ADL thesis topics for 2021/2022

1. Mapping

1.1. Use Dashcam video to map the road area and markings

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There are different approaches to autonomous driving, but most of them require maps to understand the surroundings and do the planning. Mapping with a specialized mapping car is expensive and might not be available. The aim of this project is to use car dashcams for mapping as they are pretty widespread and accessible devices. They can be used to gather the images and extract the road features for maps. There are several options like Nvidia neural networks (free space, lane markings) or segmentation to detect and map driveable area and lane markings. Detected features can then be projected from camera frame to map frame using either flat ground assumption or an elevation model.

1.2. Map traffic lights using camera images or lidar point cloud

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Traffic lights are an essential feature for self-driving cars. Detecting traffic lights from camera images is not that big of a challenge. The more significant challenge is to know which traffic light is associated with which lane. One simple way to solve this is to store the links between traffic lights and lanes on the map. So when a self-driving car detects a traffic light, it can retrieve the lane associations from the map and act according to the relevant traffic lights. To be able to do this the traffic light exact positions need to be mapped and this is what this project is about. Different data (camera images, lidar point cloud, car odometry, GNSS localization) and methods (detect traffic lights using Yolo, 3D point cloud processing, 3D image reconstruction, triangulation) could be used.

1.3. Generate high-definition vector map for Apollo

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There are several open-source software stacks available in autonomous driving and often they need different map formats. Autonomous Driving Lab is interested in testing and validating different approaches to autonomous driving, and hence we need to be able to generate maps in different formats. The purpose of this project is to generate maps in OpenDrive format required for Apollo software. The input to the generator are map layers in our custom GIS database.

- Apollo: https://apollo.auto/
- OpenDrive: https://www.asam.net/standards/detail/opendrive/

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2. Localization

2.1. Fallback to lane following in case of GNSS failure

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Using Global Navigation Satellite Systems (GNSS) is one of the primary sources used for localization (positioning). Knowing your precise current position is essential in map-based trajectory following. Sometimes GNSS localization can be not accurate enough or just fail. Such events cannot be allowed in fully autonomous driving, so there must be some fallback to rely on in such cases. The purpose of this project is to develop a fallback method to mitigate GNSS failures. One simple option is to continue with lane following until the GNSS regains its accuracy or stop safely when GNSS localization is lost completely. The goal of this project is to develop a method for fusing map-based and lane-following trajectories.

2.2. Better positioning by using raw GNSS data and post-processing

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The positioning accuracy of an average mobile phone is 2-5 meters. To use mobile phones as dashcams for mapping, better location accuracy is desirable. This can be achieved by recording GNSS raw data and postprocessing it later together with additional info about the atmosphere conditions at that moment and precise satellite locations. This can be done with newer Android phones. The goal of this project is to investigate these methods, taking hints from Google Smartphone Decimeter Challenge and comma.ai laika and rednose projects.

- Google Smartphone Decimeter Challenge: https://www.kaggle.com/c/google-smartphone-decimeter-challenge/
- comma.ai laika: https://github.com/commaai/laika
- comma.ai rednose: https://github.com/commaai/rednose

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3. Base autonomy

3.1. Get a selected autonomous driving software stack to work with actual car

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Several open-source software stacks for autonomous driving are available. Autonomous Driving Lab (ADL) is interested in testing different software stacks to learn about their positive and negative sides. Testing this software means that it should also be tested with the existing research platform (Lexus RX450h) in ADL. This project is about selecting one of the following software stacks and get it working in real life with a real car:

- Apollo: https://apollo.auto
- Autoware.Auto: https://www.autoware.org/autoware-auto
- Tier IV Architecture Proposal: https://github.com/tier4/AutowareArchitectureProposal.proj/

3.2. Autoware API for test scenarios

Supervisors: Tambet Matiisen, Kertu Toompea
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To validate autonomous software for real-world use, it is commonly tested in simulation first. We have developed a simulation environment of Tartu city centre, accompanied with test scenarios to validate the behaviour of the car. Currently these test scenarios only support Apollo autonomy software. We also want to support Autoware.AI software using the same API interface. As Autoware.AI is built on ROS, implementing the API comes down to sending the correct ROS messages from API calls. The goal of this project is to implement this API.

