README.md

RoboND-RoboticInference-Project-P5

Robotic Inference Udacity Project using NVIDIA Digits 6.1

Abstract

The objective of the project is to implement a classification system for a robotic application.

It builds an inference engine extracting information from a race truck.

The data was collected using a donkeycar2 robocar following a standard track.

The trained model uses NVIDIA DIGITS infrastructure to classify if the rover needs to go: straight, turn left or right.

Introduction

In the last few year the development of robotics applications using Machine Learning framework has exploded.

This project explores the usage of NVIDIA's DIGITS software to be used as an inference engine.

Two models where built using the software; the first one using the standard dataset provided by Udacity to get used to the software, parameters and so on. Then, another model to be used with the collected data for the specific robocar usage, a classifier to detect a robot within a truck and the possible actions to do: go `Straight`, turn `Left` or `Right`.

Background

This project was entirely resolved using Udacity's workspace and the NVIDIA DIGITS system using Caffe deep learning framework as the backend.

The first model called `Candy Boxes and Bottles` builds a classifier capable of discriminating between three classes at roughly 75% accuracy with a latency of no more than 10ms.

The second step used or own inference system on a model called `Directions` to explore possible usage on small scale robots within a known environment.

Candy Boxes and Bottles

For the first part of the project, the images provided are 256x256 RGB images. The training was done with 30 epochs with GoogLeNet and the SGD Optimizer.

- Model: GoogLeNet
- Epochs: 10
- Learning Rate: 0.01

Directions

Next, using GoogLenet model with same parameters was used for the second classifier. The focus was to build an inference system for identifying 3 possible classes:

- Straight
- Left

- Right

Data Acquisition

Candy Boxes and Bottles

The data was downloaded from here based on the following comment on slack.

```
wget https://s3-us-west-1.amazonaws.com/udacity-robotics/Content+Workspace+Use/P1_data.tar.gz
tar -xvzf /data/P1_data.tar.gz
```

The structure of the data is:

```
P1_data/
├── Bottle/
│   ├── Bottle_1.png
│   ├── Bottle_2.png
│   └── ...
├── Candy_box/
│   ├── Candy_box_1.png
│   ├── Candy_box_2.png
│   └── ...
└── Nothing/
    ├── Nothing_1.png
    ├── Nothing_2.png
    └── ...
```

For training and validation the data was automatically separated as follows:

Training

- Bottle: 3426 images
- Nothing: 2273 images
- Candy Box: 1871 images

Validation

- Bottle: 1142 images
- Nothing: 758 images
- Candy Box: 624 images

Directions

For this phase a robocar was run to follow a standard race track in recording mode. After a few laps, it recorded thousand of 160x120 RGB images.

Then, a cleaned subset was classified in the 3 classes. The dataset can be validated on the data folder. It includes the training data organized as follows:

```
data/
├── Left/
│   ├── 47_cam-image_array_.jpg
│   ├── ...
│   └── 48_cam-image_array_.jpg
├── Right/
│   ├── 46_cam-image_array_.jpg
│   ├── ...
│   └── 47_cam-image_array_.jpg
└── Straight/
    ├── 25_cam-image_array_.jpg
```

```
├── ...
└── 26_cam-image_array_.jpg
```

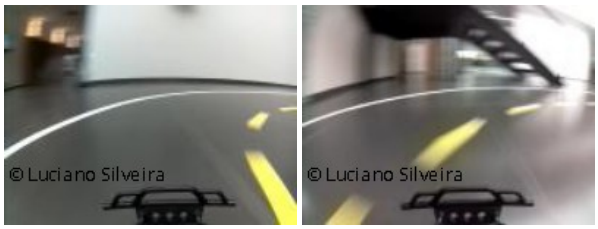
The images distribution by class is:

- Left: 702 images
- Right: 719 images
- Straight: 841 images

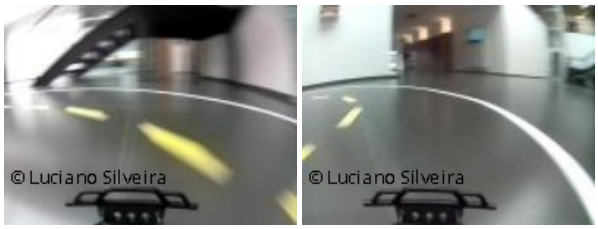
The validation set including a imagelist.txt validation file.

