Research Statement for Simon Xi Yang Li

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Title: Software Architecture and Algorithms for a 1-to-10 Scale Autonomous Driving Vehicle in the Bosch Future Mobility Challenge

Objective:

My research objective is to develop and evaluate software architecture and algorithms for a 1-to-10 scale autonomous driving vehicle, with the aim of participating in the Bosch Future Mobility Challenge (BFMC). The competition focuses on undergraduate and master's students developing algorithms for autonomous vehicle control in a simulated city-like environment, using 1/10-scale model cars provided by the organizers.

Overview:

My work explores key algorithms, such as PID control for speed and direction regulation, Hough transform and Histogram filter for lane detection, and odometry and Kalman filter for vehicle localization. Additionally, the YOLO object detection system identifies and tracks objects on the road. These algorithms contribute to various functionalities, such as lane following, path planning, sign detection, turning, and parking maneuvers.

Software Architecture:

The software architecture for the autonomous driving vehicle is built on the ROS framework, which facilitates communication, control, and coordination between different components of a robotic system. The software system is divided into four sub-components or layers: Sensing and Input, Perception and Scene Understanding, State Machine, and Vehicle Control and Actuation.

Lane Detection and Following:

Two methods for lane detection were tested: Hough Transform and Histogram Filter. The lane following procedure processes each frame of image data to determine the lane center's position and whether a stop line was detected. A PID controller is used to determine the steering command that will correct the car's position.

Sign Detection:

A custom dataset was created to include various objects in traffic scenes, such as traffic signs, lights, pedestrians, and vehicles. Using PyTorch and the YOLOV5 algorithm, the dataset was trained for real-time object detection in images. The training results achieved a precision above 95% for all classes and an mAP@0.5:0.95 of 95.57%, indicating excellent performance.

Intersection Maneuvers:

The autonomous vehicle system detects signs indicating an upcoming intersection and transitions to the approaching intersection state. The system fits a trajectory using an exponential function and uses a fine-tuned PID controller to adjust the steering angle to keep the vehicle on the desired trajectory.

Localization:

The vehicle is equipped with sensors (IMU and encoder) used for localization. An extended Kalman filter (EKF) is utilized to integrate sensor measurements with GPS data, estimating the state of the system.

Navigation:

The map configuration is modeled as a directed graph, with locations as nodes and possible paths as edges. Distinct sections or locations of the map are defined and grouped. The path planner takes starting and destination nodes, using Dijkstra's shortest path algorithm to output a list of all node locations and decision points for the vehicle to follow.

Conclusion:

Through the development and evaluation of software architecture and algorithms, my research contributes to the understanding and advancement of autonomous driving technology. By participating in the BFMC, I aim to promote innovation and encourage the development of new technologies related to autonomous driving, showcasing the potential of self-driving technology to revolutionize the transportation industry.