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Start: Possible from now on **Duration:** 6 Months

☐ Experimental ☐ Application-orientated ☒ Theory-orientated

Your interests:

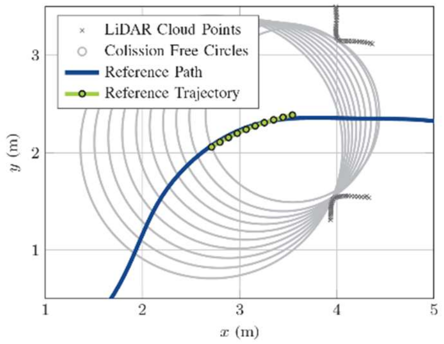
☒ Optimal control and motion planning ☒ Simulation
☒ Good understanding of dynamic systems ☒ Theory

Master Thesis

Safe Motion Planning under Tightened Safety Margins

Motivation: For an autonomous system, safe navigation through its environment is of importance, particularly when operating in dynamic and a priori unknown environment. To enable online motion planning, the planning is typically based on a simplified model that allows for online replanning with a sufficiently long prediction horizon. However, the use of a simplified model results in infeasible trajectories that inevitably lead to tracking errors when tracked by the autonomous system. These tracking errors can introduce a critical safety risk: although the planned trajectory may be collision-free in theory, tracking errors between the model and the actual system dynamics can cause collisions with obstacles.

Method: A recently developed method at the IRS enables the computation of a so-called *Tracking Error Bound* (TEB), which describes a region of possible deviations of the real system from a planned trajectory. The TEB is derived using a concept from game theory, specifically a *Captivity-Escape Game of Kind*. In this framework, the planning model and the tracking system are modelled as two players, with the player representing the planning model attempting to "escape" the defined TEB region. The solution of this game yields an optimal tracking policy for the real system, which can be employed as a safety controller to ensure that the system remains within the TEB at all times. This TEB serves as safety margin for planning.



LiDAR scans (environment) and estimations of the admissible safety margins of a trajectory that approaches a narrow gap.

Problem: When approaching environments with narrow gap or other scenarios that require a tightened safety margin, collision avoidance is currently not guaranteed by simply reducing the TEB with the existing method. The player representing the planning model could lie outside the reduced TEB, meaning that safety can no longer be ensured.

Task: The objective of this work is to extend the existing concept in such a way that safe motion planning remains possible even when safety margins are tightened. To achieve this, the work includes the formulation of relevant requirements, a literature review of existing approaches that address similar challenges (e.g., funnel methods), and an analysis of their suitability with respect to the defined requirements. Furthermore, the theoretical foundations of the Captivity-Escape Game approach will be revisited and refined. Based on this, the method will be adapted or extended—particularly the optimal tracking policy—to meet the new requirements. This may also involve modifications to the overall architecture of the motion planning and safety control framework. The results will be generated through implementation, scenario selection, and simulation, followed by a discussion of the outcomes with respect to the previously defined requirements.