Path Planning

ECE 495 T21
Winter 2021

Overview

- 6-lane track, 3 lanes each direction, 6946m long
- 50 mph speed limit
- Total acceleration limit: 10 m/s^2
- Jerk limit: 10 m/s^3
- Be able to follow a lane smoothly
- Change lane smoothly when vehicle in front is too slow
- Avoid collisions at all cost
- As close to speed limit as possible
- Assignment repo: https://github.com/udacity/CarND-Path-Planning-Project

Setup

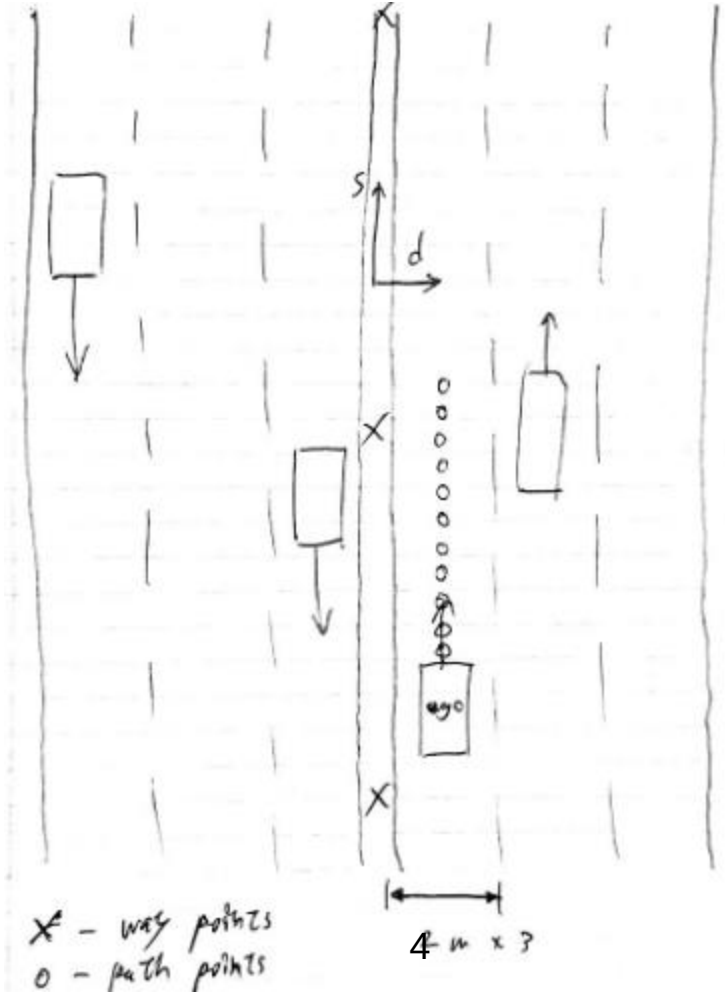
- Follow the instructions in the project repo
- Need to install uWebSockets before you can build and run the project. First, `sudo chmod u+x install-ubuntu.sh`, then `./install-ubuntu.sh`. Do the mac version if you have mac. For windows, try install from source (see instruction in repo)
- Go to the directory where you downloaded the simulator, do `sudo chmod u+x <simulator-name>` as well
- Replace the `main.cpp` file in `src` with the one posted on Learn
- Put `spline.h` into the `src` folder
- Build and run the project
- Start simulator

Alternative Setup 1 - Docker

- If you are unable to run the path planning code but you can run the simulator on your machine, another option is to use a docker container for the path planner and run the simulator normally.
- Instructions for path planner in docker
    - Download the docker_files.zip for A8
    - Place the Dockerfile, build.sh and run.sh files into your CarND-Path-Planning-Project folder
    - cd in to the CarND-Path-Planning-Project folder
    - sudo bash build.sh (This must be run after making changes to the code)
    - sudo bash run.sh

Alternative Setup 2 – Virtual Machine

- If you are unable to get the assignment working on your own machine then you can try loading this virtual machine I created.
  - It lags with my laptop (intel i7-6600U CPU).
- I have a separate video tutorial going through the following:
  - Download the premade Xubuntu 18 with assignment 8 working VM at https://drive.google.com/open?id=1FDsKlZ2Yq5t05QWnUBP22i42-TvTeGKC
  - Load it into VirtualBox and increase processor amount
  - Run the VM (account password: ece493)
  - Start the path planning assignment code and the simulator



Road Layout

- s and d: Frenet coordinates
  - S is how far you are along the road
  - D is the lateral distance you are from the center of the road
- Each lane is 4m wide
- Way points: points along road center, given to you, use them as reference points to generate path points
- Path points: equally spaced out points which the ego vehicle will follow, 0.02s each

Rubric

Trajectory generation (4 points)

