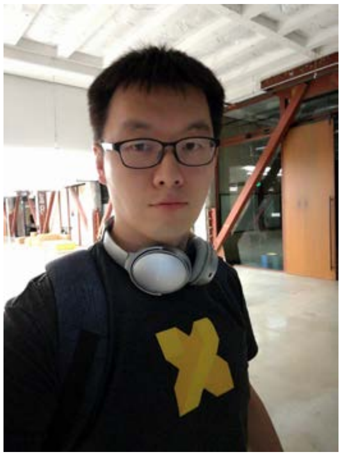
Electrical & Computer ENGINEERING

Carnegie Mellon University

Ph.D. Defense

Improved Trajectory Planning for On-Road Self-Driving Vehicles Via Combined Graph Search, Optimization & Topology Analysis



Tianyu Gu

February 14, 2017 | 8:00am ET | GHC 8115

Committee

Dr. John Dolan,
advisor, CMU-ECE, RI

Prof. Howie Choset,
CMU-ECE, RI

Prof. Gary Overett,
Sun Yat-sen University

Dr. Jin-Woo Lee,
General Motors R&D

Abstract:

Trajectory planning is an important component of autonomous driving. It takes the result of a route-level navigation plan and generates the motion-level commands that steer an autonomous passenger vehicle (APV). Prior work on solving this problem uses either a sampling-based or optimization-based trajectory planner, accompanied by some high-level rule generation components. However, these schemes are limited in the following respects:

- Sampling-based planners yield global resolution-complete optimal trajectories, but suffer from the curse of dimensionality and sampling sub-optimality (i.e., almost never reach a local optimum). Optimization-based planners can find a local optimal trajectory, but suffer from the unawareness of a global optimum.
- Both types of trajectory planner lack explicit tactical or behavior-level reasoning capability. They rely on the high-level behavioral decision making component to make motion-level decisions that do not necessarily comply with the maneuverability of the planner and the APV.

In this thesis, we adapt existing algorithms and propose new methods in the fields of optimal control, graph search and topological analysis to design an improved trajectory planning system. The core contributions of our work are summarized below:

- A hybrid trajectory planner for on-road autonomous driving that maintains the key advantages of both the sampling-based and the optimization-based planners while reducing their limitations.
- A novel type of edge-augmented graph that allows sampling-based planners to numerically approximate certain trajectory optimization methods.
- A novel backward induction method based on topological analysis to perform configuration-space segmentation over a direct acyclic graph (DAG) as an efficient way to explore the topological structure of a global configuration space.
- A novel maneuver pattern distinction method based on trajectory sampling and topological analysis to distinguish region-based, topology-based and overtaking sequence-based patterns for motion-level tactical reasoning.
- Adaptation of the linear quadratic regulator (LQR) controller for model-feasible trajectory smoothing, and of the iterative-LQR (1^{st}-order differential dynamic programming) for focused execution-feasible trajectory optimization.
- Identification of useful principles and functions for constructing cost terms for trajectory evaluation.