AutoDrive: A Self-Driving Toy Car

Team Pink Flamingo

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Motivation

- Much of the research into autonomous vehicles is guarded by private companies like Waymo and Uber, limiting the public understanding of this technology and making it difficult to regulate.
- We believe that it is imperative for research to be done from an open, objective academic standpoint in order to form a basis of publicly accessible research and serve as a foundation for future research investigations.
- Through researching the ideal behavior of an autonomous vehicle, training a self-driving model incorporating this behavior, and building a physical proof-of-concept miniature self-driving car, much knowledge can be gained about the design and implementation of autonomous vehicles.
- We used this process to learn about the mechanics driving self-driving cars, testing processes that can validate the safety of self-driving models, and the bounds on vehicle handling that are imposed by human physical and psychological comfort.

Goals

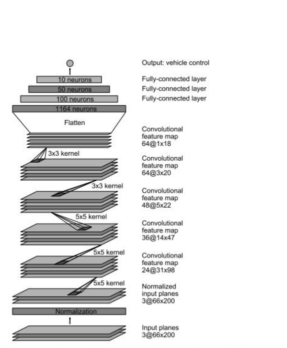
Technical Goals:

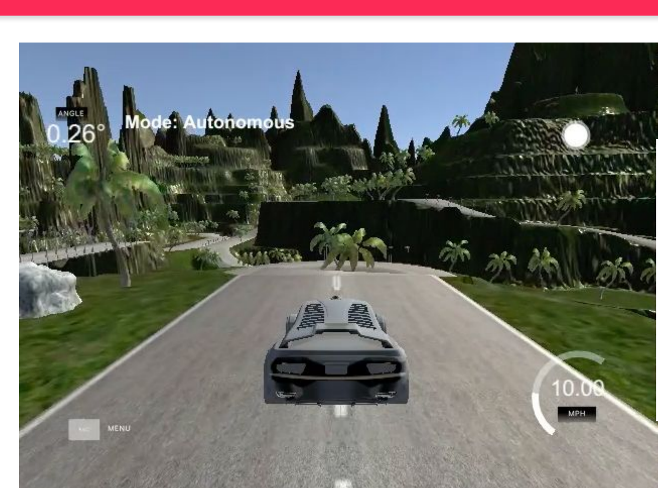
1. Assemble a Raspberry Pi-controlled RC car mounted with a camera
2. Train an end-to-end neural network that steers the vehicle in a simulator and transfer this model to the miniature AV prototype
3. Explore efficient algorithms and hardware acceleration to support autonomous driving systems

Research Goals:

4. Explore the risks and real-world compatibility of self-driving models
5. Determine ideal bounds on longitudinal, lateral, and vertical acceleration for an autonomous vehicle
6. Determine relationship between autonomous vehicle speed and perceived comfort, safety, and trust of passengers

