A. Title Pages

Faculty Research Grant Final Report

Self-driving RC Car: Development of an Intro AI Project for Undergraduate Students

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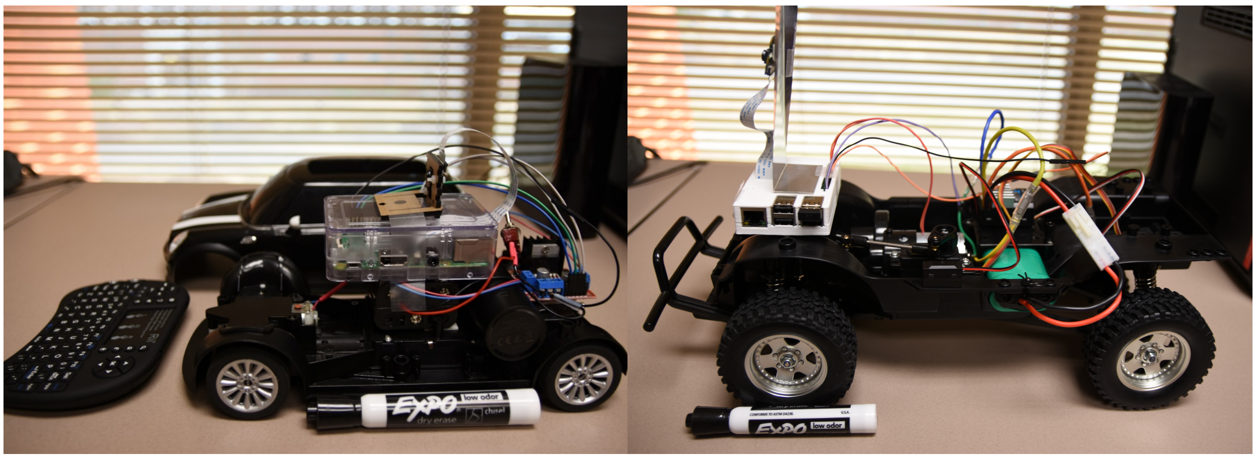
B. Restatement of problem researched or creative activity

It is an exciting time that AI becomes real. Empowering the students with AI technology becomes essential to the current generation of engineering students. As a result, fostering students' interests in AI, and promoting AI in undergraduate education are of great importance. Self-driving technology is one of the most attractive domains in AI and have achieved great success in recent years. A number of highly intelligent autonomous vehicles are commercially available in the market now. Most major automobile manufacturers, such as Toyota, Ford, Mercedes Benz, and BMW, have a timeline for self-driving cars [1], and have put great efforts into the development of driverless-car technology. So do the high-tech companies like Google, Uber, Nvidia, Intel, and so on. All these advancements are inseparable from the progress of Artificial Intelligence (AI), especially the dramatic progress in deep machine learning. This project is to develop a self-driving RC car. The developed self-driving RC car is served as an introductory platform for AI technology to undergraduate students. Based on this platform, the students are able to explore and understand the neural network based navigation and the principles of machine learning. We have also compared Convolutional Neural Network (CNN) to the classic shallow neural network in terms of navigation performance.

C. Brief review of the research procedure utilized

From the hardware perspective, we select Raspberry Pi 3 B to serve as the in-vehicle micro-computer, a Raspberry Pi compatible camera to capture the live data of the vehicle front view, and a small RC car. We first re-engineer the RC car to be controlled by the Raspberry Pi. Two versions of the RC cars are built, as shown in Figure 1. Our first model suffers the issues of the load capability and power supply. It is not working well on tracks outdoor and tracks on carpet. As a result, the second version of the RC car platform with a larger power and load capability is constructed. Then, the student assistant helps collect driving data by manually operating the RC car on tracks outdoor and on designed tracks with lanes indoor. A total of 4 hours driving data are recorded. After cleaning and sorting the data, around 20 minutes of completed runs, 18,000 frames are kept. We used about 2,500 frames to train our final CNN navigation model, and about 2,500 frames for validation. The employed CNN model, inspired by the CNN architecture in NVIDIA's real self-driving car [2], has 5 convolutional layers and 4 fully-connected layers.



(a) (b)

Figure 1. Re-engineered RC Car (a) Version 1; (b) Version 2.

D. Summary of findings

The most import finding of this project is that the self-driving technology draw great interests from students and a scaled self-driving RC car facilitate the students' understanding of machine learning algorithms. Supported by this grant, the participated undergraduate student Andrew Lea gave a presentation at the 102nd Annual Meeting of the Arkansas Academy of Science in April 2018 at Jonesboro, AR, as well as at the Undergraduate Research Symposium in March at ATU. He has also been invited to give presentations and share his experience in this project with 3 classes of local high school students at the Russellville High School in April 2018.

Another major finding in theory is that a CNN based architecture is effective in predicting the steering of the car by directly mapping the front camera view video frames to the steering commands. The prediction accuracy is assessed by the Root Mean Square Error (RMSE). Our trained CNN model is run on the collected training and validation data. The results are listed in Table 1. It shows good prediction accuracy on the collected validation data. In addition, we find the prediction accuracy is largely affected by the quality of training data and the imaging conditions.

Table 1. RMSE of Proposed CNN Model on Collected Data

	RMSE on Training Data	**RMSE on Validation Data**
Trained CNN Model	0.0736	0.1219

Table 2 Run-time Average Processing Time

Operations	**Average Processing Time (ms)**
Video frames capture	66.7
Image Pre-processing	24.2
CNN inference	192.5
Total	283.4

The third major finding is the runtime capability of a CNN based navigation on a low-cost embedded platform like Raspberry Pi 3 B, which is powered with the Broadcom BCM 2837, a quad-core ARM Cortex A53 at 1.2 GHz/512KB L2. Table 2 shows the average processing times on 1,000 video frames. The memory is 1GB LPDDR2 with a peak bandwidth 8.5GB/s. Broadcom VideoCore IV GPU is not used to accelerate computing due to the software limitation.

E. Conclusions and recommendations

In conclusion, this project achieves great success in attracting students' interests and facilitating students' understanding in AI technology. A CNN based end-to-end navigation model is evaluated and proved its effectiveness in terms of prediction accuracy. However, the limited hardware recourses restrain an effective real-time navigation. Further research is planned to measure the camera and motor control latency, optimize the control sequences, and integrate a microcontroller to offload the motor controls from the center CPU inference. The developed RC car platform also provides further opportunities in the future for the students to explore not only the machine learning based navigation, but also other important topics in self-driving area like objects detection and object recognition.