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Term 3, Project 1 – Path Planning

The behaviour planner of an autonomous car travelling on a highway aims to emulate typical decisions made by a human driver when negotiating traffic. The overall process can divided into three task:

- Sensor fusion and costing
- Behaviour planning
- Trajectory generation

Sensor Fusion and Costing

In this step (line 295 to 423), the sensor fusion data provided by the simulator is used to determine where each vehicle is on the map. The state of each vehicle in proximity to the ego vehicle allows the planner to determine what the state of the surrounding environment is in order to make the correct decision. Using the relevant state data of each vehicle (namely the along path position **s**, the lateral path position **d** and the **speed** of the vehicle), the lane (lines 323 – 337), the relative along path position (line 346) and relative speed (line 349) to the ego vehicle can be determined. With the relative states of the surrounding vehicles known, the following logical steps need to be considered:

- Is the lane ahead of the the ego vehicle clear? (line 354)
- Is the lane left of the ego vehicle clear? (line 369)
- Is the lane right of the ego vehicle clear? (line 381)

If there is a car in the ego vehicle’s lane, and is in close proximity to it, then the relative state information of the car is passed into the cost function (line 357) to determine the cost of keeping the current lane. Similarly, if the car is in either the left or right lane, and is in close proximity to the ego vehicle, then cost associated with merging into the left or right lane is determined (line 372, line 384).

The cost function (line 169 – 200) used to determine the cost of keeping the current lane, merging left or merging right is driven by the relative speed and position of the surrounding cars relative to the ego vehicle. The position cost function (line 188) is based on the shape of a Gaussian distribution, which maximises the cost of vehicles within a certain distance of the ego vehicle (set to 40 metres, which is 1-sigma). The maximum cost is assigned to vehicle directly alongside the ego vehicle. The cost decays away as vehicles are further than this range (forward and behind the vehicle).

The speed cost function considers the relative position and speed of the vehicle. Vehicles that are ahead of the ego vehicle and are moving faster than the ego vehicle add less cost than vehicles that are ahead of the ego vehicle but moving slower. Similarly, vehicles that are behind the vehicle, but moving slower than the ego vehicle cost less than vehicle behind the ego vehicle, but moving faster. This trend can be captured by the logistic function (line 196), with the function adjusting for the cases where the vehicle is in front or behind the ego vehicle by changing the sign of the exponent gain in the logistic regression function. The cost per vehicle is the sum of the position and speed cost, with the overall cost for each lane the product of each vehicle cost in that lane.

In addition to the cost of the vehicles in each lane, the total cost associated with lane changes are increased if the lane is not clear. This prevents the ego vehicle from performing a dangerous lane changes by making it too costly. Similarly, if the ego vehicle is in the furthest left or furthest right lane, the cost of performing a further left or right lane change is made extremely high to prevent the vehicle crossing into oncoming traffic or off the road entirely. Following all cost calculations, the lowest cost action is determined and passed into the behaviour planning segment.

Behaviour Planning

The behaviour planning segment uses the information from the sensor fusion and costing segment to determine the correct action to take. The logic to determine which action to take is as follows.

- Only consider a lane change if the lane ahead is occupied (line 426).
- If lane ahead is occupied, and the lowest cost is to merge left – merge left (line 430).
- If lane ahead is occupied, and the lowest cost is to merge right – merge right (line 435).
- If lane ahead is occupied, and the lowest cost stay in lane – keep lane.
- If decision to keep lane is made, slow ego vehicle to match the vehicle ahead (line 442 - 458), and attempt to maintain a safe following distance (30 metres in this case) (line 305).

In the keep lane state, the ego vehicle aims to maintain a safe following speed and distance behind the vehicle ahead. This is done by adjusting the reference velocity of the ego vehicle as a function of the maximum allowable acceleration, the safe distance separation and the speed difference between the ego vehicle and vehicle ahead (line 449).

Trajectory Generation

The trajectory generation segment is driven by the desired lane action from the behaviour planning segment, and is an adaptation of the trajectory generation example discussed in the project Q&A. In this segment, a spline path is generated by connecting the current and previous path points, along with projected points ahead of the vehicle (30 metre intervals) in the ego vehicles frame (line 502 – 546). A portion of the previous trajectory is appended to the current trajectory to maintain path continuity between updates, with the new points spaced to maintain the reference speed calculated in the behaviour planning segment (line 551 - 592). The resulting path, in the ego vehicle frame is transformed back into global coordinates, then returned to the simulator to be driven along.