Name: Chun-Yen Yeh (ID: cyyeh4), Huey-Chii Liang (ID: hcliang2)

Course: ECE484 - Principles of Safe Autonomy

Date: October 4, 2023

ECE484 - MP2 Group Assignment

Problem 4 (15 points)**. Longitudinal Controller**: How do you establish the relationship between the track's curvature, the vehicle's current state, and its target velocity? Could you elaborate on the methodology employed to derive this mapping? Specifically, how have you optimized the process for efficiency while ensuring safety?

Relationship & Mapping

Target velocity is derived by the following two steps:

1. Compute the average of waypoints' curvature(*avg_curve*) that lie within lookahead distance as Figure 1 shows.
2. Map *avg_curve* linearly within *min_velocity* and *max_velocity by the function below:*

```
def get_mapped_vel(avg_curve, min_curve=0.0, max_curve=self.argv.max_curve,
                   min_vel=self.argv.min_vel, max_vel=self.argv.max_vel):
    """ linear mapping """
    avg_curve = min(max_curve, avg_curve)
    avg_curve = max(min_curve, avg_curve)
    return max_vel - (max_vel - min_vel) * avg_curve / (max_curve - min_curve)
```

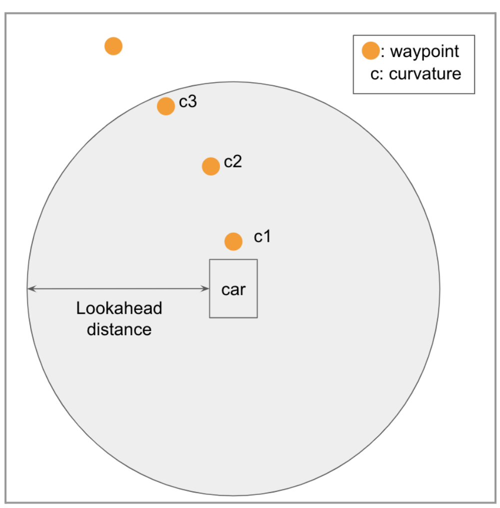


Figure 1

Optimization

First of all, we build a control over our target velocity, maintaining it within *min_velocity(=8)* and *max_velocity(=12).* This ensures that the velocity is neither too low, which would result in inefficiency, nor too high, which would pose a danger.

For safety, our initial approach focused only on curvature of the nearest waypoint. However, we found that the vehicle struggled to maintain control, particularly during sharp turns. To solve this, we have refined our approach by incorporating additional "future" waypoints into our calculations. This look-ahead strategy enhances the vehicle's predictive capabilities and safety.

In terms of efficiency, we optimize our target velocity by making it inversely proportional to the curvature of the route. This strategy allows the vehicle to maintain its velocity even on slightly curved paths, ensuring that it operates efficiently without unnecessary slowdowns.

Note:

- We compute the curvature of each way point by the following formula (ref: wiki)

$$\kappa = \frac{\sqrt{\left(z''y' - y''z'\right)^2 + \left(x''z' - z''x'\right)^2 + \left(y''x' - x''y'\right)^2}}{\left(x'^2 + y'^2 + z'^2\right)^{3/2}},$$

- Parameter selection:
  - *min_curvature = 0.0*, *max_curvature = 0.03*
  - *lookahead_distance = 10.0*

  According to Figure 2, most of curvature's value is bounded within 0 - 0.03. To mitigate the impact of sharp turns on our model, we truncated curvature values exceeding 0.03 to 0.03. For parameter *lookahead_distance,* we set it to *10*.0 by experiment. If it's set to a value less than *10*, it results in the consideration of an insufficient number of points. Conversely, when set to a value greater than *10*, it includes waypoints that are too far away.

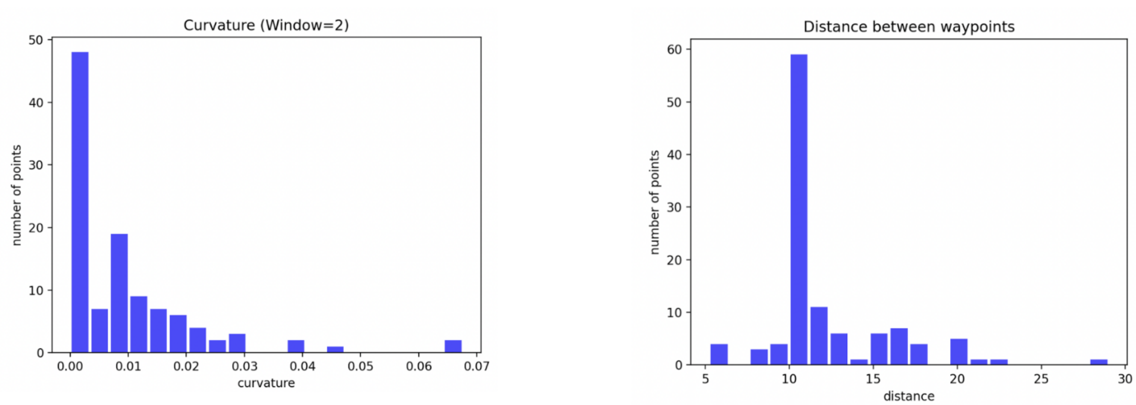
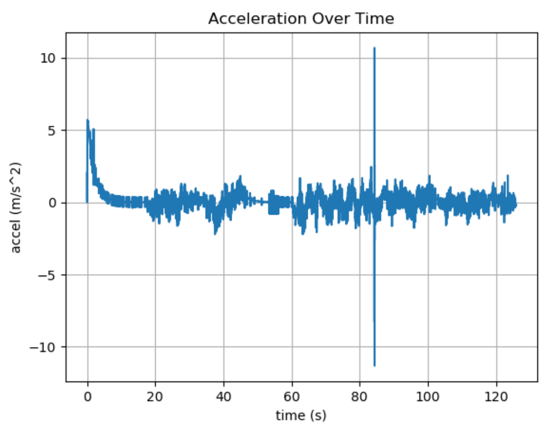


