Search Based Software Engineering for Testing Autonomous Cars

Train Generator:

Lane keeping functionality of self-driving cars

Team Members:

1. Manoj Huilgol
2. Yuki Okumura
3. Dinesh Kovi

Motivation

The main idea of the lane keeping functionality is derived from **End-to-end learning for lane keeping of self-driving cars**

In this paper, the model is trained using End-to-end approach by training with only camera images and steering angles

The model predicts the proper steering angles from the real world images. The huge amount of real world images are collected from **Comma.AI** dataset

https://readwrite.com/2020/01/21/how-self-driving-cars-can-shape-our-future/

Why BeamNG over Comma AI ?

BeamNG simulator	CommaAI dataset
Proper scenarios can be generated with required complexity based on neural network architecture	Includes real-world images with huge diversity and traffic participants which is too complex for simple architecture
Various road configurations and weather conditions can be simulated	Non-trainable images need to be identified and filtered
The BeamNG provides a very realistic physics during car crashes	Needs complex neural network to train the AI
An extensive testing can be performed using BeamNG simulation	End-to-end approach might not be sufficient to accurately predict steering angles

The Proposed Approach

BeamNG setup
- Setup the training environment with BeamNG simulator (attach camera, sensors, etc.)
- Choose the relevant scenarios to train the AI

Collect Data
- Drive through the selected scenario to collect the data
- Store the camera images and steering angles

Train AI
- Pre-process the data (Normalize angles and apply image augmentation)
- Train the Deep neural network with the images and steering angle

Evaluation
- Predict the steering angles for the new images
- Evaluate the prediction with actual steering angles of new images

Test the AI
- Integrate the trained AI with DriveBuild
- Test the lane-keeping functionality of AI across various test cases

BeamNG Setup

Front facing camera

- Resolution: (320 x 160 x 4)
- Mounted at the centre
- Field of view: 120
- 14K frames with 4D representation

Steering angle

- Steering angles collected for each image
- The values range from 0 to 500
- Calibrated further to a range of (-1, 1)

Scenarios

- Training scenarios:
  - Italy
  - Utah
  - West coast usa
  - East coast usa

Simulating obstacles

- Static obstacles using different objects and shapes
- Dynamic obstacles by spawning AI driven cars at random points

This functionality is now removed since it is not used in the test cases of DriveBuild

Data collection

Initially, the ego car is driven manually to collect the data – (however, the results turned out to be bad since manually driving the car on the lane lead to inaccurate steering angles and hence the AI was trained with bad training data)

In order to overcome this difficulty, the BeamNG AI is used to drive through the defined scenarios

The BeamNG provides **drive_in_lane** functionality which can be used with an aggression level of 0.6 to accurately collect the training data without letting the BeamNG AI crash or drive too fast.

The camera images and corresponding steering angles are collected at a frequency of 20 Hz

