Assignment 1: Obstacle Avoidance

Overview

In this assignment, you will implement a simple local obstacle avoidance planner to navigate around obstacles perceived by the 2D LIDAR, accounting for the kinematic and dynamic constraints of the car.

Strategy

A simple kinematic-aware C-space greedy local planner was introduced in class (Lectures 1-3). You should start with the approach outlined in class, and then implement any extensions you see fit to improve performance. Here is a suggested sequence of steps to follow, to build up to the obstacle avoidance planner.

1. Implement 1-D TOC on an arbitrary arc.
2. For a fixed arc, implement obstacle detection and integrate it with 1-D TOC to drive up to the observed obstacle.
3. Implement a scoring function to select between paths of different curvature options.
4. Finally, for each time-step, select the best option to drive along, and execute one time-step of 1-D TOC along the selected arc.

Latency compensation will be crucial to accurate execution on the real cars.
Motion parameters to use: Max speed of 1m/s, Max acceleration and deceleration of $4m/s^2$.

Questions

For the following questions, the parameters of your car are as follows:

- Length: l
- Width: w
- Wheel base: b
- Track width: d
- Obstacle safety margin: m

Assume that the distance from the rear axle to the rear end of the car is the same as the distance from the front axle of the car to the front end of the car. The car is symmetric laterally. Observations are made in the base_link frame of the car, which is coincident with the center of the rear axle of the car. The car is turning along an arc of radius r, and observes a point p=(x,y).

1. Which point of the car traces an arc of maximum radius? What is that radius, in terms of r and other car parameters?
2. Which point of the car traces an arc of minimum radius? What is that radius, in terms of r and other car parameters?

3. Under what conditions will p first hit the inner side (the side closer to the center of turning) of the car as the car drives forward?
4. Under what conditions will p first hit the front of the car as the car drives forward?
5. Under what conditions will p first hit the outer side (the side farther to the center of turning) of the car as the car drives forward?
6. What is the maximum distance (the free path length) the car can move forward along the arc before it hits the point p?
7. If the current velocity of the car is v, and the maximum magnitude of deceleration is a, what is the minimum stopping distance of the car? [This will determine which curvature options should be ruled out, depending on their free path lengths]

What to turn in

Turn in a single pdf document that describes your algorithm, parameters, and performance. Include a link to a public github repository of your code. **Important: please make sure the release is made public only after the due date**. Include a link to a video of your algorithm running on the real car. The video must demonstrate your robot operating in a number of different settings to demonstrate its obstacle avoidance behavior. You must include the answers to the questions listed earlier, and must additionally address the following questions:

- What parameters does your algorithm require, and what is their impact?
- How were the parameters tuned?
- What challenges did you encounter, and how did you overcome them?
- How could you further improve upon your results?
- Include a link to your github repository
- Describe the contribution of each team member

The report does not have a page limit, but please answer the questions precisely and concisely, preferably in 4 pages or less.

Extra Credit

Note: Extensions for extra credit should only be attempted after the primary implementation is complete.

1. High-speed obstacle avoidance at 2+ m/s
   Demonstrate your algorithm avoiding obstacles in cluttered environments while travelling at high speeds
2. J-turns and U-turns
   Given an observed laser scan, plan and execute a J-turn or a U-turn to turn the car around 180 degrees, while avoiding obstacles. You will have to keep track of previous observations, and predict the relative motion of the car with respect to obstacles no longer in the viewable area of the LIDAR.

Brainteaser: Hurricane Ida is blowing through town and the rain is coming down in buckets. If you want to get from a store to your house in the 9th Ward on foot while staying as dry as possible, should you walk or run? Why?