Autonomous Vehicle Engineering at UCA: A Progress Report

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Abstract

Engineering Physics students enrolled in Senior Design 1 and 2 at University of Central Arkansas (UCA) have been engineering autonomous vehicles in the past 5 years. An educational self-driving platform powered by an off-the-shelf RC car and a Raspberry Pi single board computer has been developed. The development of such a platform is not frozen. In this article, we will introduce the latest updates on this platform, including several upgrades on the brain and the perceptive devices on-board. We will also propose the upscaled autonomous driving solutions to incorporate these upgrades.

Keywords

Undergraduate student poster, Artificial Intelligence, Robotics, Self-Driving, Behavioral cloning

Introduction

As robotics and artificial intelligence (AI) technologies are rapidly evolving, more and more college students are attracted and demanding the educational resources to explore related fields. To fulfill such needs, a pragmatic project of building AI-powered autonomous robots (self-driving vehicles) is introduced to the students in the Engineering Physics program at the University of Central Arkansas (UCA). In the past 5 years, an educational self-driving platform, BearCart, has been developed along the Senior Design courses [1].

The platform involves a robot that can navigate itself in its environment, similar to a Roomba or self-driving robot. It is featured with an off the shelf RC car as the body and a Raspberry Pi single board computer (SBC) [2] as the brain. A convolutional neural network (CNN) model as the consciousness is embedded to autonomously make decisions of driving based on its vision input (a webcam). The behavioral cloning strategy from AI is employed to update the CNN model with human drivers' experience. While the current configuration has already offered plenty of opportunities for students to practice AI and robotics, upgraded technologies have potential to further improve the robot's autonomous driving performance.

In the 2024 - 2025 academic year, we plan to upgrade BearCart's hardware configurations to include more advanced sensing and actuating components. While keeping behavioral cloning as the backbone algorithm, we plan to update the software to adapt to physical changes in the system. Stay tuned for more details.

Methods

1. Behavioral Cloning

The behavioral cloning approach [3] will serve the backbone of the autopilot as illustrated in Fig. 1. An upscaled neural network model will take a bundle of sensors' observation, $\hat{\mathbf{o}}$, as the input and output action, $\hat{\mathbf{a}}$, to imitate human driver's behavior in the designated environment. A human driver's action, $\mathbf{a}$, is the output signal of a gamepad based on the driver's operation. We assume the driver's brain takes observation, $\mathbf{o}$, from the perceptive organs (mainly the eyes) and generates internal controlling signal, $\mathbf{u}$, to perform all the operations on the gamepad. Previously, $\hat{\mathbf{o}}$ was only indicated by the image pixels from the RGB camera. We will extend it to incorporate the features from newly added sensors, such as the lidar and the depth camera. The autopilot model will be trained using recorded $\hat{\mathbf{o}}$ and paired human driver's actions, $\mathbf{a}$. We will model the difference between human driver's actions and the predicted actions from the autopilot model with the error, $\mathbf{e} = ||\mathbf{a} - \hat{\mathbf{a}}||$. Then, by minimizing this error, the autopilot's behavior will gradually approach the human driver's behavior. Consequently, the data from an outstanding human driver is supposed to train a successful autopilot.

