Autonomous Vehicle Lateral Control System

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***Abstract*—The goal of this project is to create a lateral control system that enables a self-driving car to safely switch lanes with full independence. Its uniqueness originates from the project's cost-effectiveness and its ability to be tested on a college campus. These aspects are desired as the project has the potential to be scaled to full size vehicles and to expand the research and development at Northern Illinois University.**

I. Introduction

Autonomous vehicle technology has been in development for the past twenty years. Over these two decades, the technology has significantly improved [1]. Despite the advance of autonomous function in vehicles, total lateral autonomy in vehicles is yet to be seen. Therefore, detailed research into the design and fabrication of highly autonomous vehicles is a growing field. Simplistic lateral autonomous systems have been developed but do not allow for safe lane changing as their algorithms never meet their safety requirements for a lane change. More complex solutions take too much time to compile data, thus making them useless [2].

A system that authorizes autonomous vehicles to safely and successfully switch lanes must be established to continue progress in autonomous vehicle technology. This project developed such a system and proposes a lateral control system that allows for a virtual simulation of vehicular lateral autonomy. The lateral control system is cross compatible to physical vehicles.

Two distinctive qualities of the project stem from its ability to be tested on a college campus and its efficiency in terms of cost. These attributes are preferred when a project has the aims to be scaled to full-size vehicles and to evolve the research and development at Northern Illinois University (NIU), as this project does. The full-size scalability realizes the autonomous vehicle industry's demand for a solution to the lack of safe and effective lateral control systems.

Additionally, NIU is able to have an impact in the automotive industry if research in the area of self-driving cars is cultivated and refined at the university. Research and design throughout the project yielded a virtual simulation of an autonomous vehicle lateral control system that serves as a foundation for future researchers.

II. Methods and Materials

This project utilized an array of sensors consisting of a tracking camera, a depth camera, a LIDAR (Light Detection and Ranging), a powerful processing unit, and an open source electronic speed controller. The T265 tracking camera and the D435 depth camera are both a part of Intel's RealSense technology line. The tracking camera was chosen for localization. It uses Visual Inertial Odometry Simultaneous Localization and Mapping (V-SLAM) to know its location with respect to the surrounding environment. The depth camera was chosen for its ability to identify lane lines and aid in lane keeping. It can also support object detection by knowing the depth of objects, or how far away the object is from the camera. The Slamtec RPLIDAR A2M8, with its 360° angular range, was the primary object detection sensor selected due to its impressive range of vision.

A formidable processing unit is critical to the project. Without this piece of hardware, the necessary calculations from the algorithms responsible for lane changing, lane keeping, and object detection would not be possible. The NVIDIA Jetson TX2 was picked for its abilities to do just that. Its relationship to the other sensors is detailed in Fig. 1. Additionally, to effectively test autonomous technology on a remote-controlled (RC) car, the vehicle must move at slow speeds. An open source electronic speed control, or VESC, allows for the selected processor to take full control of the

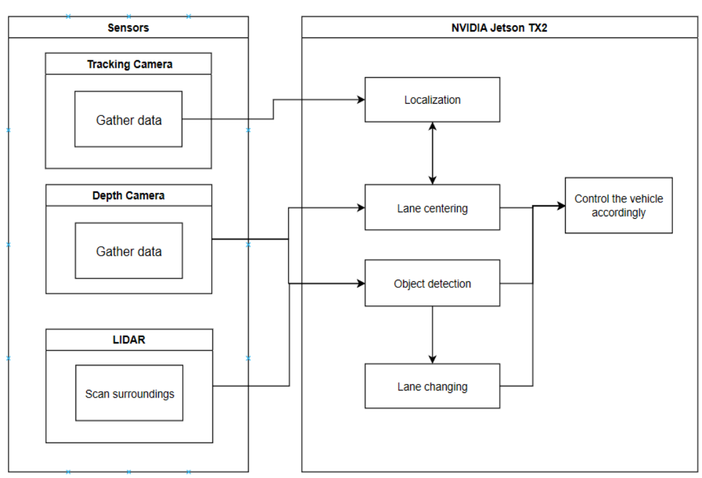

Figure 1. A block diagram illustrating the sensors and processor for the system and their functions.

vehicle's motor. This will allow the vehicle to move as slowly as needed during testing.

Due to physical limitations in early 2020, these pieces of hardware are being represented by CARLA, an open source autonomous vehicle simulator. This simulator enables a theoretical application of a longitudinal and lateral control system that allows for both autonomous speed control and lane changing.

III. RESULTS AND DISCUSSION

Through the CARLA simulator, an abstract application of imaging sensors, a LIDAR, and a processor were achieved. This application was a longitudinal and lateral control system created via python scripts. These control systems enabled lateral autonomy, lane keeping, object detection, and object avoidance. Both the lateral and longitudinal autonomy of the virtual car were established through two independent proportional integral derivative (PID) control scripts. These control scripts operated on data made readily available by the simulator itself. In the case of the lateral PID controller, the error was determined by extracting the location of the center of the lane and comparing it to the location of the center line of the virtual vehicle. This difference was then fed into the PID script as the input. The output of the PID script aided with steering, thus enabling fully autonomous lane changing. The path that the virtual car took is overlaid on the desired path in Fig. 2.

Not only was full lateral autonomy and lane keeping achieved, but object detection and avoidance were also implemented into the lateral control system. Through the Carla simulator, stationary vehicles were generated. The autonomous vehicle had its onboard sensors detect how far the stationary vehicles were away from it. When the distance reached a certain threshold, the autonomous vehicle initiated a lane change to an open lane. This resulted in a smooth path of travel for the virtual vehicle despite obstacles being randomly generated by the simulator.

IV. CONCLUSIONS

This simulation, being the theoretical application of hardware, allows for easy implementation of an autonomous lane changing algorithm to real vehicles at different scales.

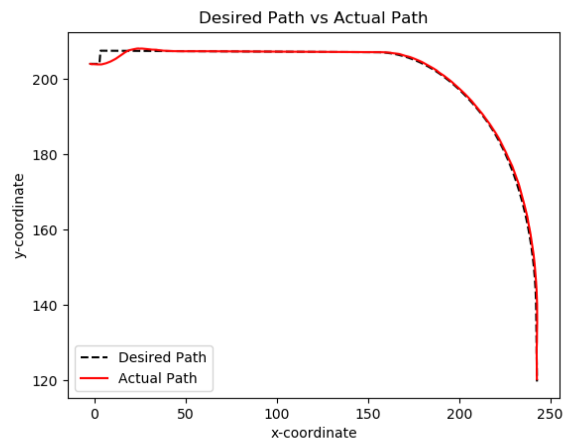

Figure 2. Top view plot of the path the CARLA vehicle takes.

Not only will the lane changing algorithm be able to give differently scaled vehicles the ability to switch lanes autonomously, but it will also enable them to detect obstacles and avoid them via autonomous lateral movement. Furthermore, the objects were avoided in an efficient manner without giving up the consistency of the vehicles path of travel. Given these two products, this control system has expanded the research and development of autonomous vehicles at NIU. It will permit the next group of students to continue to make an impact on the future of autonomous technology at NIU and be in the fore front of innovation within autonomous technology.

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