Project 3

Topics:

- Particle Filter
- ICP- Iterative Closest Points
- Visual Odometry

1. **Particle Filter** (35%)

Particle filters sample a distribution with a collection of *particles*, generate a prediction of the distribution by forward predicting each particle using motion model and then compare and update that prediction using a measurement and its uncertainty characteristics. Use the attached Google Colab notebook for this section.

a. Load the attached files – (Odometry and GT data) and plot the GT trajectory and landmarks from
starting point (x_0, y_0, θ_0) based on motion model.

$$\begin{pmatrix} x_t \\ y_t \\ \theta_t \end{pmatrix} = \begin{pmatrix} x_{t-1} \\ y_{t-1} \\ \theta_{t-1} \end{pmatrix} + \begin{pmatrix} \delta_{trans}\cos(\theta_{t-1}+\delta_{rot1}) \\ \delta_{trans}\sin(\theta_{t-1}+\delta_{rot1}) \\ \delta_{rot1}+\delta_{rot2} \end{pmatrix}$$

b. Assume spin LiDAR 2D sensor (1 layer, 360 degrees) which in each iteration calculates the range and azimuth (r, φ) <u>only from the closet landmarks</u>.
Sensor measurement noise (Q): (σ_r=1, σ_φ=0.1).

c. Run Particle Filter!! (15 %)

- Initialize particles array:
  i. N particles (N=1000)
  ii. The starting point of the robot is (x_0, y_0, θ_0) – generate hypothesis pose for each particle based on the following initial distributions.
  $x_0 \sim N(0{,}2)$, $y_0 \sim N(0{,}2)$, $\theta_0 \sim N(0.1{,}0.1)$
  iii. Set the initial weight for each particle.
  iv. History- remember the last positions to draw path of particle.

- Run noise odometry data according to motion model:

$$\begin{pmatrix} x_t \\ y_t \\ \theta_t \end{pmatrix} = \begin{pmatrix} x_{t-1} \\ y_{t-1} \\ \theta_{t-1} \end{pmatrix} + \begin{pmatrix} \delta_{trans}\cos(\theta_{t-1}+\delta_{rot1}) \\ \delta_{trans}\sin(\theta_{t-1}+\delta_{rot1}) \\ \delta_{rot1}+\delta_{rot2} \end{pmatrix}$$

  σ_{rot1}=0.01, σ_{trans}=0.2, σ_{rot2}=0.01

- Apply sensor measurement: find the (r', φ') of the closet landmark to car (use the real location of the car).

- Apply measurement prediction: find the $(r(i), \varphi(i))$ values of the closet landmark to each Particles.

- Apply sensor correction- use Mahalanobis distance technique to calculate the weight for each particle based on the measurement prediction $(r(i), \varphi(i))$ and the sensor measurement (r', φ').

- Perform resampling (low variance technique) and continue to the next iteration!

- Estimate the pose of the robot from the particles (best particle)

d. Analysis Results: (20 %)
  i. Please illustrate the main steps (GT,landmarks, particles and estimate pose) through figures depicting the process the robot discover the correct trajectory. Additionally, explain your results by comparing them to GT (x,y) and including an animation
  ii. Please calculate the MSE (Mean Square error) for frames ranging from the 10^{th} frame to the end. Additionally, Please explain the results
  iii. Find the minimal set of particles (e.g, check-500,100,50,30,20..) that still maintain good performance as determined by the MSE criteria, under the same conditions. Please explain your results.
  iv. Please mention the pros and cons of Particle filters, listing at least two for each, could you provide suggestions on how to overcome the cons to develop a better mechanism?