- Watch Udacity's Q&A video, answer the following questions:
    - 1) how is lane following achieved? (1 points)
    - 2) how to use spline to generate a smooth trajectory? (2 point)
    - 3) how to avoid collision with the car in front? (0.5 points)
    - 4) how to avoid cold start? (0.5 points)
    - Can elaborate on 2) (4-6 sentences), but for 1) 3) 4), 2 sentences maximum

Rubric

Behaviour Planning (5 points)

During 2 miles of driving, achieve the following (1 point for each item):

- 1) Perform lane shift when front vehicle is too slow, done at least once.
- 2) No collisions
- 3) Count(Exceed(speed lim || acc lim || jerk lim)) <= 1
    - If any limits are exceeded for more than 2 sec straight, you lose this point
- 4) Complete 2 miles within 3 min
- 5) No limits exceeded

Important note: An achievement can only be unlocked by successfully completing the previous ones, for example, if you fail 1), then you automatically lose marks for 2)-6); if you fail 2), you automatically lose marks for 3)-6) and so on.

Rubric

- Writeup (2 points)
    - Briefly explain your approach for behaviour planning and any modifications to the provided trajectory generation code (7-10 sentences)

Helper Functions

- Functions in helpers.h are helper functions provided to you
- Please don’t explain them in your write-up
- Understanding how to use them is enough

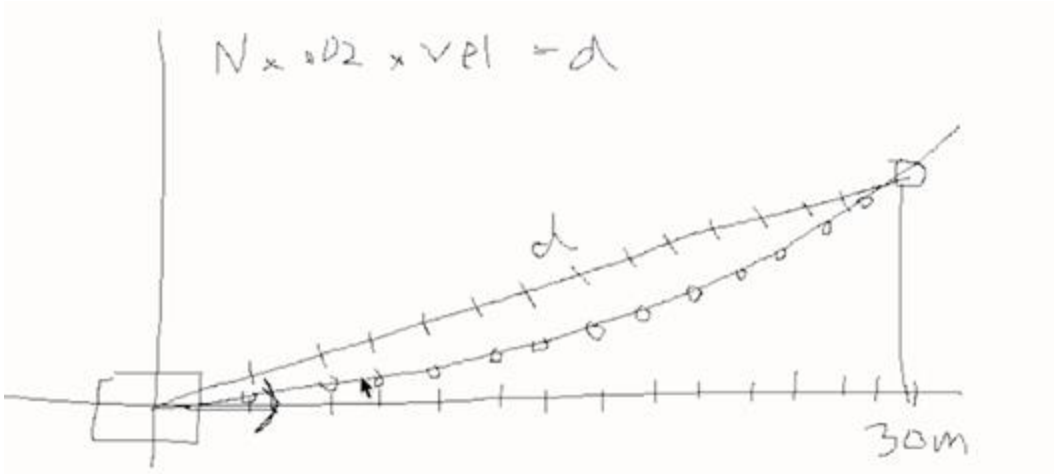
Starter Code

- The code for Task 1 is provided to you in “main.cpp” on Learn
- Enables the ego vehicle to:
    1. follow a lane smoothly
    2. avoid collision with vehicle in front in the same lane
- Feel free to modify it as you see proper

Task 1: Trajectory Generation

- Use spline to generate path
- Assignment Q&A video: https://www.youtube.com/watch?time_continue=369&v=7sI3VHFPP0w&feature=emb_logo
- 12:00-19:00 Lane following
- 19:00-40:00 Generate a smooth path for the ego to follow (i.e. a set of path points)
- 40:00-48:30 Collision avoidance
- 48:30-53:00 Avoid cold start
- 53:00-58:00 How lane change happens
- Note: code from the help video will be provided

How does Spline Work?



- Fit a spline to several sparse waypoints
- Distance horizon: 30m ahead of the starting position of the car along its original heading
- Use original heading as x direction here
- Obtain the y position of the end point (the big circle) corresponding to the distance horizon using spline function
- Compute d using trigonometry
- Compute N using d (m), velocity (m/sec), and 0.02 sec
- Divide 30m along x direction into N parts, find all corresponding y values on the spline
- Now you have the path points to follow in order to traverse the spline
- Note: local coordinate system here

Task 2: Behaviour Planning

- Finite state machine: design several functions to help the ego decide when to switch lane, and which lane to switch to etc.
- Cost functions: evaluate the cost of the possible states, say cost of stay in the same lane, cost of switching lane etc.
- Make decisions and use the trajectory planner to execute the decisions
- Lots of freedom for this task, you can be very creative here

Tips

- When running the simulator, choose lower resolution to make sure it runs fast enough
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Helpful Blog Posts

https://towardsdatascience.com/teaching-cars-to-drive-highway-path-planning-109c49f9f86c

https://medium.com/@mithi/reflections-on-designing-a-virtual-highway-path-planner-part-1-3-937259164650

https://medium.com/@mithi/reflections-on-designing-a-virtual-highway-path-planner-part-2-3-392bc6cf11e7

https://medium.com/@mithi/reflections-on-designing-a-virtual-highway-path-planner-part-3-3-a36bf629d239