Ph.D. Thesis Defense

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"Autonomous Aggressive Driving: Theory & Experiments"

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Abstract:
Autonomous vehicles represent a major trend in future intelligent transportation systems. In order to develop autonomous vehicles, this dissertation intends to understand expert driving maneuvers in different scenarios such as highway overtaking and off-road rally racing, which are referred to as ``aggressive'' driving in the context of this dissertation. By mimicking expert driving styles, one expects to be able to improve the vehicle's active safety and traffic efficiency in the development of autonomous vehicles.

This dissertation starts from the system modeling, namely, driver modeling, vehicle modeling and traffic system modeling, for which we implement different Kalman type filters for nonlinear parameter estimation using experimental data. We then focus on the optimal decision making, path planning and control design problems for highway overtaking and off-road autonomous rally racing, respectively. We propose to use a stochastic MDP for highway traffic modeling. The new concept of ``dynamic cell'' is introduced to dynamically extract the essential state of the traffic according to different vehicle velocities, driver intents (i.e., lane-switching, braking, etc.) and sizes of the surrounding vehicles (i.e., truck, sedan, etc.). This allows us to solve the (inverse) reinforcement learning problem efficiently since the dimensionality of the state space can be maintained in a manageable level. New path planning algorithms using Bezier curves are proposed to generate everywhere C^2 continuous curvature-constrained paths for highway real-time lane-switching. We demonstrate expert overtaking maneuver by implementing the proposed decision making, path planning and control algorithms on an in-house developed traffic simulator. Based on the trajectory learning result, we model high-speed cornering with a segment of steady-state cornering for off-road rally racing. We then propose a geometry-based trajectory planning algorithm using the vehicle's differential flatness. This approach avoids solving optimal control problems on-the-fly, while guaranteeing good racing performance in off-road racing.

Committee:

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