ITK ENGINEERING

Autonomous Lane Detection in a Simulated Environment

TUM Data Innovation Lab

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Wednesday, 17. Feb 2018

TUM MI, Garching bei München

Agenda

- Introduction
- Tools Set-up
- Environment Generation
- Convolutional Neural Network
- Interface to Test the Model
- CNN Improvements
- Network Results
- Demo
- Outlook
- References

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Introduction

- Autonomous driving:

„[s]elf-driving means the autonomous driving of a vehicle to a specific target in real traffic without the intervention of a human driver.“ [Daimler AG]

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- Simulated environment:

- SCRUM:
  - ✓ Weekly meetings, 3 times per week
  - ✓ 5 Sprints, every 3 weeks

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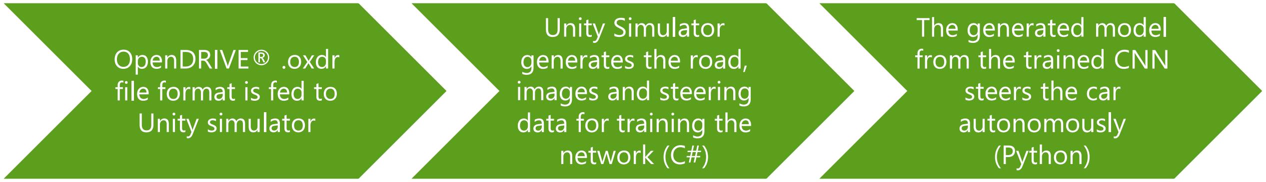
Tools Set-up

- Simulator:
  - ✓ Udacity's Self-Driving Car Nanodegree program
  - ✓ Unity game engine
- Programming Languages:
  - ✓ Python (Interface and CNN)
  - ✓ C#.NET (Unity)
- Additional:
  - ✓ TensorFlow with Keras
  - ✓ OpenDRIVE®
  - ✓ OpenRoadEd



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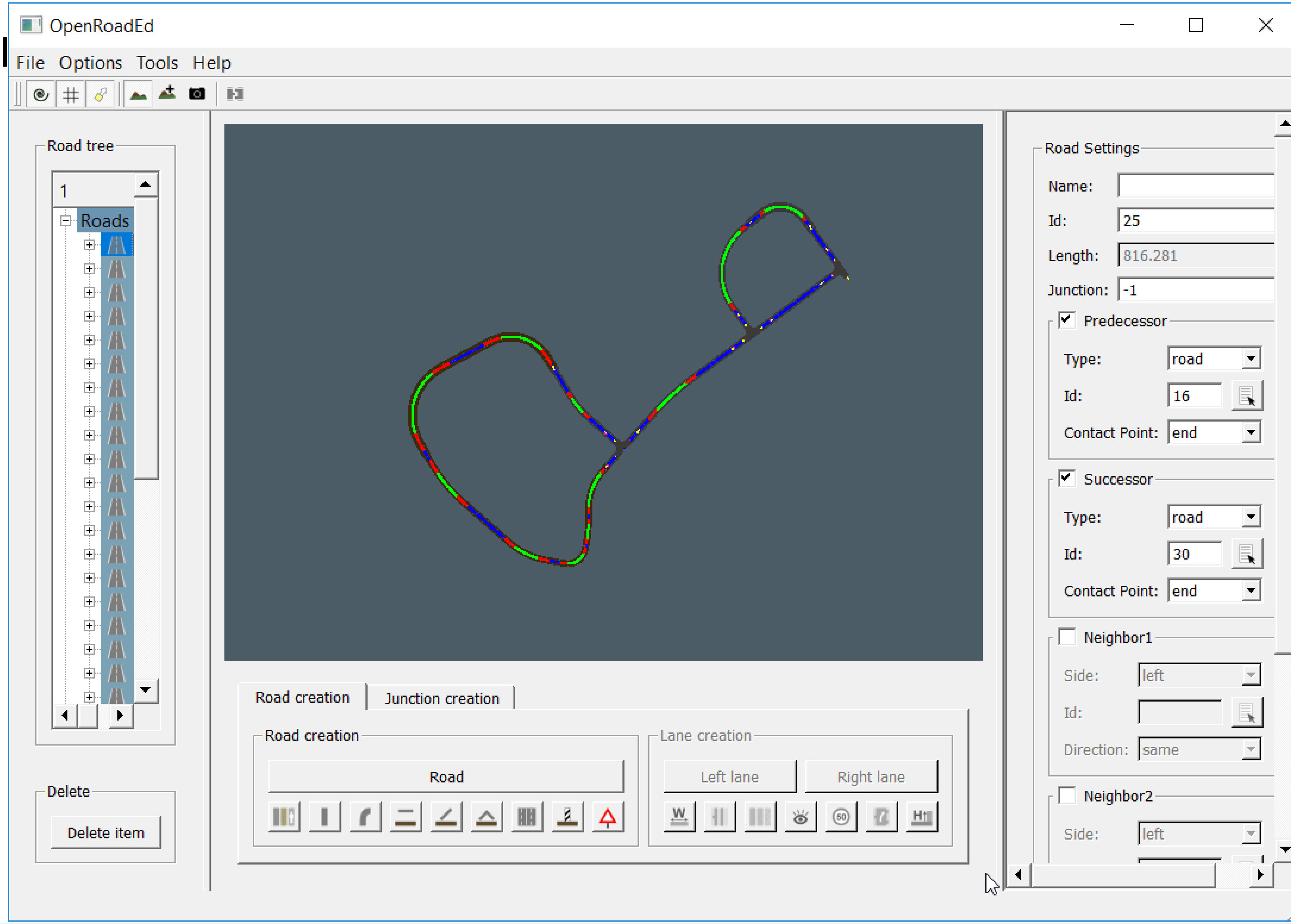
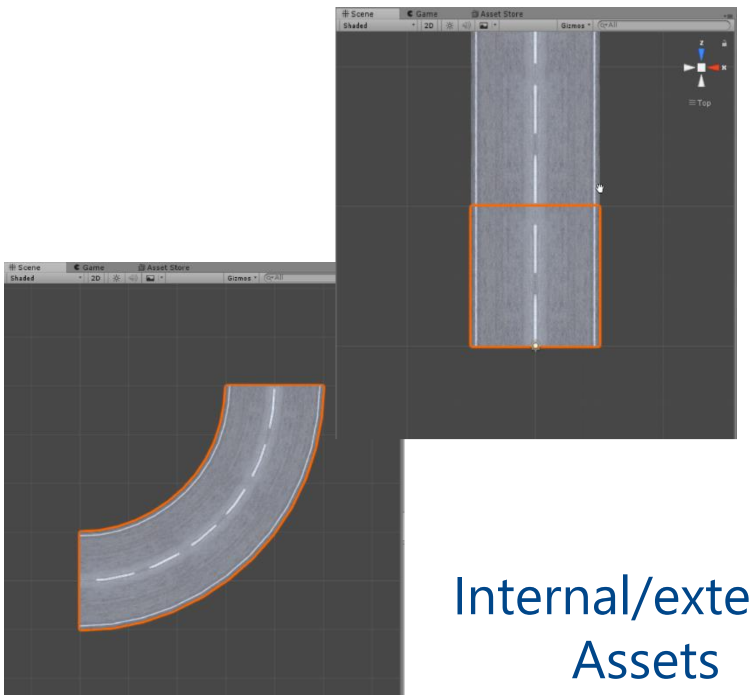
Environment Generation



