Submission for the AImotive planning assignment

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1 Introduction

The objective of this document is to give a brief overview of the approach employed to solve the problem of traversing a road intersection by an autonomous vehicle while minimizing a performance criteria and respecting kinodynamic constraints as well as obeying the traffic laws. This problem tackles several issues including collision prediction, planning, and control of the vehicle.

There exist a plethora of approaches ranging from reactive control based on the concept of artificial potential field (APF) to probabilistic motion planning techniques such as RRT* to techniques from automated road management such as priority-based coordination and control [Gregoire, 2014]. Refer to [Hoy *et al.*, 2015] for a more comprehensive review.

The proposed implementation is based on Model Predictive Control (MPC) and the collision cone principle. This approach seems to show great potential in providing efficient navigation and easily extends to robust and nonlinear problems.

2 Collision prediction

I had the opportunity to collaborate with prof. Zvi Shiller who co-authored the seminal work on velocity obstacles and collision avoidance in a dynamic environment [Fiorini and Shiller, 1998]. In the current implementation, I rely on the concept of Collision Cone (CC) [Chakravarthy and Ghose, 1998] and Velocity Obstacle(VO) for collision prediction. The collision prediction is based on the Line Of Sight (LOS) kinematics and in particular the following condition (Eq(16) in [Chakravarthy and Ghose, 1998])

$$V_{\theta 0}^2 \leq p^2 V_{r0}^2 \tag{1}$$

Due to space limitation, please refer to [Chakravarthy and Ghose, 1998] for more details.

3 Model Predictive Control

MPC is a feedback scheme in which an optimal control problem, looking ahead in time for a finite horizon, is solved at each time step. The first part of the optimal sequence is applied and the optimization is repeated at regular intervals. Since optimization techniques naturally handle hard constraints, MPC can be explicitly aware of the constraints, such as speed or control limits and obstacle avoidance, and operate close to, but within, their boundaries.

3.1 Third-order point mass model of the ego-vehicle

$$x[t+1] = x[t] + v[t] * dt + 1/2 * a[t] * dt + 1/6 * J * dt \tag{2}$$

$$v[t+1] = v[t] + a[t] * dt + 1/2 * J * dt \tag{3}$$

$$a[t+1] = a[t] + J[t] * dt \tag{4}$$

4 Wrapping it up in a simple algorithm

References

[Chakravarthy and Ghose, 1998] Animesh Chakravarthy and Debasish Ghose. Obstacle avoidance in a dynamic environment: A collision cone approach. *IEEE Trans. Syst. Man, Cybern. Part ASystems Humans.*, 28(5):562–574, 1998.

[Fiorini and Shiller, 1998] Paolo Fiorini and Zvi Shiller. Motion Planning in Dynamic Environments Using Velocity Obstacles. *Int. J. Rob. Res.*, 17(7):760–772, jul 1998.

[Gregoire, 2014] Jean Gregoire. *Priority-based coordination of mobile robots.* PhD thesis, Ecole Nationale Supérieure des Mines de Paris, 2014.

[Hoy *et al.*, 2015] Michael Hoy, Alexey S. Matveev, and Andrey V. Savkin. Algorithms for collision-free navigation of mobile robots in complex cluttered environments: A survey. *Robotica*, 33(3):463–497, 2015.