Lehrstuhl für Fahrzeugtechnik
TUM School of Engineering and Design
Technische Universität München

Semester Thesis, IDP, Master Thesis

Advancing Automated Driving Safety

Safety is a key aspect for automated driving. It significantly increases development resources and costs, but remains crucial. At the chair of automated driving, we are using our research vehicle EDGAR and its digital twin vEDGAR to develop and test new automation algorithms, including safety algorithms. While there is an existing safety layer, the research into online safety algorithms (such that the car evaluates the safety during driving) is still ongoing. One key method of this approach is the self-awareness, creating an understanding of both internal and external factors on the system safety. You will contribute with your thesis in this area.

Potential Tasks:

There are multiple directions in which the current safety framework for EDGAR could be advanced.

1. **Experimental Evaluation of a Safety Framework:** The current implementation of the self-aware safety framework is tailored to remote driving. You will investigate the application for automated driving software by sampling test cases in the simulation and conducting experiments with different parameter sets — Python
2. **Increasing Static Environment Understanding:** The current environmental information in the safety approach is based on static maps that create vector fields. These static maps might, however, be outdated during the driving task. You will investigate potential fields to update these vector fields during the driving, e.g. in case of second row parkers. — Python
3. **Line of Sight Evaluation for Occluded Areas:** In case of safety, the visibility of potential crash opponents needs to be evaluated. In your thesis, you will evaluate when this first line of sight is achieved based on a current LiDAR scan — Python
4. **Improving Particle Simulation for Risk Calculation:** Currently, a particle simulation is used to approximate the interaction with traffic. You will investigate the potential limitations of this simulation and develop methods to improve its accuracy in risk calculation — C++
5. **Natural Vulnerable Road Users Behavior:** During Testing of automated driving functions, we want to create critical scenarios for the system. Using the existing safety framework, you will implement an interface that recreates these scenarios in CARLA. — Python
6. **Temporal Predicition of Image Quality Metrics:** Image Quality Metrics play an important role to quantify the potential remote driver reaction. You will evaluate and extend an existing prediction of the image quality metrics — C++

If you are interested in one of these topics, feel free to reach out to me: nils.gehrke@tum.de

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Advancing Automated Driving Safety - Experimental Evaluation of a Safety Framework

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Problem Formulation

A particle-based safety approach currently evaluates the residual risk of remote drivers with a degradation in latency and spatial perception. You will use this framework, to assess theoretically the applicability of the current frame for safety evaluation of automated driving systems. You will then evaluate the framework by testing the safety with and without the framework in different test cases using our virtual testvehicle vEDGAR.

Possible Approach:

The chair already has an existing simulation pipeline vEDGAR that will be used by you. You will first check the current implementation of the residual risk framework for contradicting assumptions related to automated driving vehicles and derive the modes of degradation from the literature. You will then sample test cases from the literature and test the degradation of the automated driving system in these test cases. Your final analysis will compare the number of crashes and near crashes between the system with and without the safety layer.

Requirements:

You need interest into the topic of simulation and automated driving and experience with Python. C++ knowledge is of help. I am looking for students who have fun finding their own solutions for a problem and developing their own approaches. Experience with CARLA is of help, but not a must. If you are interested, please reach out to me via: nils.gehrke@tum.de with your transcript of records.

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Advancing Automated Driving Safety - Increasing Static Environment Understanding

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Problem Formulation

A particle-based safety approach currently evaluates the residual risk of remote drivers with a degradation in latency and spatial perception. The particles are propagated through a vector field that is generated offline using open drive map data. It can however occur that the offline vector field is not matching the current environment due to blocking vehicles (e.g. second row parker). You will investigate another method to update the offline vector field while driving based on lidar point clouds

Possible Approach:

The current vector field generation is based on open drive maps. The vector field represents the path a vehicle would take while driving on the road. You will now investigate methods to modify and correct this vectorfield online. A suggest method is the use of potential fields that generate a new vector field based on sinks and sources placed within the vector field at positions not populated with static objects in the environment. This approach is then compared to the previous offline approach with regard to the accuracy of the residual risk framework.

Requirements:

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Advancing Automated Driving Safety - Line of Sight Evaluation for Occluded Areas

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Problem Formulation

To evaluate the reaction of the ego vehicle to crash opponent, the first visual contact needs to be evaluated based on a current 3D scan of the environment. You will use provided tracks and the current LiDAR Scan of the vehicle to evaluate at what position on the ego vehicle track the first line of sight is given. The approach is then validated using the real research vehicle.

Possible Approach:

LiDAR Data can be reduced to an occupancy grid map. Based on assumptions about the overall geometries of objects in the environment, the first line of sight contact to an opponent vehicle can be estimated. You will thus investigate general geometric shapes of objects and use these shapes to check of line traces are going through occupied voxels in the occupancy grid. This approach will be evaluated on actual data from the environment.

Requirements:

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Advancing Automated Driving Safety - Improving Particle Simulation for Risk Calculation

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Problem Formulation

Currently, a particle approach is used to evaluate the potential crash risk in a current scene. The particles represent potential traffic participants that might crash with the ego vehicle. Based on certain assumptions, the reaction of the ego vehicle to these other particles is calculated. In your work, you will investigate the current limitations of this approach and improve these. At the end, the improved particle description will be compared against datasets, a test track and the previous implementation.

Possible Approach:

You will investigate the performance of the approach along a certain test track with challenging scenarios. These scenarios can be derived from known limitations of this approach. Based on your findings, you will concretize these limitations and research approaches to improve the particle simulation for this specific observation. Ultimately, you will test your algorithm on the test track again and evaluate it against the previous algorithm. In addition, the behavior of your particles will be compared to the behavior of actual vehicles in datasets.

Requirements:

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Advancing Automated Driving Safety - Natural Vulnerable Road Users Behavior

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Problem Formulation

To evaluate safety concepts for automated driving, a vivid and dynamic environment for the driving system is required in the system. With your work, you will address this need. By spawning randomized agents that behave naturalistic, you will simulate the everyday chaos. After implementing this random traffic, you will investigate the potential to trigger individual agents into engaging with the ego vehicle via safety-critical behavior.

Possible Approach:

Based on available methods in the literature and a naturalistic cyclist and vehicle model, you will implement a pedestrian model. You will then generate randomized traffic that will not interact or impede with the ego vehicle. Your results will be compared to data recorded in the city of munich. After finishing this step, you will implement a trigger that allows to trigger safety-critical situations with the ego vehicle. This might be e.g. rapid overtakes of bycicles, sudden swaps to the road by bycicles, pedestrians crossing the road behind parking vehicles, or cyclist suddenly appearing while turning left or right.

Requirements:

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Advancing Automated Driving Safety - Temporal Predicition of Image Quality Metrics

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Problem Formulation

Image quality metrics are important to understand the amount of information stored in a provided image or video sequence. You will develop a heuristic of the metrics MSE, PSNR and VIF based on data generated with the simulation environment CARLA. This heuristic will then be used to predict the image quality metric for dynamic objects in the image based on a ego vehicle track and the other object track. The heuristic will be experimentally evaluated on real and simulated data.

Possible Approach:

You will define reference scenarios based on the literature and generate video sequences of those scenarios using the CARLA simulator. Based on the available segmented image, also the image area with the vehicle is extracted. You will then generate data using multiple compression rates and evaluating the metrics MSE, PSNR and VIF at them. You will then investigate the data on patterns to predict future image quality values.

Requirements:

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