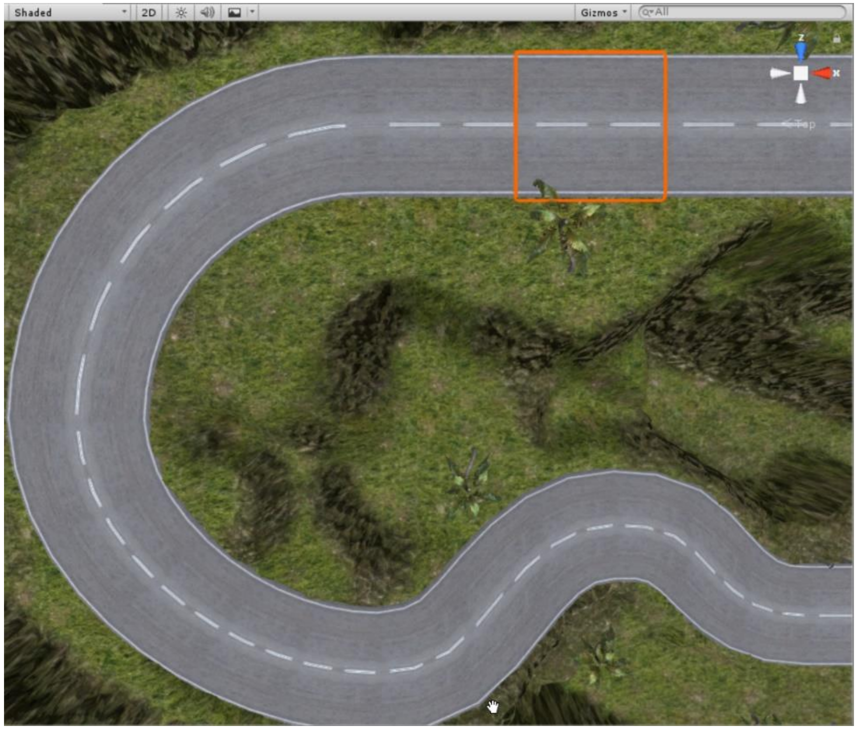
Environment Generation

In XML format with the specifications of openDRIVE®

1. Environment generation in OpenDRIVE® .oxdr format using OpenRoadEd App
2. feeding the generated .xodr file to Unity engine, Generation of the environment from .xodr file in C# code
3. Using the generated environment as a scene to be displayed as the virtual simulation environment



Internal/external Assets



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Machine Learning

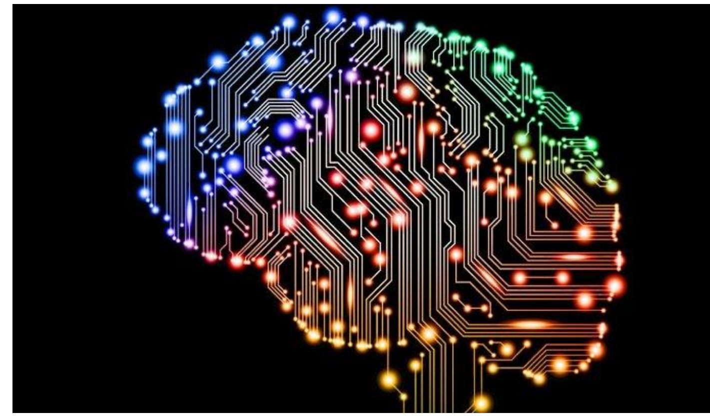
- Learn from experience

Machine Learning

Supervised Learning
-> Labeled Data

Un-supervised Learning
-> Not Labeled Data

Reinforcement
-> Reaction to environment



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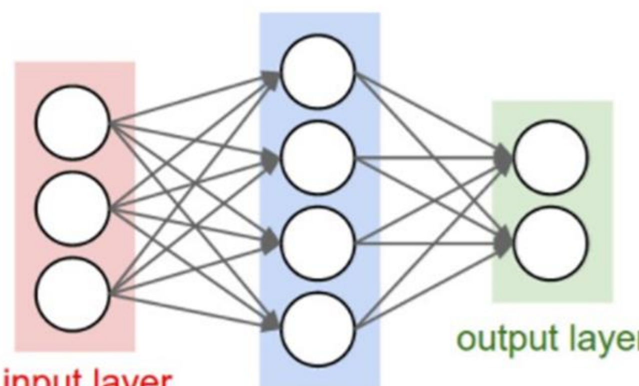
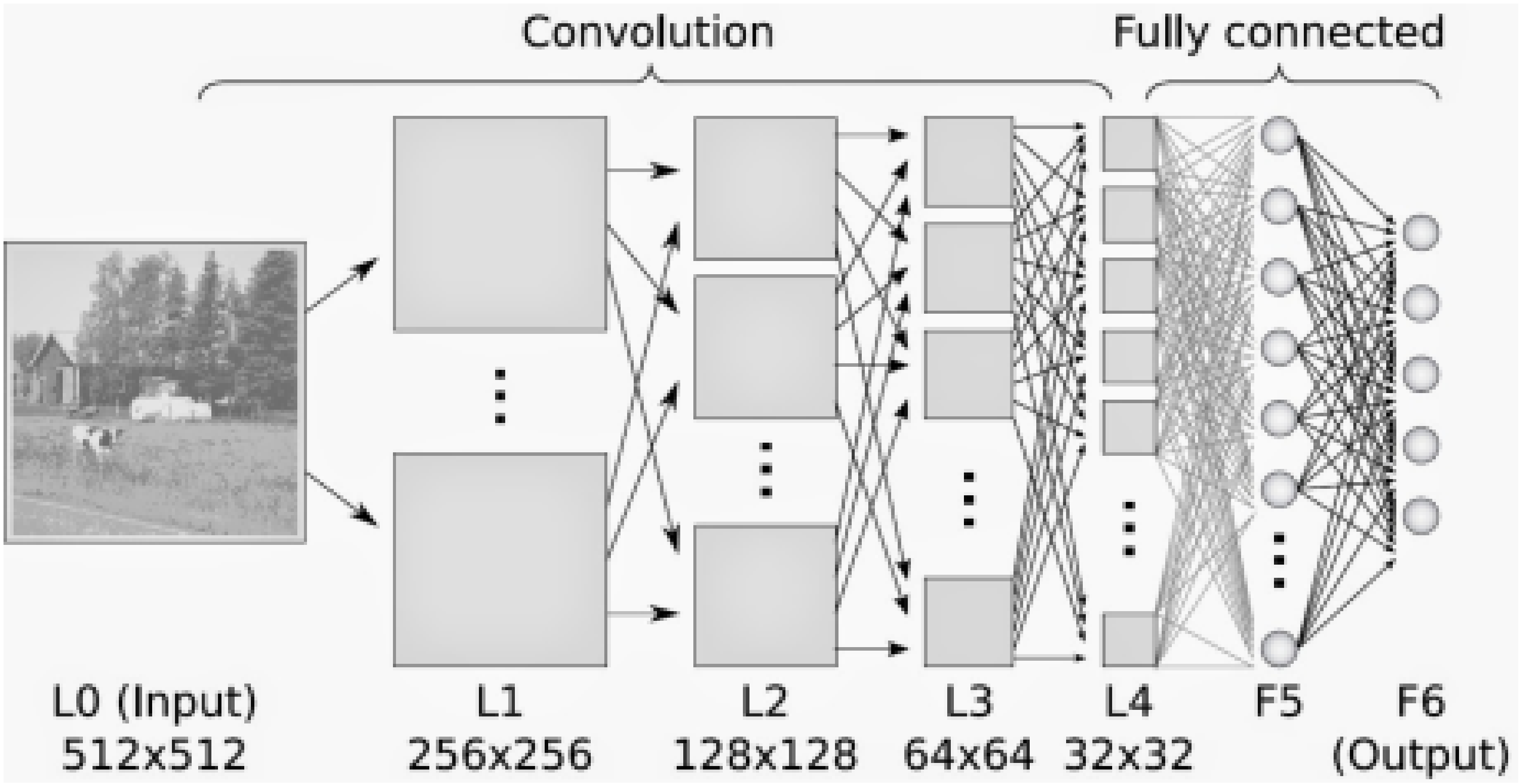
Deep Learning



