{\begin{pmatrix} x_t \\ y_t \\ \theta_t \end{pmatrix} + \begin{pmatrix} -\frac{\hat{v}_t}{\hat{\omega}_t}\sin(\theta) + \frac{\hat{v}_t}{\hat{\omega}_t}\sin(\theta + \hat{\omega}_t\delta t) \\ \frac{\hat{v}_t}{\hat{\omega}_t}\cos(\theta) - \frac{\hat{\hat{t}}_t}{\hat{\omega}_t}\cos(\theta + \hat{\omega}_t\delta t) \\ \hat{\omega}_t\delta t + \hat{\gamma}\delta t \end{pmatrix}}_{f(u_t,\mathbf{x}_t)}$$

, where $\hat{\gamma} \sim \varepsilon_{\alpha_5 v_t^2 + \alpha_6 \omega_t^2}$

- Approximated motion model, i.e., replacing true motion $\hat{v}_t$ and $\hat{\omega}_t$ by executed control (v_t, ω_t)

$$\underbrace{\begin{pmatrix} x_{t+1} \\ y_{t+1} \\ \theta_{t+1} \end{pmatrix}}_{\mathbf{x}_{t+1}} = \underbrace{\begin{pmatrix} x_t \\ y_t \\ \theta_t \end{pmatrix} + \begin{pmatrix} -\frac{v_t}{\omega_t}\sin(\theta) + \frac{v_t}{\omega_t}\sin(\theta + \omega_t\delta t) \\ \frac{v_t}{\omega_t}\cos(\theta) - \frac{v_t}{\omega_t}\cos(\theta + \omega_t\delta t) \\ \omega_t\delta t \end{pmatrix}}_{f(u_t,\mathbf{x}_t)} + N(0, Q_t)$$

Sensor Model: correction step

$$\underbrace{\begin{bmatrix} r_t^i \\ \theta_t^i \end{bmatrix}}_{z_t^i} = \underbrace{\begin{pmatrix} \sqrt{(m_{j,x} - x)^2 + (m_{j,y} - y)^2} \\ \text{atan2}(m_{j,y} - y, m_{j,x} - x) - \theta \end{pmatrix}}_{h(x_{t,j,m})} + N(0, R)$$

, where $m_{j,x}, m_{j,y}$ denotes the coordinates of jth landmark detection at time t, $R = \begin{bmatrix} \sigma_r^2 & 0 \\ 0 & \sigma_r^2 \end{bmatrix}$, and $\mathbf{x}_{t,x}^- = x, \mathbf{x}_{t,y}^- = y$

PF with EKF

Extended Kalman filter prediction and correction steps for each particle, and the real robot position and the estimated robot position are plotted over the time as shown below.