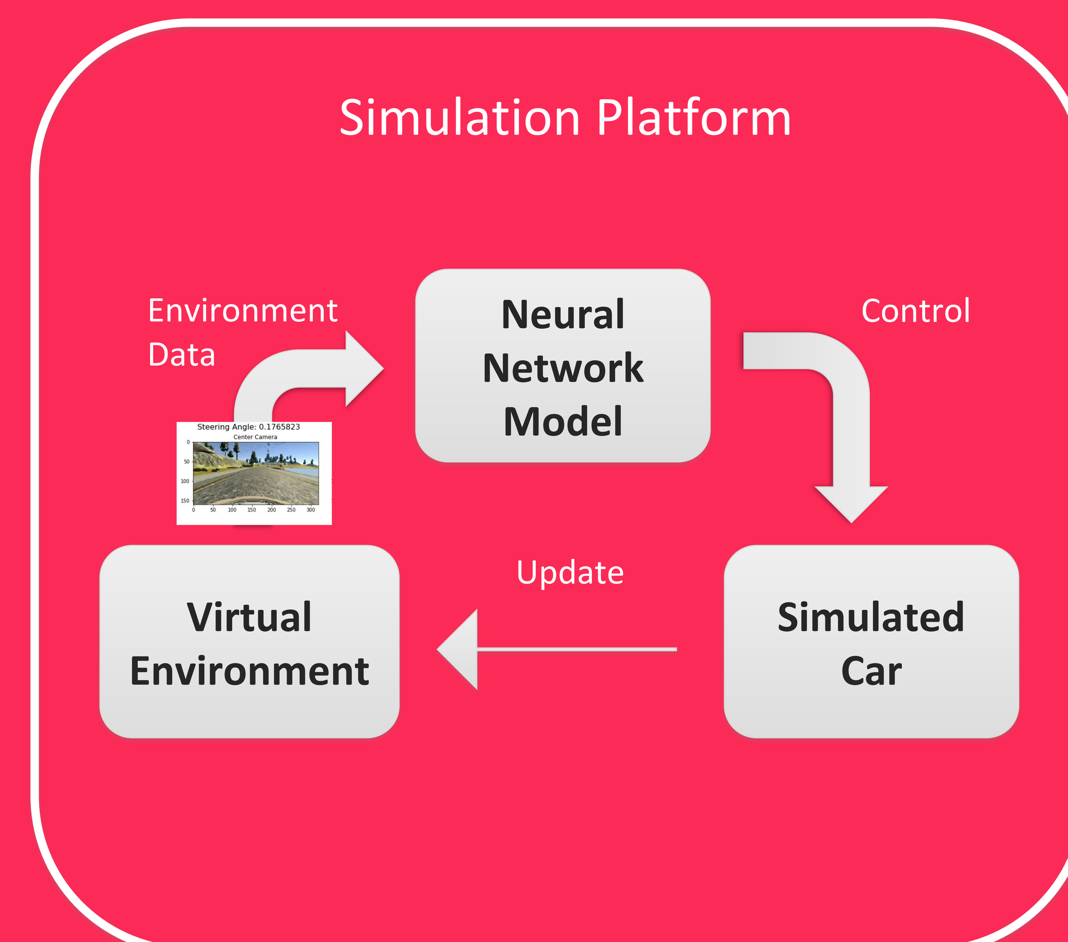
Training a Neural Network

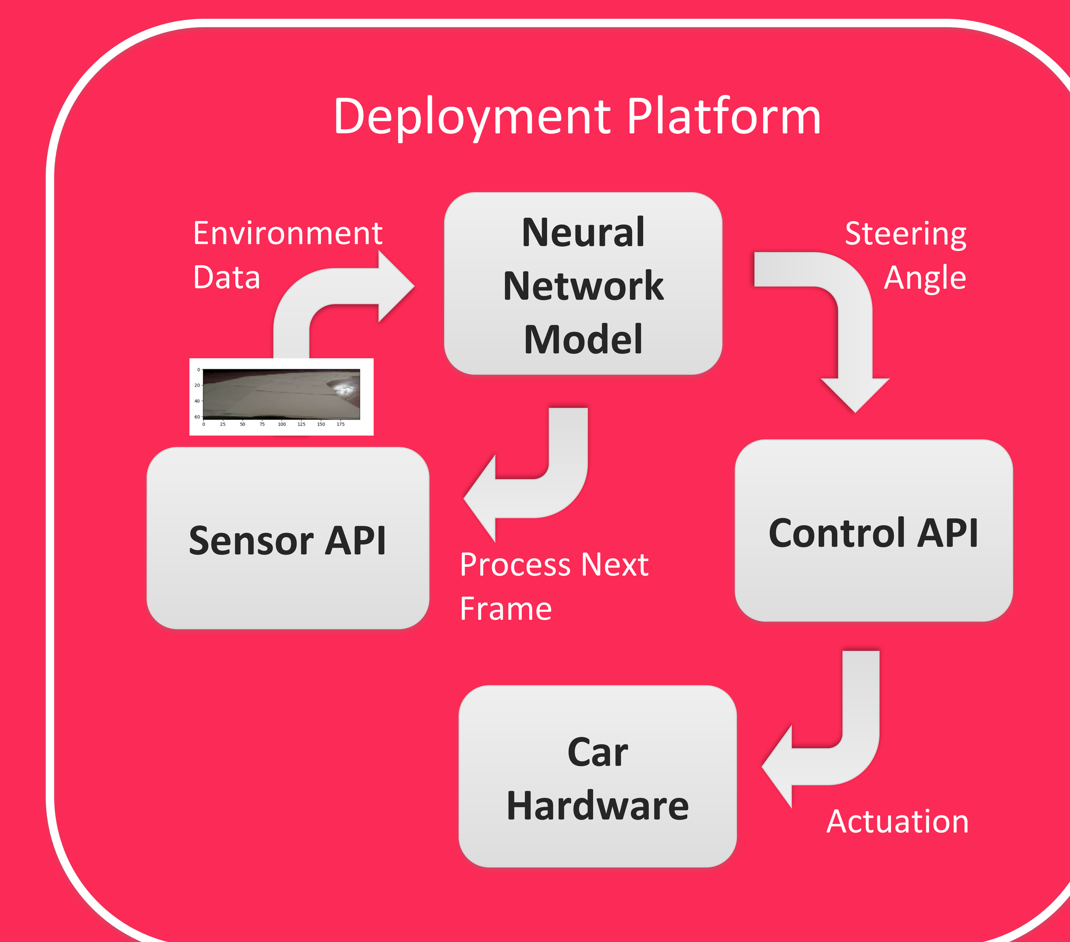




- Convolutional Neural Network (CNN) architecture developed by Nvidia autonomous vehicle team
- Produce training data by manually driving the vehicle in a simulator
- Simulation provides image labeled with the steering angle assumed by the vehicle
- Two full loops of data (400 MB) is collected to train the network for 8 hours on a CPU.