Convolutional Neural Networks

- Using multiple copies of the same neuron in different places



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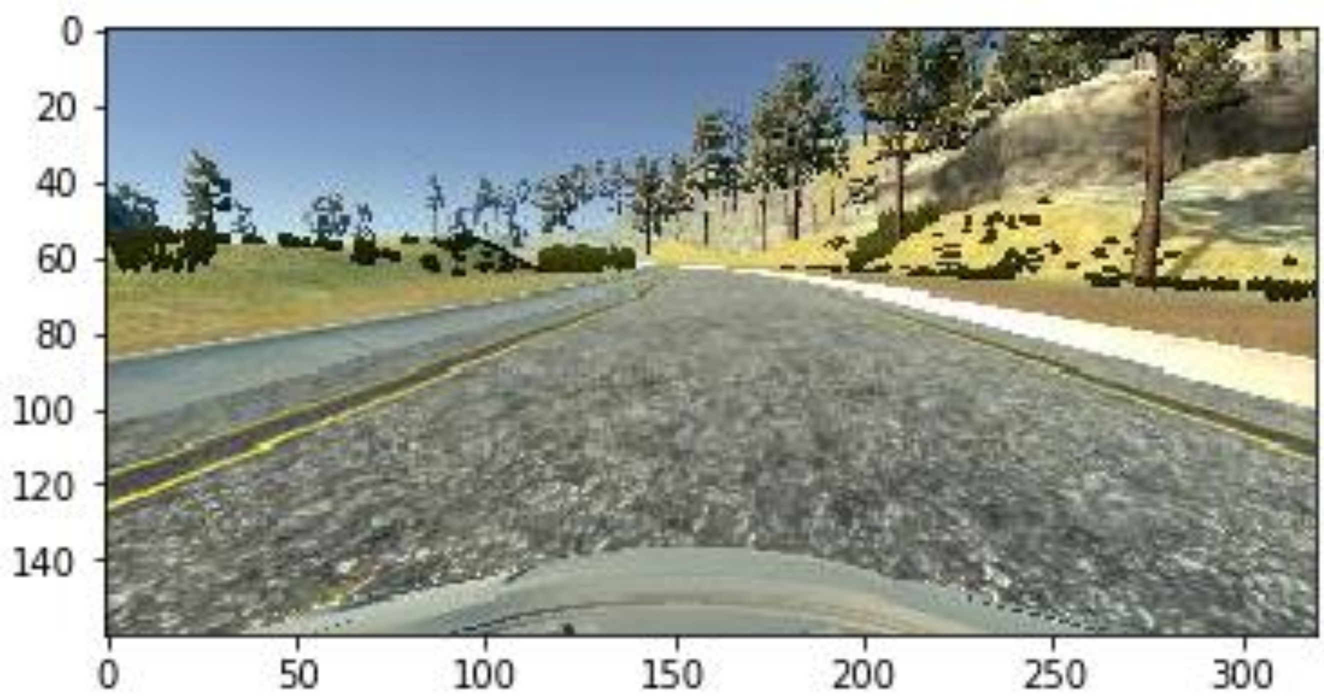
Loss Function

- Measures the compatibility between a prediction and the ground truth label
- Penalizing some measure of complexity of the model

$$Mean\ Squared\ Error = \frac{1}{n}\sum_{i=0}^{n}(\mathrm{y}_{(\mathrm{i})} - \hat{\mathrm{y}}_{(\mathrm{i})})^2$$

Image Received from Simulator

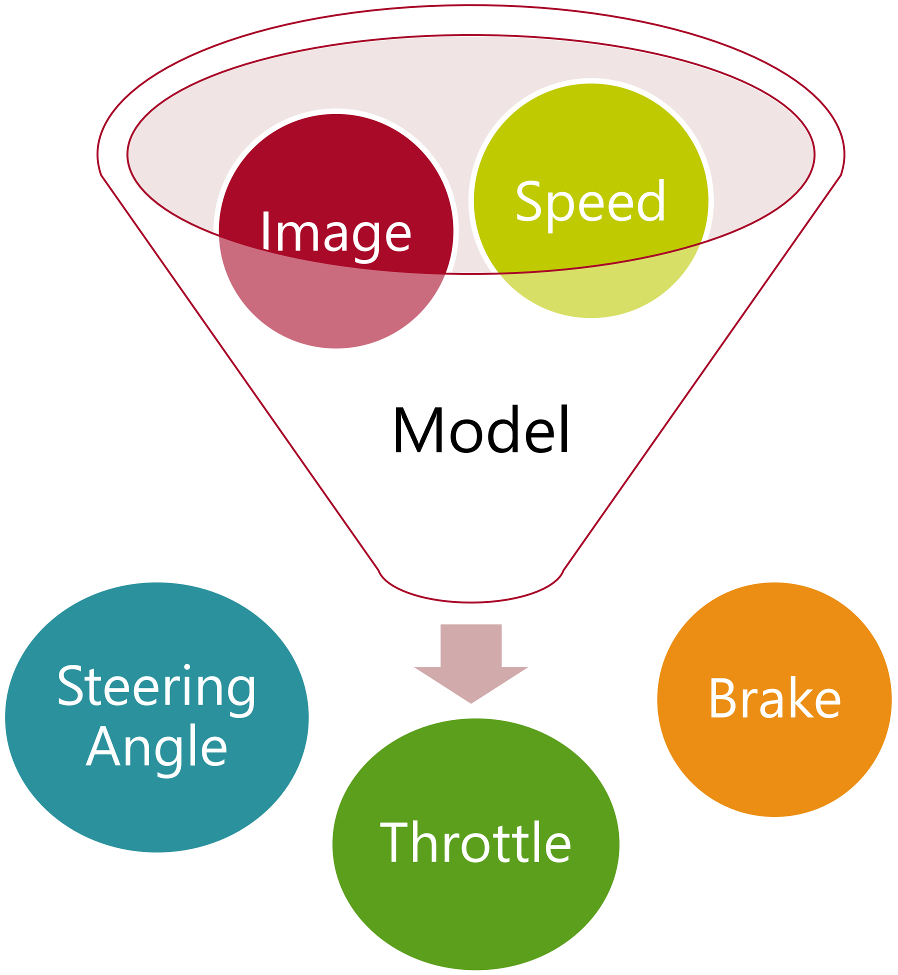
- Images used to train the model
- Size of Image : 160 * 320 * 3



Data Sample (.CSV) Received from Simulator

Steering angle	Throttle	Brake	Speed
0	0	0.4606265	13.05383
0	0	0.3536329	11.81833
0	0	0.1376654	10.90094
-0.1	0	0	9.877307
-0.25	0	0	9.801888
-0.45	0	0	9.677054
-0.3205477	0	0	9.583974
-0.1090438	0	0	9.527431
-0.2079084	0	0	9.447891
-0.3579084	0	0	9.375011
-0.3219513	0	0	9.279725
-0.113026	0	0	9.225466
0	0.05866113	0	9.15232
0	0.2672702	0	9.211304
0	0.4814161	0	9.511002
0	0.5307518	0	9.850943
0	0.2689583	0	10.13124

Model Input vs. Output



Input Pre-processing

- Images are normalized by dividing by 255
- Range of Speed : [6.58111200e-07, 30.5654]
  - ✓ This is normalized to range [0 , 1]