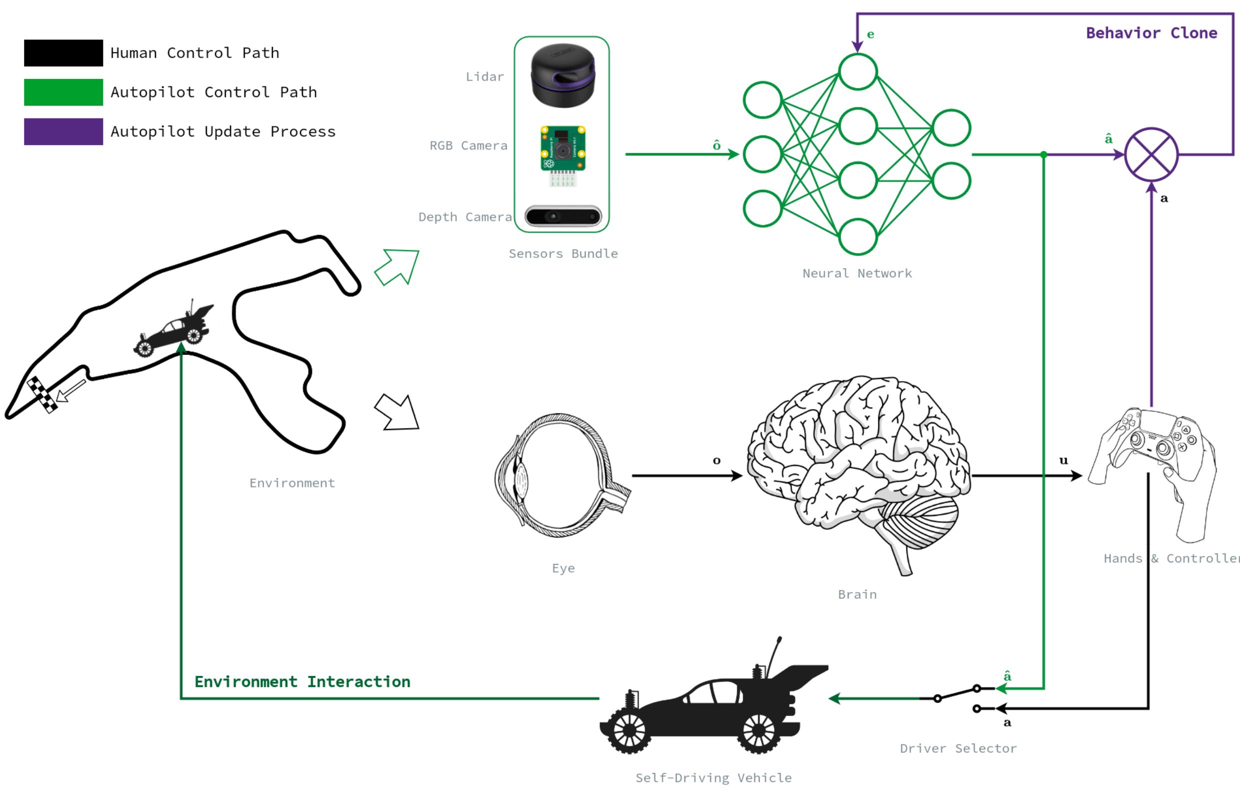

Fig. 1 Behavioral Cloning under self-driving context

2. Hardware Upgrades

We will upgrade the drivetrain, the on-board computer, and the robot's sensors. Table 1 compares the old configurations to the new ones. With these new configurations, we can improve the robot's self-driving performance.

Table 1. Hardware upgrade list

Old Config	New Config	Functionality	Improvements
Brushed DC motor	**Brushless DC motor**	Main engine propels robot forward and backward	Longer-lasting, better low-speed controllability.
H-Bridge DC motor driver	**Sensored electronic speed controller (ESC)**	Controls the brushless DC motor	Higher current sustainability, smaller.
Raspberry Pi SBC	**Jetson Orin Nano Development board** [4]	Runs AI models onboard.	More powerful GPU, Faster processing speed.
N/A	**Depth camera**	Inputs vision data and senses inertial changes.	Richer information awareness.
N/A	**Lidar**	Scans surroundings.	360 degrees sensing.

3. Software Layout

We'll keep the software layout from the BearCart project. The project's software is mainly composed of three Python scripts and a configuration file, as shown in Fig. 2. While one can adjust the drivetrain configurations (speed limit, steering range, controller key binding, etc.) in a text file formatted in JavaScript Object Notation (JSON), the major developing activities will be focused on the Python scripts. Our goal is to update these scripts so that they can adapt to the new features and configurations.

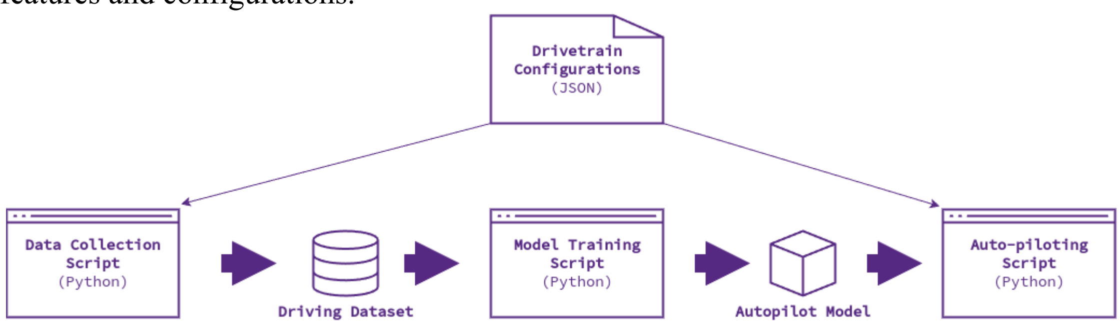

Fig. 2 BearCart software layout

Results

The upgraded components of the robot will be orchestrated as Fig. 3 depicts.

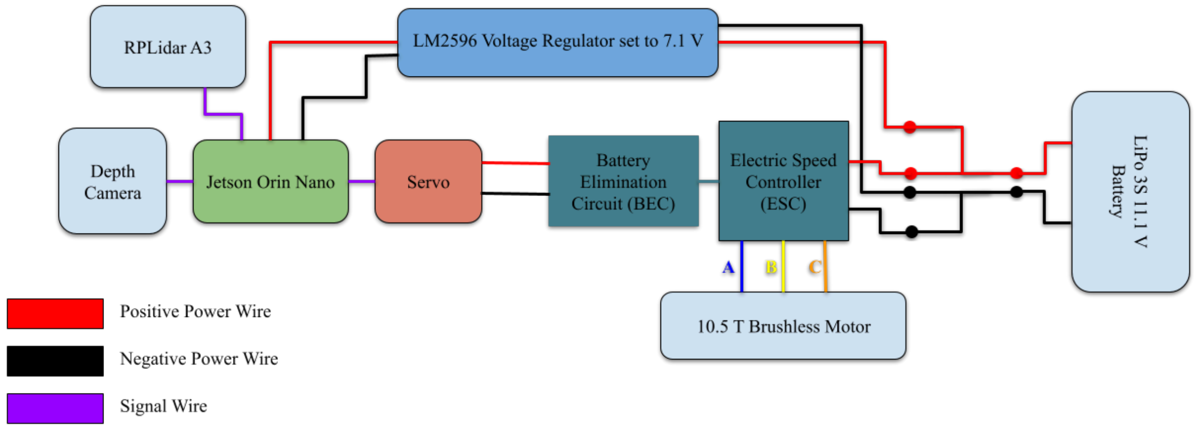

Fig. 3 Robot's components wiring

The major updates on the software side will be:

- Storing the laser scan (from the Lidar) and the depth image (from the depth camera) data in the driving dataset.
- Modifying the autopilot model structure so that it takes the laser scan and the depth data as the input.

Summary

This project focuses on improving our self-driving robot. It is in progress. When the 2024 - 2025 academic year arrives, we intend to get the lidar and depth camera working, finish the mechanical design (3D-printed parts needed for the robot), and get the software to start working. We expect the robot's upgrades to set a good foundation for our next generation AI and robotics education platform.

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Biographical Information

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