Fundamentals of Mobile Robots

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Exercise 1

- **Deadline**: 1.26.2024 (**before** the exercise class)
- **One** report per group.
- Only the provided **template** of exercise is acceptable.
- Please use the Teams channel to ask your questions.

Problem 1: [35 points]

Consider the following Differential Drive Robot whose control inputs are the angular velocities of the left and right wheels, ω_l and ω_r, respectively. As shown in Figure 1, the distance between the wheels is $d = 0.4m$ and the radius of the wheels is $r = 0.1m$.

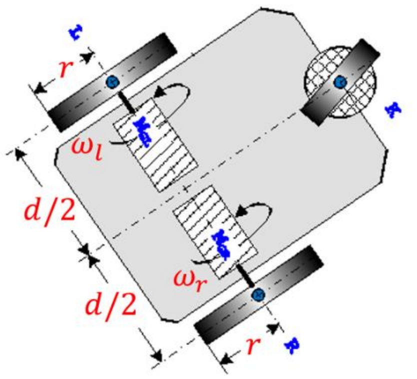

Figure 1 *Differential Drive Robot*

1. Define the state variables for kinematic of the robot. And then, derive the kinematic differential equations in state space form (**the equation must be in vector format**).
2. What is the command that we have to execute in the terminal in order to play back the rosbag?
3. Create a ROS node and subscribe to the wheel odometry data. Using both the **Forward Euler** and **Euler Midpoint** methods estimate the robot state trajectories.
4. Create a simple animation that shows the pose of the robot in a x-y plane during the time. [point: +10 % Bonus]

ROS bag file description :

The first column of data denotes the angular velocity of the left wheel, and the second one represents the angular velocity of the right wheel. The time step of data collection is 0.1s.

Problem 2: [25 points]

1. Consider a scalar random variable in a continuous space x with a Normal distribution $\sim N(\mu, \sigma^2)$. Make the following distributions and plot the probability density functions of each set in a single figure for $-10 < x < +10$. Then describe your findings.

    - Set 1: $N_1(0, 0.1^2)$, $N_2(0,\ 0.3^2)$, $N_3(0,\ 0.7^2)$
    - Set 2: $N_1(-5, 0.5^2)$, $N_2(0,\ 0.5^2)$, $N_3(+5,\ 0.5^2)$

2. Consider the given discrete random variable (discrete_random_variable.csv) with a Normal distribution.

    - Plot the bar chart of the probability versus random variable.
    - Calculate the **Expectation** and **Covariance** of the variable.

Problem 3: [40 points]

Consider a robot working in 1D discrete space (0<x<+10) with a wall located at x=0 (See Figure 2). The robot has a sensor that measures its distance (d) to the wall. At the current time, the robot position belief is defined by $N(4,\ 0.35^2)$, and the sensor model is $d\ =\ x\ +\ n$ where n denotes the noise with a Normal distribution of $N(0,0.15^2)$. Note: discretize the x into 100 numbers in the interval of 0 < x < 10.

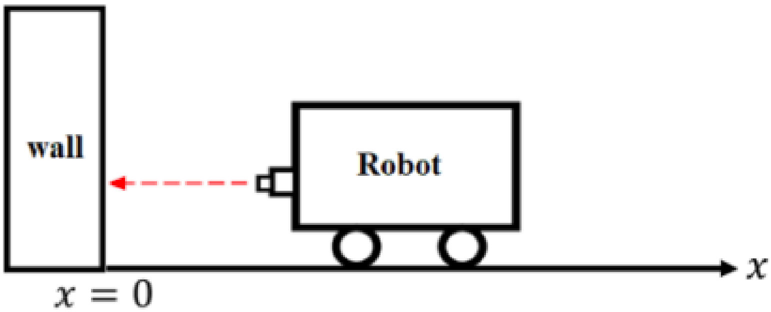

Figure 2 Robot in 1D space

1. Plot the robot position belief without sensor measurement. Plot the probability distribution of the robot position—p(x|d)--given the sensor measurement d = 3.6.

2. Assume that robot moves by the control policy of $u_k = -0.1Ex(x_k)$. In this case, the motion of the robot can be described by $x_{k+1} = x_k + u_k + w$ where x_{k+1} is the next position of the robot after applying the control action, and w denotes the environmental disturbance with a Normal distribution of $N(0,0.2^2)$. Iterate the motion three times and plot the belief distribution $bel(x)$ after each iteration.

3. Assume that after the third iteration, the robot receives d=2.5 from the sensor. Apply the sensor measurement step like part 1 and plot the belief distribution of the robot position.