Ground Truth Data Pre-processing

- Steering Angle, Throttle, Brake are the ground truth data

- Range of each parameters :
  - ✓ Steering Angle : [-0.956159400, 0.8500001]

    (negative values for left turns and positive values for right turns)
    - This is normalized to range [0 , 1]
  - ✓ Throttle : [0.00000000 , 1]
  - ✓ Brake : [0.00000000 , 1]

CNN to Train Model

Speed1
Speed2
Speed3
.....
Input

Steering angle1
Steering angle2
Steering angle3
.....
Brake1
Brake2
Brake3
.....
Throttle1
Throttle2
Throttle3
.....
Ground Truth

Feature Extraction & Representation (Convolution)

Mapping (Maxpooling)

Steering angle1
Steering angle2
Steering angle3
.....
Brake1
Brake2
Brake3
.....
Throttle1
Throttle2
Throttle3
.....
Predictions

Back Propagation (Adam)

Basic Neural Network Details

- Image size : 160 * 320 * 3
- Total images : 13842
- Training set : 11212
- Validation set : 1245
- Testing set : 1385
- Loss = mean_squared_error
- metrics= mean absolute error
- Optimizer : Adam
- Batch size : 32
- Epoch : 100

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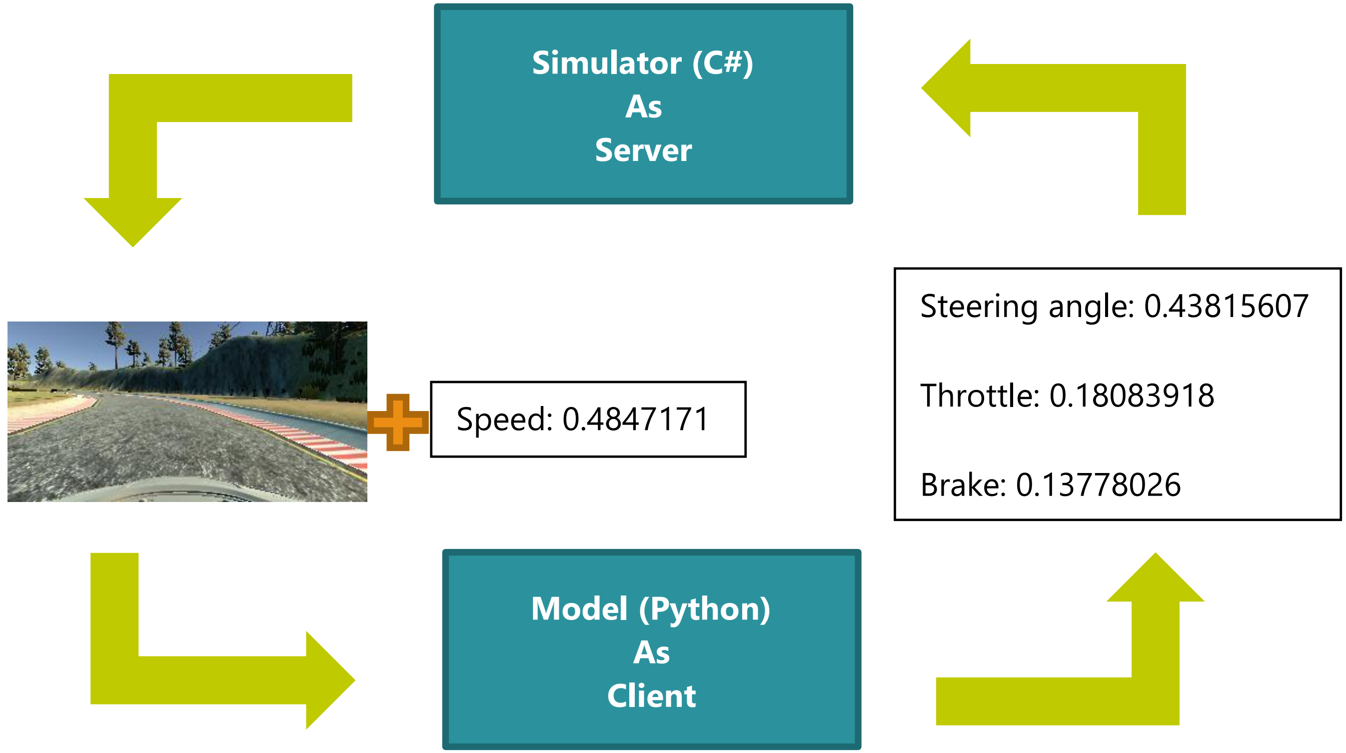
Interface to Test the Model

- Socket-IO:




```
Creating image folder at C:/Users/atabari/Pictures/itk
RECORDING THIS RUN ...
(1232) wsgi starting up on http://0.0.0.0:4567
(1232) accepted ('127.0.0.1', 56613)
connect  5f438d2f9861479886369278c5890917
Received data (Steering_angle, throttle, speed):   0.0 0.0 0.438
Image saved under: C:/Users/atabari/Pictures/itk\2018_02_03_22_06_14_161
1/1 [==============================] - 0s
Predicted values (Steering_angle, throttle, brake): -0.5097607970237732 0.09022938460111618 0.0146
```

Interface to Test the Model

- Normalization: Speed / 30 , Image / 255
- Scaling: [0, 1] → [-1, 1]

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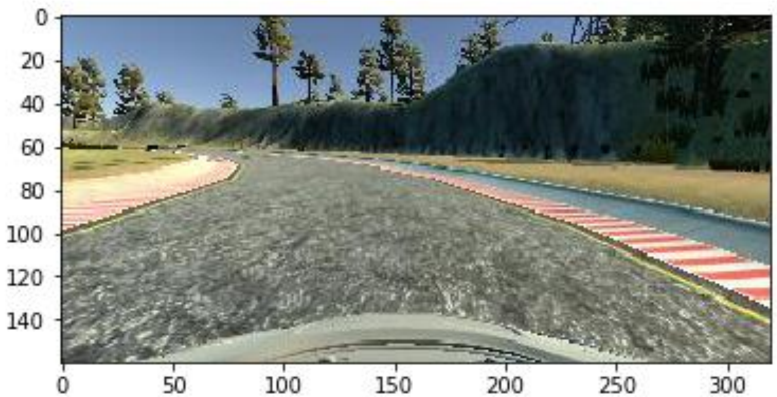
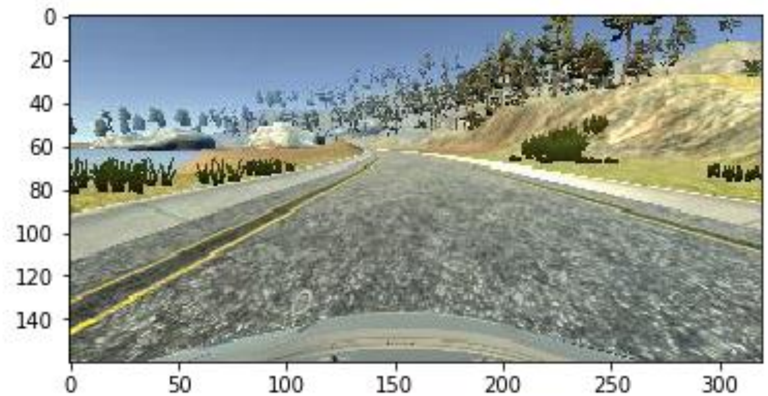
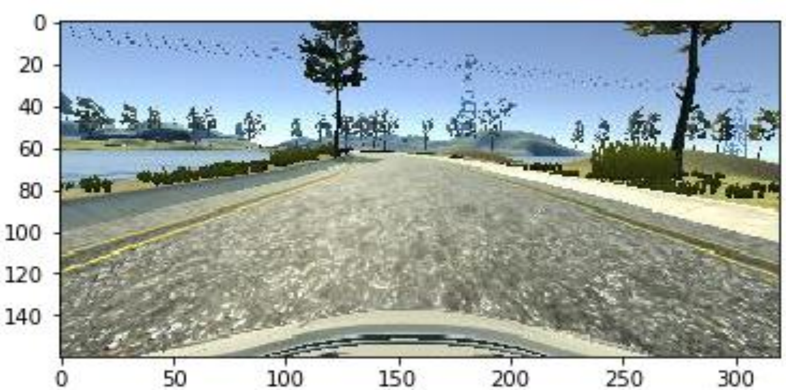
Original Image Received from Simulator

