Automated driving in complex environments

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Description

Self-driving vehicles obtain the vehicle's state and environment information from sensors and sensor-fusion algorithms and use actuators to influence the vehicle's motion. Planning and decision algorithms that determine the vehicle's movement are essential in such systems. For a given route computed by a navigation system, a self-driving vehicle might need to decide which vehicles to leave right of way for, which lane to place itself in or when to change lanes. Based on such decisions the vehicle needs to plan and execute combined longitudinal and lateral maneuvers. The decisions and planned maneuvers should provide a comfortable ride, while also ensuring that the vehicle travels safely on the road. Additional aspects like keeping fuel consumption and emissions as low as possible might also be considered. Since the vehicles operate in dynamic environments, decisions and maneuvers need to be computed and updated in real-time to ensure safe and smooth interactions with other road users.

Background & Motivation

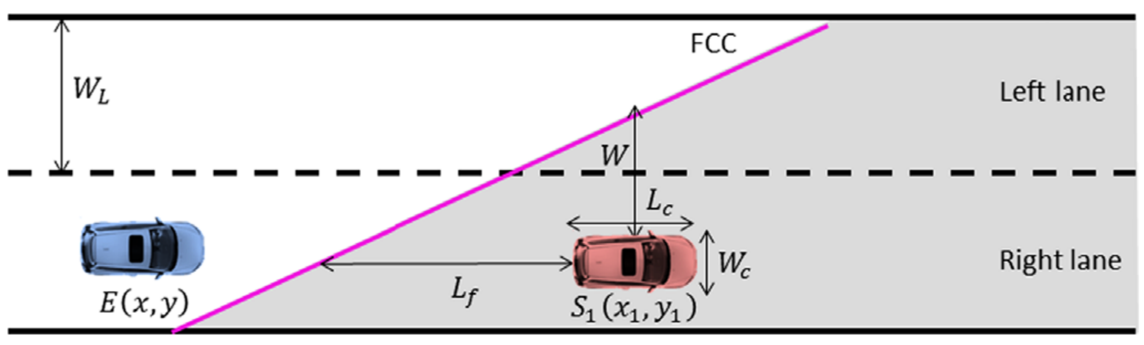

Figure 1: Model predictive controll path planning. Figure taken from [1].

Research so far has focused on algorithms for "highway-like" environments with limited variation of possible traffic situations. Provided the monotonous highway environment, the design of reliable path planning algorithms is challenging for these "simple" traffic situations and might require use of advanced methods. See for example [1], where an algorithm utilizes constrained optimal receding horizon control to solve the problem of choosing lane and vehicle speed. Figure 1 shows a model predictive control path planning formulation.

Research Goal & Question

The goal in this project is to consider decision making and path planning in complex traffic situations including crossings and roundabouts. In [2] and [3] different algorithms for cooperative driving in intersections are developed and studied. However, these algorithms rely on communication between vehicles i.e. that other road users broadcast their intentions which might be limiting if the self-driving vehicle needs to operate in an environment where both manual and self-driving cars co-exist. This project will only consider algorithms using on board sensors. Without direct communication between vehicles, the behavior of the surrounding traffic needs to be treated as uncertain and this imposes additional challenges in the design of the algorithms. The algorithms will have to adopt a precautionary behavior, especially in situations where the sensors field of view can be partially occluded or the sensing range is too short. To study this, algorithms for estimation and prediction of the behavior of other road users will also be developed within the project.

Methods & Preliminary Results

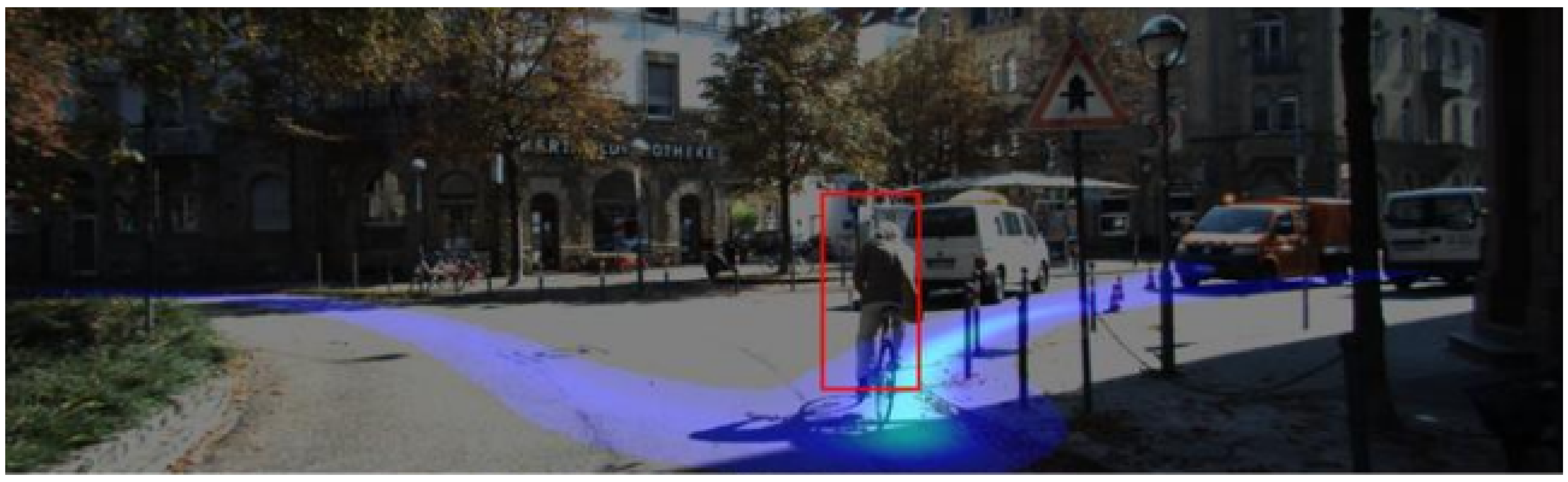

Figure 2: Pedestrian intent prediction. Figure taken from [4].

Path planning and decision problems can generally be formulated as constrained optimization problems. Constrained optimization is especially beneficial for solving problems where safety needs to be ensured, since there is a natural way of imposing safety constraints. This approach has been shown to be successful in e.g. [1] for simpler traffic situations where the problem structure allows the use of efficient optimization solvers that utilize properties like convexity. For complex situations it is difficult to keep the problem formulation convex and thus enable the use of these efficient solvers.

Estimation and prediction of road users is of great interest since the information might help improving the path planning and decision making. By representing movement as probabilities, the stochastic nature of the road users might be handled in a suitable way. Intent prediction proposed by [4] is shown in Figure 2.

Summary

To summarize, the suggested project will focus on decision and planning algorithms that:

- Can handle complex traffic situations
- Don't rely on vehicle-to-vehicle communication
- Are computationally cheap
- Accounts for the quality of the sensor system and the uncertain behavior of other road users
- Guarantee safety of computed solutions

Bibliography

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