Motion Planning for Non-holonomic Autonomous Vehicles

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Introduction

The availability of driver assistance systems and autonomous functions has increased rapidly for production vehicles in recent years. These systems are being developed for active safety systems and aim at assisting the driver in all driving situations.

To further develop the technology and reach closer towards fully autonomous vehicles, several research projects have been initiated by the scientific society.

Parking a car into a parking lot and maneuvering it through a narrow corridor are rather common driving scenarios in an urban environment. Due to Non-holonomic constraints as a limited steering radius, the lateral motion of a vehicle is restricted and the orientation cannot be changed without a longitudinal movement.

An advanced driver assistance system (ADAS) is vital to serve human drivers in these situations and ensure safety, efficiency, and convenience. Motion planning for parking and maneuvering tasks plays an important role in such an ADAS and is an essential milestone to achieve fully automated driving cars.

Problem Background

One of the main challenges in developing a practical path planner for free navigation zones arises from the fact that the space of all robot controls and hence trajectories is continuous, leading to a complex continuous variable optimization landscape. Much of prior work on search algorithms for path planning yields fast algorithms for discrete state spaces e.g., using Dijkstra or A* method, but those algorithms tend to produce paths that are non-smooth and do not generally satisfy the non-holonomic constraints of the vehicle.

Another approach is to directly formulate the path-planning problem as a non-linear optimization problem in the space of controls or parametrized curves, but in practice guaranteeing fast convergence of such programs is difficult due to local minima.

An alternative approach that guarantees kinematic feasibility is forward search in continuous coordinates, e.g., using rapidly exploring random trees (RRTs) or hybrid A* method. The key to making such continuous search algorithms practical for online implementations lies in an efficient guiding heuristic.

Another practical challenge is the design of a cost function over paths that yields the desired driving behavior. The difficulty stems from the fact that we would like to obtain paths that are near optimal, but at the same time are smooth and keep a comfortable distance to obstacles.

Designing a path planner for an autonomous vehicle gives rise to the following challenges:

- Stability guarantees
- Performance certificate while respecting acceleration and jerk limits for driver comfort
- Taking into consideration the vehicle non-holonomic constrains and actuator dynamic
- Collision avoidance in the presence of static as well as dynamic obstacles
- Computational efficiency in view of the real-time feature of the problem

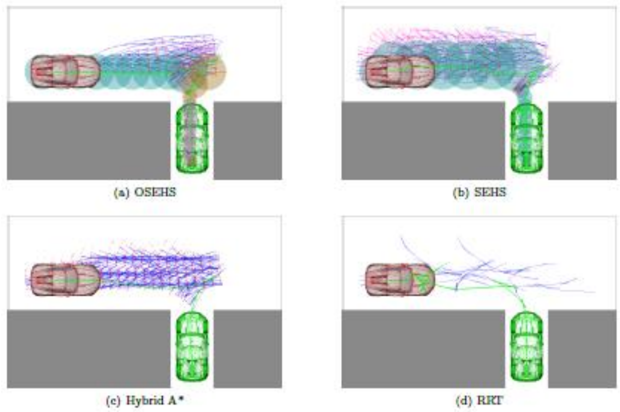

Fig. Cross parking scenario for different approach

Your Assignment

- Literature review
- Design of a motion planner for non-holonomic autonomous vehicles by:
  - Modelling the occupancy map of the road and its characteristics, such as lanes and dynamic and static objects.
  - Modeling actuators dynamic.
- Evaluation of the developed motion planner in simulation considering the real time implementation constraints
- Results are to be presented in a PowerPoint presentation and documented in a report.

Your Profile

- Knowledge in systems and control
- Knowledge of vehicle dynamics
- Experience with the software package Matlab/Simulink
- Background in Model Predictive Control and optimization is a plus but not necessary

The project involves interesting mathematical aspects as well as practical research which would be useful for those wishing to go to industry.