- Autoware.AI - https://github.com/Autoware-AI/autoware.ai
- Apollo API: https://www.svlsimulator.com/docs/python-api/dreamview-api

3.3. Create dashboard display for the autonomous car

Supervisors: Tambet Matiisen, Edgar Sepp
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During operation of an autonomous vehicle the operator needs to observe if the software is behaving correctly. This could be represented as a dashboard that shows some key characteristics: whether an obstacle was detected ahead, what is it’s distance and speed, whether traffic light was detected, what color it was showing, what is the behaviour state of the vehicle, etc. The goal of this project is to implement this dashboard. The easiest option would be to implement it as part of the Rviz user interface, possibly adding some custom extensions.

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3.4. Intent display for an autonomous car

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Driving in traffic is constant interaction between all the participants. When a pedestrian wants to cross the unregulated crosswalk, and the car is approaching, he is looking for signs if the driver has noticed him and reacts accordingly (slowing down, eye contact, hand sign). This project is about designing and implementing an indicator for an autonomous vehicle that can display the intent or state of the autonomous car to make it more understandable for other human drivers or pedestrians. In the simplest case it can be just an indicator that the car is in autonomy mode, in a more complicated case the car can let the pedestrian know: I have noticed you, I'm waiting after you, go ahead.

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4. End-to-end driving

4.1. Simulation engine for road following

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In end-to-end driving a machine learning model, typically a neural network, is trained to predict the human driving commands directly from camera images. Evaluating the driving ability of such models is challenging - it is well known that how well the predictions match the human actions is not a very good estimate of actual driving ability, because the small prediction errors tend to accumulate over time during real driving. The solution is to create a simulation from real camera images that alters the camera images in such a way as if the car would have driven a bit right or left. This simulation can be used both for evaluating the driving ability before real-world driving, and also for augmenting the training data.

- Simulator used by comma.ai: https://blog.comma.ai/end-to-end-lateral-planning/
- Simulator used by NVIDIA: https://arxiv.org/abs/2010.08776
- Simulator proposed by MIT: https://www.mit.edu/~amini/pubs/pdf/learning-in-simulation-vista.pdf

4.2. Future prediction

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When driving autonomously, it is essential to predict what is going to happen next. This can be used as auxiliary training signal for end-to-end driving models - neural networks that predict human driving commands directly from camera input. It is common to use multi-task learning with end-to-end driving by having the network to predict besides driving commands also segmentation of the image, depth map or optical flow. Predicting the next camera image seems like a good auxiliary task, because it forces the network to represent the future. The goal of this project is to train a video prediction network and potentially integrate it with an end-to-end driving model.

- https://wayve.ai/blog/predicting-the-future/
- https://wayve.ai/blog/fiery-future-instance-prediction-birds-eye-view/
- https://sites.google.com/view/fitvidpaper/

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5. Neural networks

5.1. What is the best activation function?

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There are many activation functions proposed for neural networks - tanh, relu, swish, etc. Which of them is the best for different tasks is still an open question. What about letting the neural network decide it by itself? The goal of this project is to construct a neural network that learns weights for different activation functions. Further analysis can be done afterwards - which activation functions were most commonly chosen by the training procedure?

5.2. Learning to weight the data

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When training an end-to-end driving network to imitate human driving commands from camera images, it is a common problem that most of the data consists of driving straight. This makes the neural network biased towards driving straight and reluctant to make turns. The solution is data balancing - reducing the amount of straight driving and increasing the proportion of curves. Often this is done manually or using some hand-coded heuristics. The problem becomes more complicated when the vocabulary of driving situations increases - should we reduce or increase the amount of traffic light situations? One possible solution is to let the neural network figure out by itself which data is the most useful. The goal of this project is to implement a novel neural network training schema, where the weights for data samples are learned as part of the training process. In essence this means having a separate learning rate for each training sample.

- WNGrad: Learn the Learning Rate in Gradient Descent: https://arxiv.org/abs/1803.02865