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?

Indicator of track's curvature and methodology: To detect the curve, we are interested in the next unreached waypoint. Then, the controller detects whether the difference between the next unreached x and y coordinates and current x and y coordinates of the car are less than 0.25. If this condition is met, the target velocity of the car on a straight path is set to 16 m/s, else, it is set to 9 m/s as it is on a curved path.

Optimization: To build a system that efficiently detects whether a path is straight or curved, we consider the next unreached waypoint, the vehicle is smoothly transitioning between waypoints without abrupt changes. We have replicated the safety mechanism of a human driving a car, the controller detects a curve well in advance to prevent the risk of unsafe diversion of the car.

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/s^2) 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?

This occurred around initial time and then never occurred again. This is because of the initial acceleration of the car when it speeds up from 0 m/s to 16 m/s. To mitigate this unwanted acceleration we can achieve the speed of 16 m/s by gradually accelerating for better comfort.

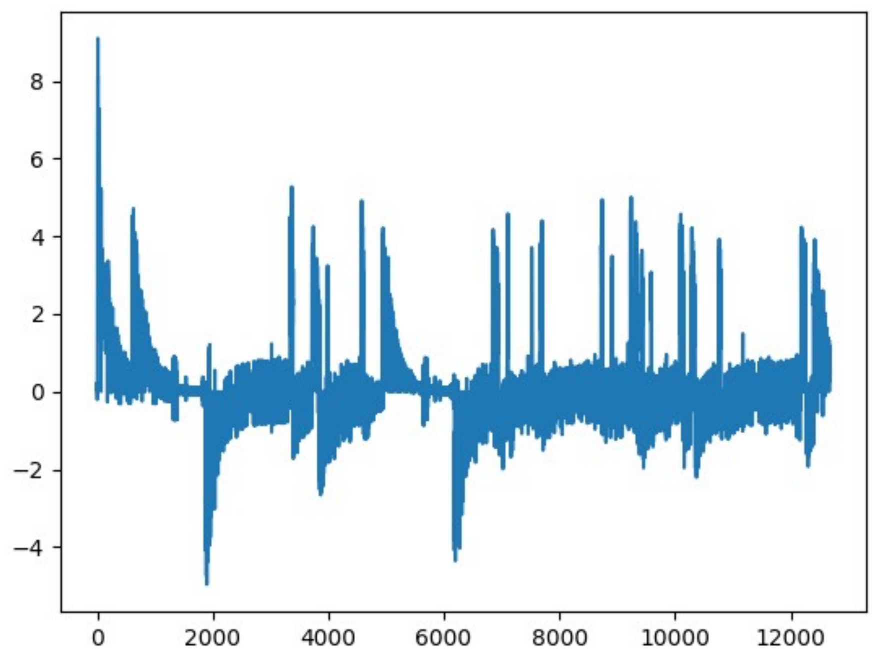

Figure 1: Acceleration vs Time

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?

If the difference between next two unreached waypoints are more than 18, then the next waypoint is taken as a target waypoint. Otherwise, the target waypoint is taken as the next-to-next future unreached waypoint. By taking the next-to-next waypoint, the car ensures a smoother transition between waypoints without abrupt changes, it provides consistent and predictive steering. The reason for implementing this is because there was a section of the track where the difference between two waypoints were more than 20 which led the car to go off-track or it did not follow the next waypoint.

The lateral controller implements the first proposed method to determine the lookahead target waypoint, however, instead of taking the nearest unreached waypoint, we used the next-to-next unreached waypoint. This gave us better stability than the first unreached waypoint. The third method would be best suited for a car at higher speeds, which is constantly changing its lookahead distance according to the path – ultimately resulting in smooth transitions in the curve.

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.

Yellow: car trajectory

Orange: waypoints

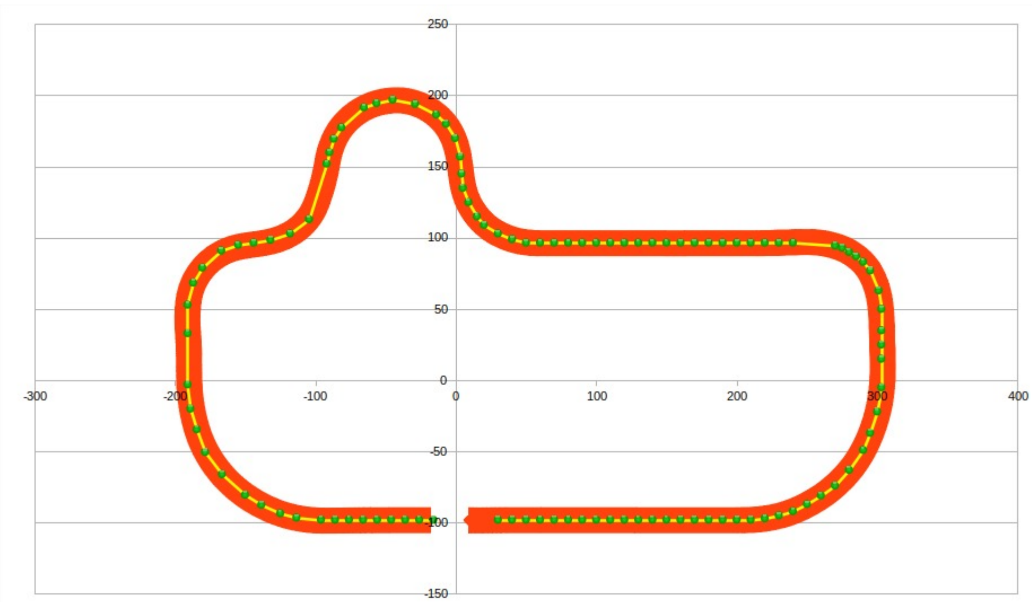

Figure 2: Car trajectory on its waypoints

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.

https://drive.google.com/drive/folders/1q48ZBjGeh2cemdZ9Atl580WFmgIzT0BW?usp=share_link