Train AI

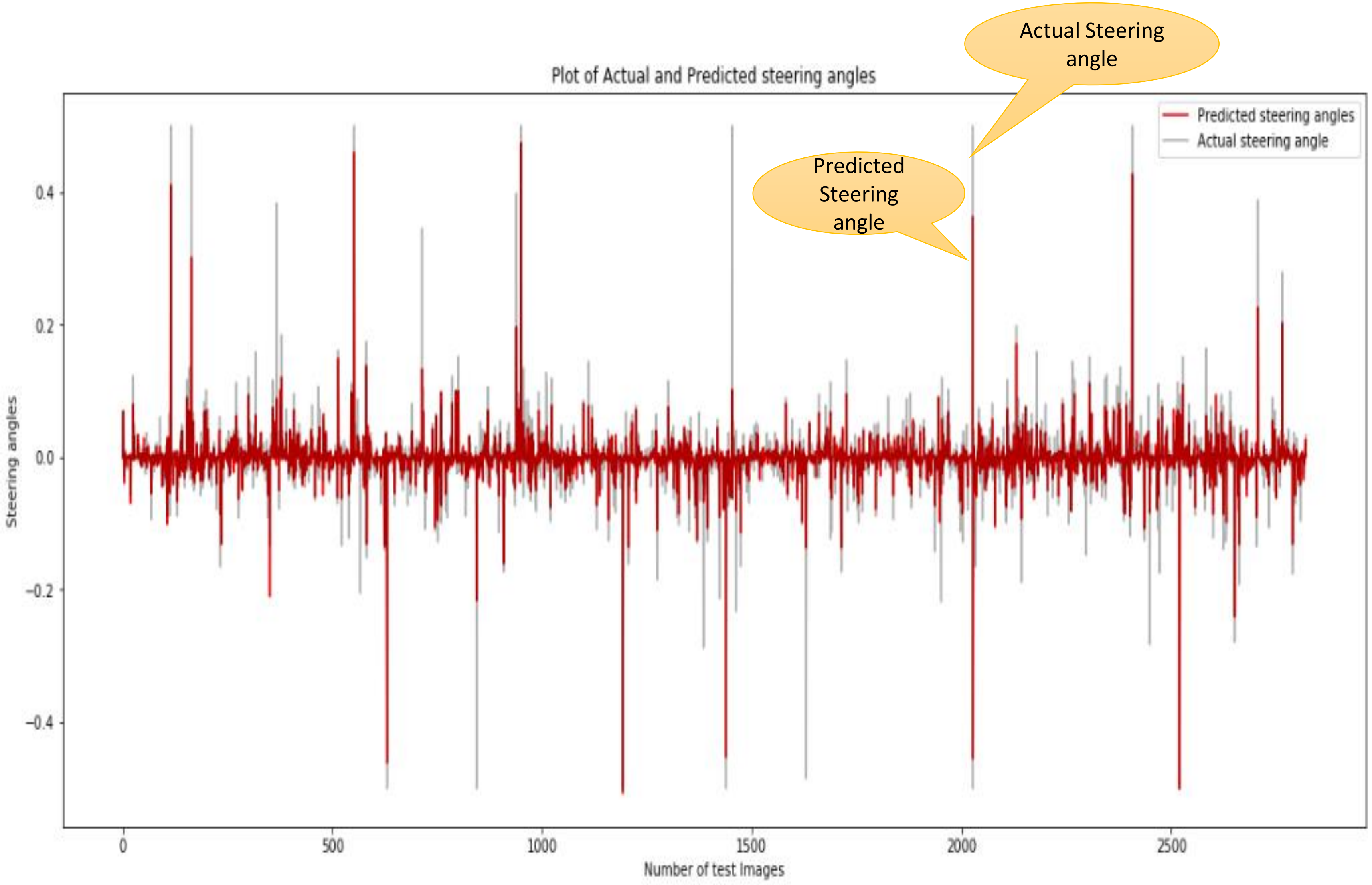
Pre-processing:

- The images are normalized from (0, 255) to (0, 1) to optimize the learning rate.
- The steering angles are normalized to (-1, 1).
- The training data is increased two-fold by applying horizontal flipping as an **Image augmentation** technique.

Training:

- The 6 layer deep Convolutional Neural Network is built to train the network with the randomly shuffled 11K image data and corresponding steering data.
- The model is trained for 80 epochs with Adam optimizer.
- The model predicts the steering angle for the given image.

Evaluation



Observations:

- From the plot, the predicted steering angle (dark red) appears to have a strong correlation with the actual steering angle
- The model needs improvement in predicting peak curves. Small to moderate steering angles appears to be closer to the actual steering angles

Integration with DriveBuild

- The Trained AI model is further integrated with the DriveBuild to test and evaluate the model with various test cases.

- The AI proves to be able to drive on the road without curves. However, it finds challenging to distinguish the road boundaries during the curvature since the AI is trained on the different road characteristics compared to test environment.

Effectiveness of the Results:

1. Since the DriveBuild scenarios are not identical to the trained scenarios in BeamNG, the AI finds it difficult to predict the accurate steering angles for road with turns.
2. In order to evaluate the AI effectively, the test cases similar to the trained AI scenarios need to be generated.

References and Further links

Train Generator Demo link:

https://www.dropbox.com/s/i4bmrx34yz0tylr/AI%20demo.mov?dl=0&fbclid=IwAR2HwXOaG3TsjqosaALDgzQcNlVLsttqg4GBTFgGxZYfGssKZjBr7W1CvjY

- https://github.com/commaai/comma2k19
- https://ieeexplore.ieee.org/abstract/document/7995975
- https://github.com/TrackerSB/DriveBuild
- https://github.com/BeamNG/BeamNGpy