Behavioral Cloning Project

The goals / steps of this project are the following:

- Use the simulator to collect data of good driving behavior
- Build, a convolution neural network in Keras that predicts steering angles from images
- Train and validate the model with a training and validation set
- Test that the model successfully drives around track one without leaving the road
- Summarize the results with a written report

1. Driving Data

1.1 Collection

The driving data bundled with the project resources felt inadequate to be training with a basic / simplistic image augmentation, processing and neural network. The initial behavior was to glide down away from the road on turns, especially left ones. Over a first few attempts of adding good turning behavior by recording specific turns, the car did progress well, but didn't seem robust and the data set was biased.

Figure 1 Data on special corners

Flipping images on a vertical axis made the car more robust over turns on track 1, but it essentially amounted to bad driving behavior in track two, *as the car learns to drive on the right lane instead of the left.* To counter this issue, driving data was recorded on the inverse track for track 1. This gave a balanced data of left and right turns cleanly made.

Figure 2 Data on reverse track (patch on left)

An additional set of fine tuning turns, straights and sharp corrections were made especially for the track 2, that made the data set more complete for running a neural network on.

Figure 5 Track 2 on joining roads

Figure 4 Correcting Trajectory in Track 1

Figure 3 Correcting Trajectory in track 2

1.2 Preprocessing

The image was normalized around a zero mean, that makes the network more efficient.

Also, the image contained data including scenery and a portion of dashboard that would possibly have contributed less to the learning. The image sections were cropped to create a significate image of interest.

2. Deep Neural Network

The Neural network used for the project was majorly inspired by work from Mariusz Bojarski, Et Al. NVIDIA Corporation, "End to End Learning for Self-Driving Cars". The design strategy shifted paradigms from using simple fully connected layers to further complex architectures. Simple LeNet and a modified GoogLeNet was tried before arriving at the final network design architecture. The chosen architecture did have enough complexity and lowered the MSE and validation loss by huge leaps. The Deep neural network consists of 5 convolutional layers as described in the image below. That data is normalized, as discussed above, using a lambda layer from Keras. The network consists of a total of 5 convolutional layers, three of which use 5x5 kernels of output channel sizes 24, 36 and 48 and two layers using 3x3 kernels of channel size 64. The initial two convolutional layers use dropout to regularize the data and support generalization of features. The convolutional layers use ReLU activation functions to introduce non-linearity in the network. The convolutional layers are then followed by 3 fully connected layers that generate the final steering value.

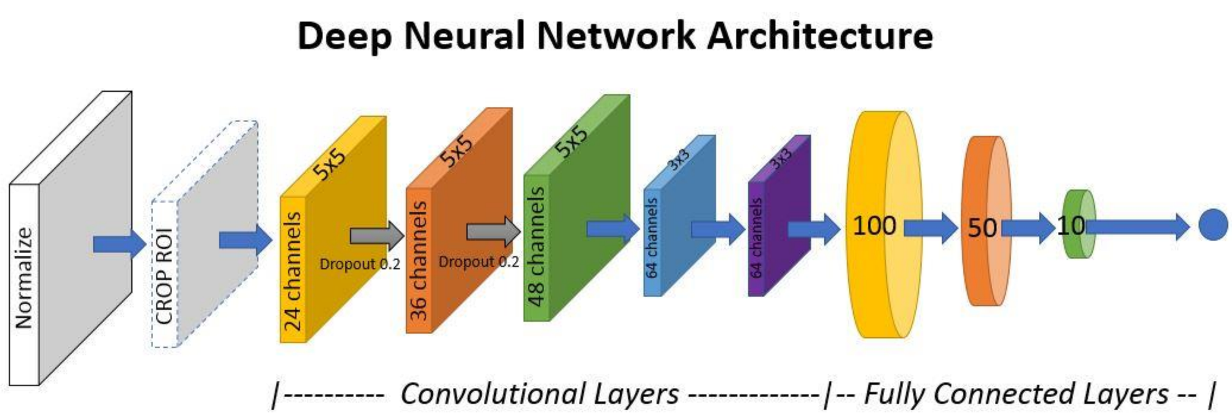

Figure 6 Deep Neural Network Architecture

3. Validation Sets and Optimization

The pipelines separates out a shuffled subset of 20**% of the training data for validation** to make sure that the model was not over fitting. To optimize the network, and **ADAM optimizer** was used which regulated the training parameters over a **mean squared error loss function**.

4. Test Run

The car was successfully driven over multiple speeds 9-30 MPH (drive.py) for track 1 and 9-15 MPH for track 2. The car maneuvers nicely through subtle and sharp turns, mud patches, absent lane markers, lanes poles (track 2), joining roads (track 2), uneven terrain (track 2) making sure it's in the correct lane and doesn't leave the road.

Attachments:

1. model.py: contains the image on loading and deep neural network implementation
2. drive.py: PID control and actuation signals to the vehicle in the simulator
3. model.h5: the h5 file to successfully run the car on both the tracks

Link to Track 1: https://www.youtube.com/watch?v=FP993-bO5V8

Link to Track 2: https://www.youtube.com/watch?v=YaSZMzprkOA

Chinmaya Patnayak
January '17 Cohort