Figure 2

Problem 5 (15 points)**. Comfort Metric Analysis**: After your controller successfully completes one lap within the specified time, please generate an acceleration-time plot. Take note that accelerations exceeding 0.5G (or 5 m/s2) may result in discomfort for passengers. Did your controller cross this threshold? If it did, how frequently did this occur, and what were the contributing factors? Do you have strategies in place to mitigate such high levels of acceleration?

Our acceleration-time plot is shown below. There are two parts that cross the threshold, one at the beginning and another around 85th second. The first time this occurred was because of our target speed range setting. We set the minimum and maximum values of the target velocity as 8m and 12m respectively. When the simulation started, the vehicle speed started to accelerate from 0m/s to 12m/s (the velocity was increased to 12m/s because the road was straight at the beginning), so the acceleration exceeded 0.5G.

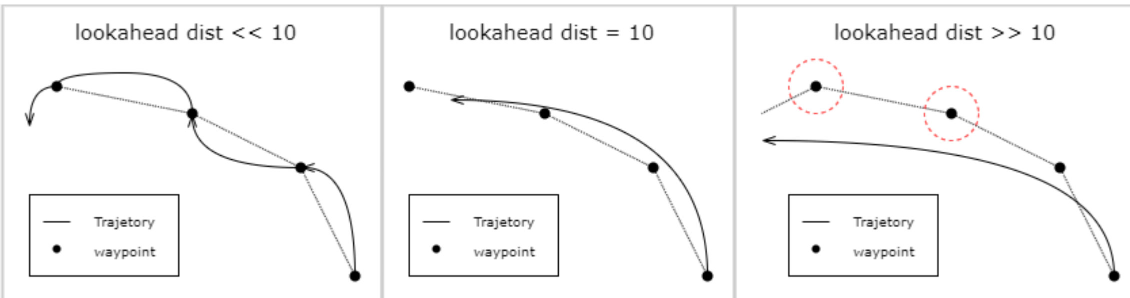


The situation at the 85th second may have been caused by the unevenness between the road and the grass resulting in the car to slide. At this point, the left side of our car drove into the grass because the turning angle was not large enough. From RVIZ, we found that the car tilted violently, so we speculated that this sliding caused the acceleration to exceed 10 m/s^2.

Although we cannot avoid acceleration changes caused by sliding, we believe that we can maintain the value of acceleration at the beginning of the simulation. One possible solution is that we can set the maximum target speed to the current speed +5 when the difference between our target speed and the current speed is greater than 5.

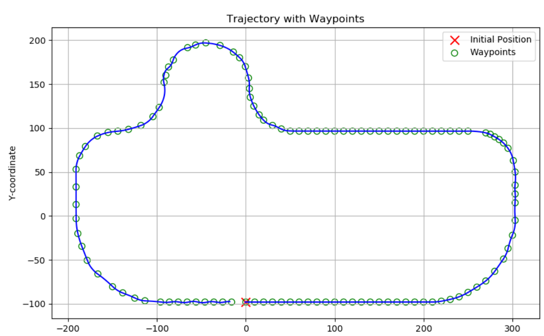
Problem 6 (15 points)**. Lateral Controller**: Could you elaborate on the criteria used to select the lookahead target waypoint? How many of the suggested methods did you explore for this purpose? Among those, which method is the most effective, and why do you think so?

We set a constant lookahead distance of 10m and use at least one waypoint to measure the steering angle, so each time we will calculate between 1 to 3 steering angles and then take their average. The reason why we choose 10m is that if we set the lookahead distance too small, the controller can only consider a few waypoints, so the steering angle adjustment is only based on the nearest waypoint. Although the car can pass each waypoint, this also prevents the car from adjusting its steering angle based on future waypoints, causing the car to swing left and right, as shown in the left image below. In contrast, if we set the distance too large, the average steering angle will become larger due to the far waypoints, making the car difficult to pass each waypoint, as shown in the right figure below.



We also explored another method proposed in the report, which is to directly select the nearest target waypoint as the look-ahead distance. We believe that our approach is more efficient because if we select the nearest target waypoint, the controller cannot obtain sufficient road information further away from the car. Therefore, when the vehicle is traveling at a high speed and encounters a large-angle turn, this method will not be able to effectively control the vehicle's turning, resulting in lower safety.

Problem 7 (15 points)**.** Draw an x-y plot recording the trajectory of the vehicle around the track. In addition, you should mark the default initial position and the waypoints in your plot.



Problem 8 (10 points)**.** Record a video for one example execution of this scenario. The video should include the GAZEBO window. Provide a link to the video and include it in the report.

[Video link](#)