System Design





Hardware-Software Correspondence

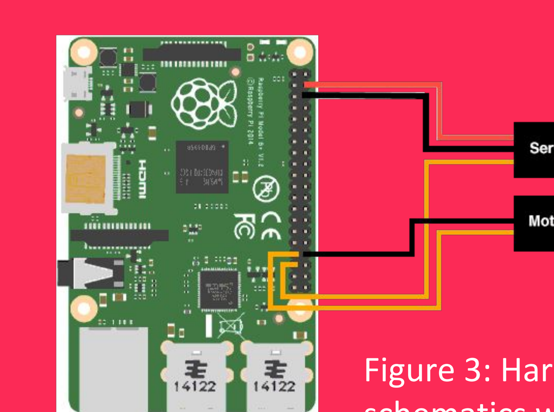


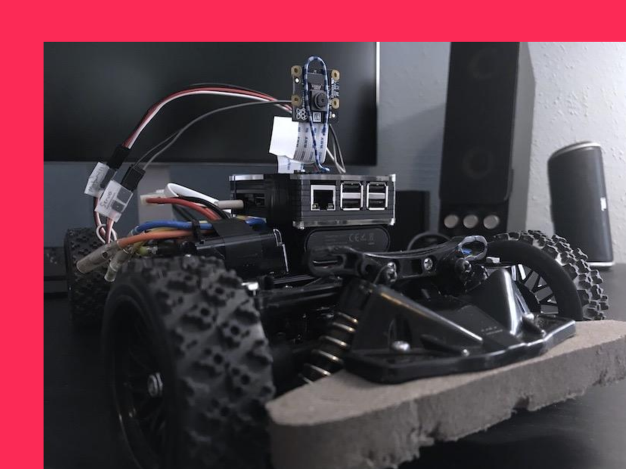
Figure 3: Hardware schematics wiring the Raspberry Pi and the RC car

Figure 1 & 2: Linear relationship between steering angle and pulse width of the signal needed to induce it

Final Prototype

Strengths:

- → Model can generalize to interpret the physical track
- → No transfer learning is needed
- → Under ideal lighting and speed, the car can drive smoothly on any track
- → Delivers promising results from being trained on a relatively limited dataset



Shortcomings:

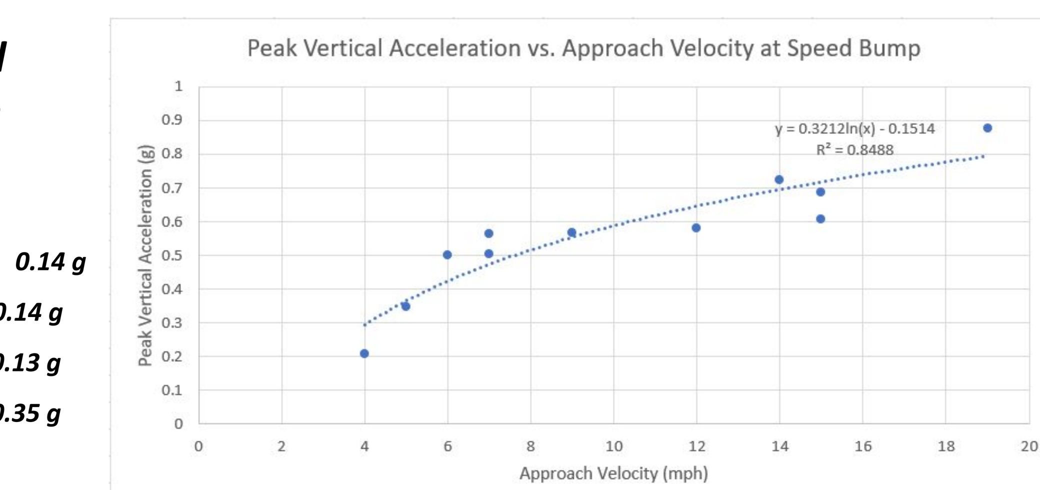
- → Cannot make very sharp turns (physically restrained)
- → Requires good and uniform lighting for acceptable image exposure
- → There must be a good color contrast between the track and the environment
- → Neural network only controls steering angle but not velocity or acceleration

Research Findings

- The variation in driving style preference among drivers will likely translate into preferences in autonomous driving style (defensive vs. assertive).
- Previous research discovered through a literature review has determined ranges of acceleration which correspond to these driving styles. It is recommended that autonomous vehicles maintain the low accelerations of light rail transit (LRT) for optimal comfort.
- However, because LRT has no analog to vertical acceleration (such as induced by speed bumps), we experimentally determined the vertical acceleration induced by different approach velocities at a speed bump using a real vehicle and a smartphone accelerometer to correlate with comfort and determine an optimal approach speed.

Recommended Constraints on Acceleration

Longitudinal acceleration:	*0.14 g*
Longitudinal deceleration:	*-0.14 g*
Lateral acceleration:	*0.13 g*
Vertical acceleration:	*0.35 g*



- Whereas recommended acceleration constraints were informed by physical comfort, ideal autonomous vehicle speed was informed by the psychological comfort of potential passengers. A simulator experiment with 12 participants across 3 speed conditions suggested that a speed of **15 mph** optimized perceived comfort and trust, while perceived safety decreased with increasing speeds, as follows:

- Research findings can be incorporated into our self-driving model as a proof-of-concept and used as a baseline for further research integrating human factors best practices with the autonomous vehicle development process.