- Images used to train the model
- Size of Image : 160 * 320 * 3







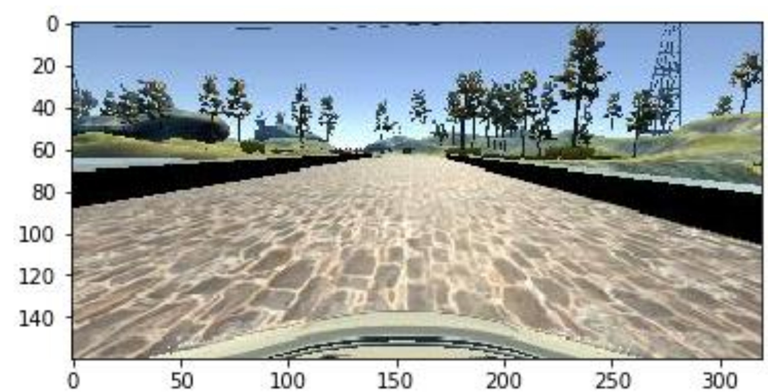
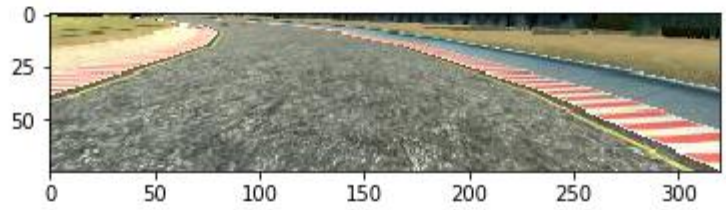
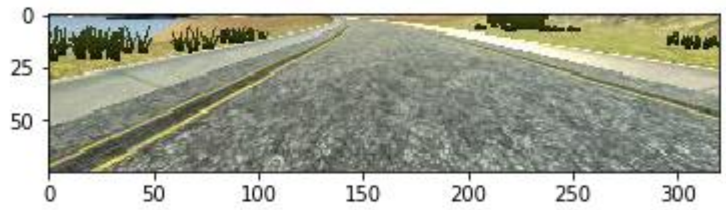
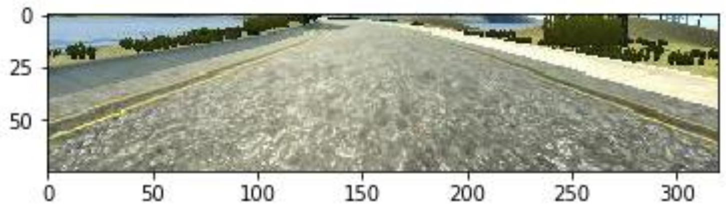
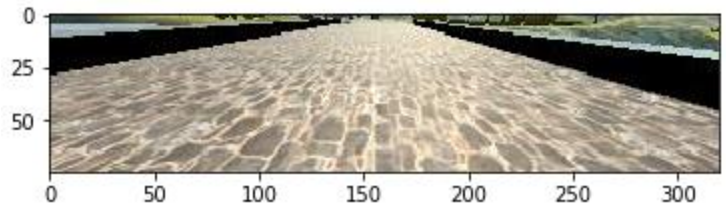


Image Pre-processing

- Images are cropped to show only the road in front
- Size of Image : 75 * 320 * 3

Training Scenario

- Data samples to train the model:
  - ✓ Car driven on road data

Model with Only Straight Road Data

Training Scenario

- Data samples to train the model:
  - ✓ Car coming back to road

Model Trained to Come Back on Road

Model Improvements

- Increase the depth of the CNN
- Sample weight added :
  - ✓ Steering angle : 2
  - ✓ Throttle : 5
  - ✓ Brake : 1

$$Loss\ function = \frac{1}{n}\sum_{i=0}^{n}(\mathrm{y}_{(\mathrm{i})} - \hat{y}_{(\mathrm{i})})^2\,(Weight)$$

Final Neural Network Details

- Image size : 75 * 320 * 3
- Total images : 17595
- Training set : 14252
- Validation set : 1583
- Testing set : 1759
- Loss = mean_squared_error
- metrics= mean absolute error
- Optimizer : Adam
- Batch size : 32
- Epoch : 100

Convolution Layers Details

Layer (type)	***Output Shape***	***Param #***	***Connected to***
main_input (InputLayer)	(None, 75, 320, 3)	0	
conv2d_185 (Conv2D)	(None, 75, 320, 12)	336	main_input[0][0]
max_pooling2d_185 (MaxPooling2D)	(None, 37, 160, 12)	0	conv2d_185[0][0]
conv2d_186 (Conv2D)	(None, 35, 158, 24)	2616	max_pooling2d_185[0][0]
max_pooling2d_186 (MaxPooling2D)	(None, 17, 79, 24)	0	conv2d_186[0][0]
conv2d_187 (Conv2D)	(None, 75, 320, 12)	6944	max_pooling2d_186
max_pooling2d_187 (MaxPooling2D)	(None, 8, 39, 32)	0	conv2d_187[0][0]
conv2d_188 (Conv2D)	(None, 4, 35, 64)	512645	max_pooling2d_187[0][0]
max_pooling2d_188 (MaxPooling2D)	(None, 2, 17, 64)	0	conv2d_188[0][0]
flatten_64 (Flatten)	(None, 2176)	0	max_pooling2d_188[0][0]
speed_input (InputLayer)	(None, 1)	0	
concatenate_44 (Concatenate)	(None, 2177)	0	speed_input[0][0], flatten_64[0][0]

Convolution Layers Details

Layer (type)	***Output Shape***	***Param #***	***Connected to***
dropout_127 (Dropout)	(None, 2177)	0	concatenate_44[0][0]
dense_150 (Dense)	(None, 64)	139392	dropout_128[0][0]
dropout_128 (Dropout)	(None, 64)	0	dense_150[0][0]
dense_151 (Dense)	(None, 1)	65	dropout_128[0][0]
dense_152 (Dense)	(None, 1)	65	dropout_128[0][0]
dense_153 (Dense)	(None, 1)	65	dropout_128[0][0]
Total params: 200,747			
Trainable params: 200,747			
Non-trainable params: 0			

