

ME 145
Robotic Planning and Kinematics

Lab Session No. 3

Line Following for Differential-Drive and Unicycle Robots

Instructions

Submit your code through iLearn. Your code and reports are due on Wednesday, November 8th, 6:00 pm. Late submissions will not be accepted.

Create a different Simulink file or script for each task below. You may copy/paste the necessary blocks if necessary.

Programming Project: Unicycle and Differential-Drive Dynamics (150 points).

- 1) (10 points) Develop a Simulink model for a unicycle robot.

Model inputs: forward velocity of the robot (V) and turning speed (Ω); initial position (X_0, Y_0) and orientation of the robot (Θ_0).

Model output: current position (X, Y) and orientation of the robot (Θ) after integrating the unicycle dynamics with the inputs above.

- 2) (10 points) Develop a Simulink model for a differential-drive robot.

Model inputs: angular velocity of left and right wheels (V_l and V_r); distance between left and right wheel (L); radius of the wheel (R); initial position (X_0, Y_0) and orientation of the robot (Θ_0).

Model output: current position (X, Y) and orientation of the robot (Θ) after integrating the differential-drive dynamics with the input above.

- 3) (10 points) Test the above models. Select $V = 1$ and $\Omega = \sin(100 \cdot t)$, where t is the time index. Compute the equivalent inputs for the differential-drive robot (use $R = 0.1$ and $L = 0.5$). Plot (use the Simulink block “Scope”) the position and orientation of the two robots, and verify that they are the same.

- 4) (10 points) Develop a Simulink model for a robot with linearized unicycle dynamics. The linearization must be around a straight-line trajectory in the horizontal (x) direction with constant velocity v .

Model inputs: linearization velocity (v); deviations of the forward velocity of the robot (Δv) and turning speed ($\Delta \Omega$); initial position (X_0, Y_0) and orientation of the robot (Θ_0).

Model output: current position (X, Y) and orientation of the robot (Θ) after integrating the unicycle dynamics with the inputs above.

- 5) (10 points) Compare the unicycle robot with its linearized model. Select $V = 1$ and $\Omega = \sin(0.01 \cdot t)$. Plot (use the Simulink block “Scope”) the position and orientation of the two robots.

- 6) (20 points) Implement a control law based on the linearized unicycle dynamics to force the differential drive robot to follow a straight line along the x direction with velocity equal to 2 m/s. Notice: your controller will give you V and Ω as control inputs, which must be converted to V_l and V_r for the differential drive robot. Test your controller: select $X_0 = -1$, $Y_0 = 1$ and $\Theta_0 = \pi/4$. Compare the trajectories of the differential drive and linearized robots.

- 7) (20 points) Implement a control law based on the linearized unicycle dynamics to force the differential drive robot to follow a straight line written as $y = \tan(\alpha)x + b$ with velocity equal to 2 m/s. Calculate the tracking

error through “Error = $-x \cdot \sin(\text{Alfa}) + y \cdot \cos(\text{Alfa}) - b \cdot \cos(\text{Alfa})$ ” and “delta_theta = Theta - Alfa”. Error is the difference between the robot’s current position and the line and delta_theta is the error between the current angle and target angle(Alfa). Notice: your controller will give you V and Omega as control inputs, which must be converted to V_l and V_r for the differential drive robot. Test your controller: select $X_0 = -1$, $Y_0 = 1$ and $\text{Theta}_0 = \pi/4$ for various values of Alfa. Compare the trajectories of the differential drive and linearized robots.

- 8) (20 points) Implement a control law based on the linearized unicycle dynamics to force the differential drive robot to follow a sinusoidal trajectory around the x direction with velocity equal to 2 m/s. Notice: your controller will give you V and Omega as control inputs, which must be converted to V_l and V_r for the differential drive robot. Test your controller: select $X_0 = -1$, $Y_0 = 1$ and $\text{Theta}_0 = \pi/4$. Compare the trajectories of the differential drive and linearized robots.
- 9) (20 points) Implement a control law based on the linearized unicycle dynamics to force the differential drive robot to follow a circle trajectory of radius 5 m centered at the origin with velocity equal to 2 m/s. Notice: your controller will give you V and Omega as control inputs, which must be converted to V_l and V_r for the differential drive robot. Test your controller: select $X_0 = -1$, $Y_0 = 1$ and $\text{Theta}_0 = \pi/4$. Compare the trajectories of the differential drive and linearized robots.
- 10) (20 points) Write three scripts to implement the previous controllers on the e-puck robot. The robot will have to perform trajectory tracking for a line, a sinusoidal, and a circle trajectory. Check the e-puck guide on iLearn for the programming and setup of e-puck.

LineTrajectoryTracking

Implement the controller in question (7) with $X_0=0$, $Y_0=0$, $\text{Angle}_0=\pi/4$, and tracking speed $V=0.001$, tracking a line with input angle Alfa

SinusoidalTrajectoryTracking

Implement the controller in question (8) with $X_0=0$, $Y_0=0$, $\text{Angle}_0=\pi/4$, and tracking speed $V=0.001$, tracking a horizontal sinusoidal trajectory.

CircleTrajectoryTracking

Implement the controller in question (9) with $X_0=0$, $Y_0=0.1$, $\text{Angle}_0=\pi/4$, and tracking angular speed $\text{Omega}=0.001$