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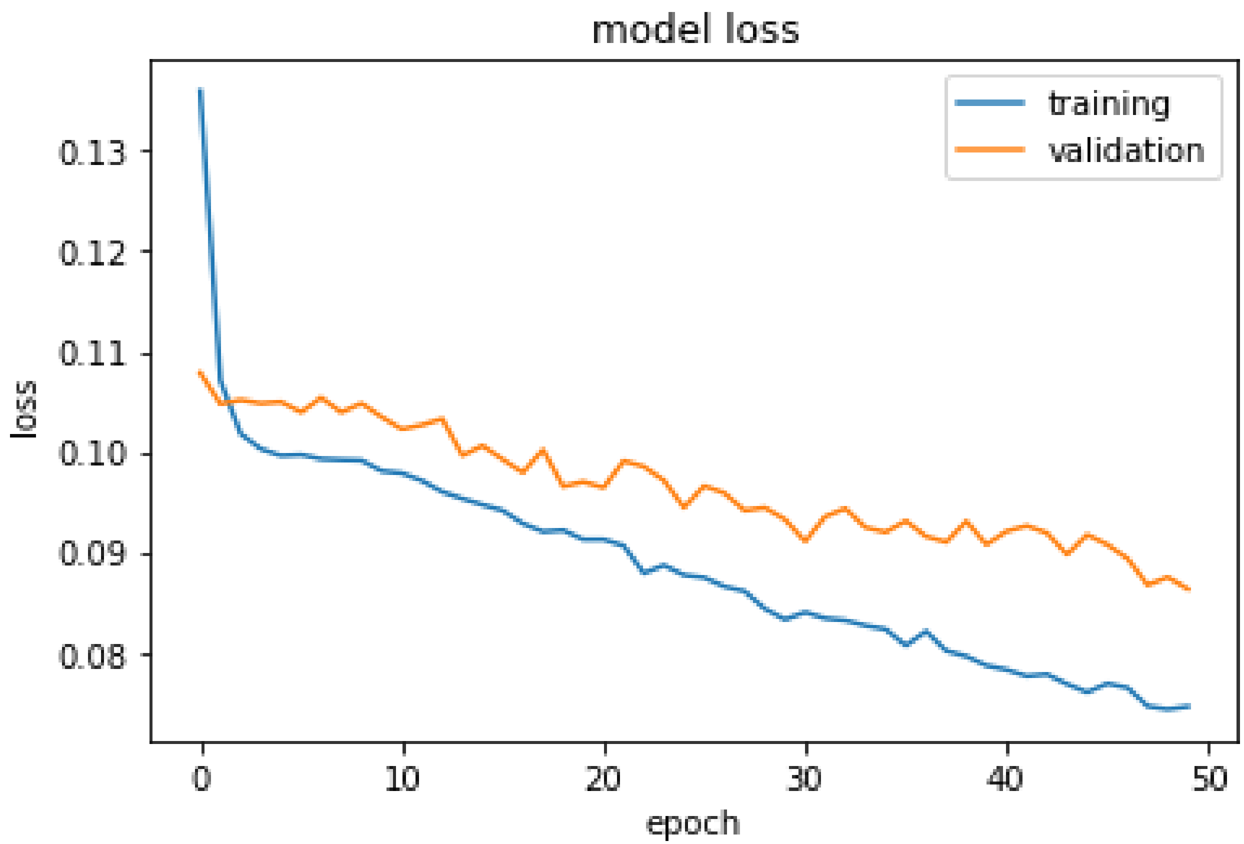
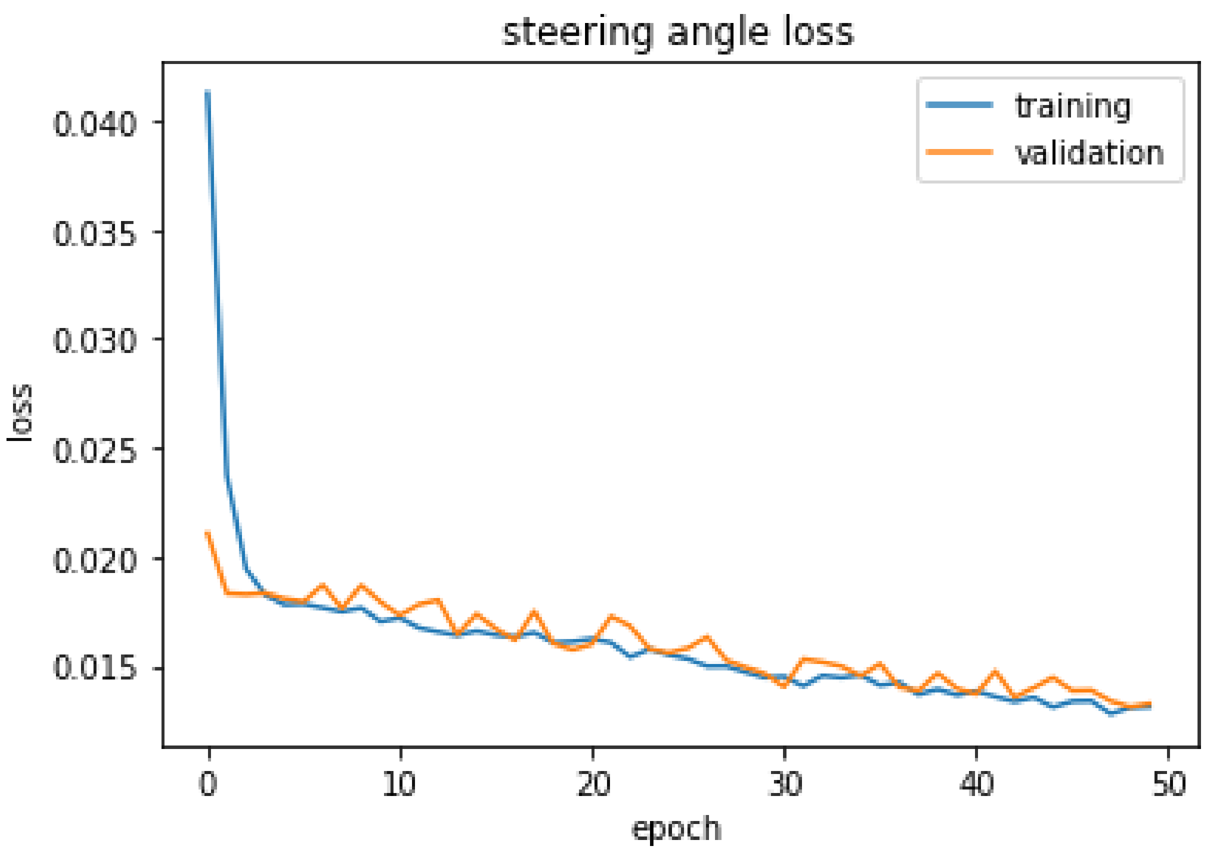
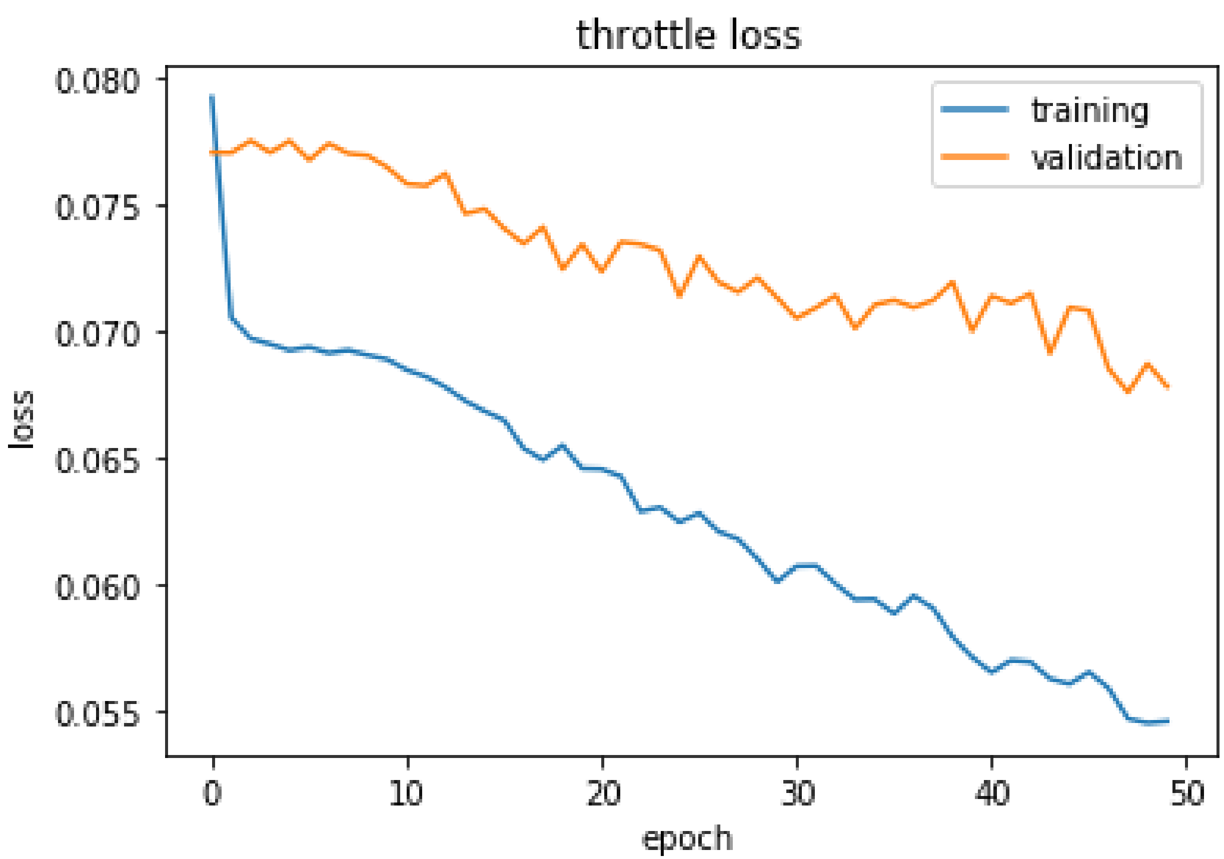
Network Results



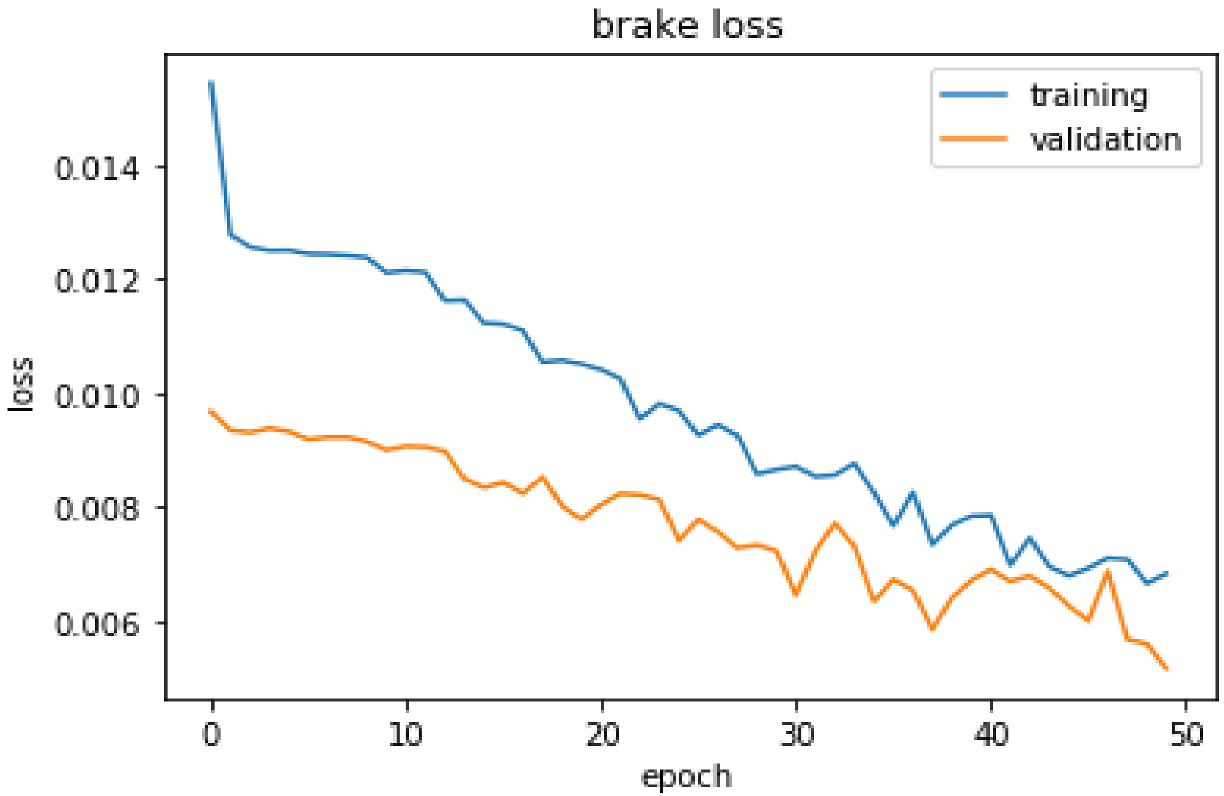
Network Results



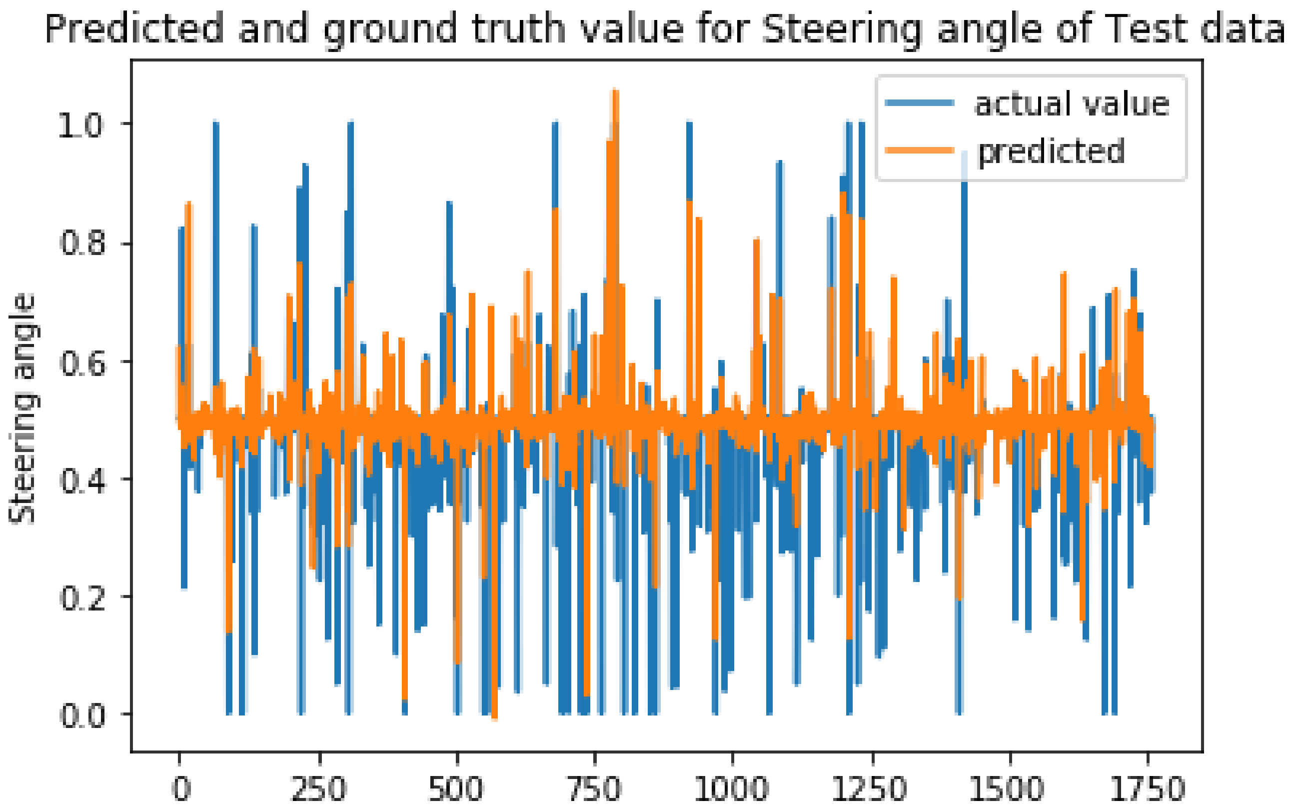
Network Results



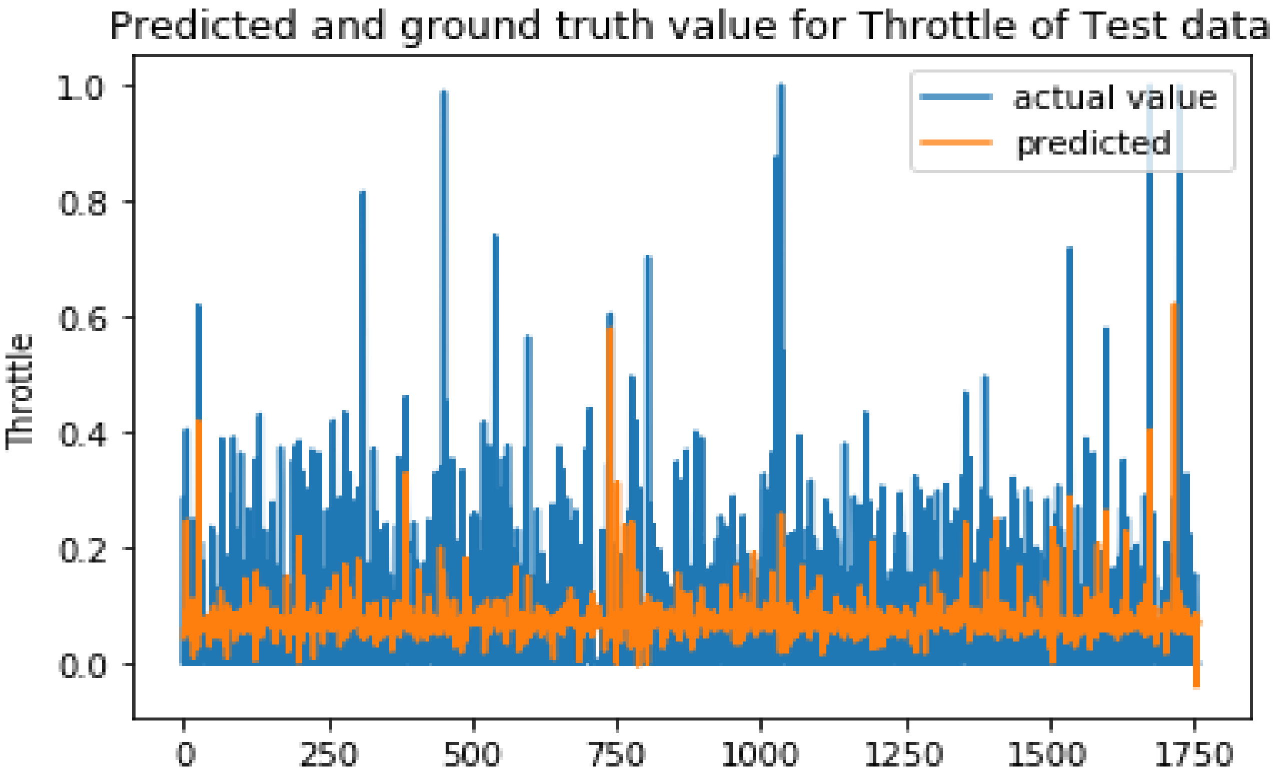
Network Results



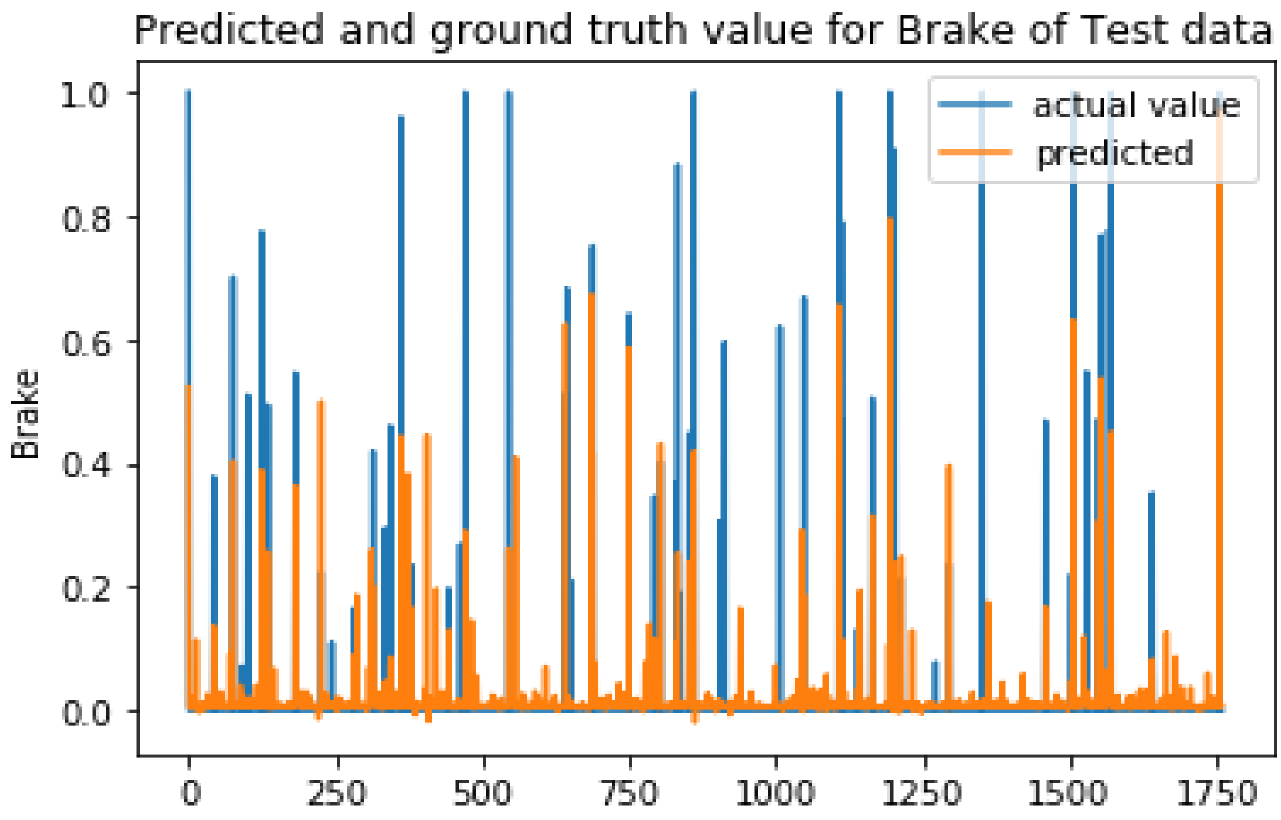
Network Results



Network Results



Network Results



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Demo

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Outlook

- To train the car with the new generated environment
- To create an environment without any steps on the corner of the road
- To use the images from left and right cameras and other additional sensors or elements
- To find the right amount of weight to be added to the throttle
- To train the car with more data to get the best-trained model
- Implementing a recurrent neural network

Thank You!

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Convolution and Maxpooling layers