Some examples:

** Right **



** Left **



** Straight **

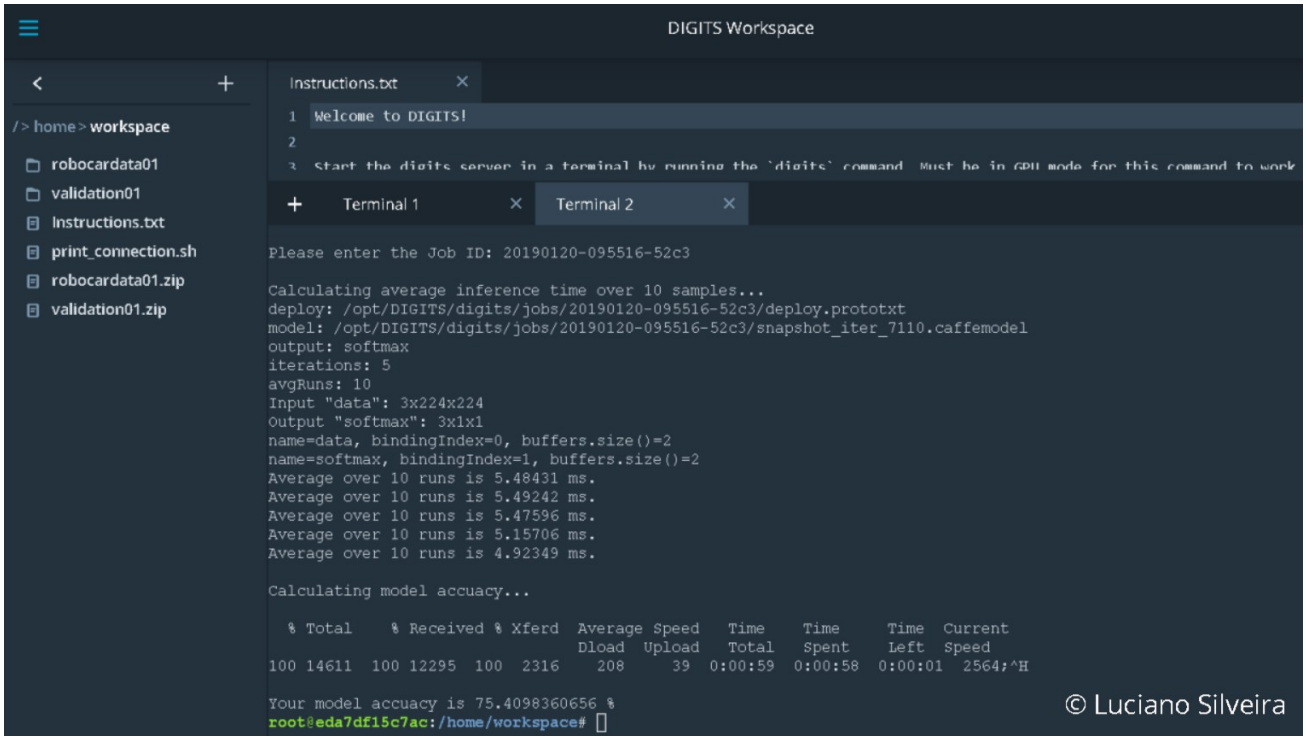
Results

Candy Boxes and Bottles

Once the training was done, the Udacity `evaluate` command was executed.

```
terminal 1 # digits | /usr/share/keep-alive
terminal 2 # ./print_connection.sh
terminal 3 # evaluate
```

As can be seen in the following image; using the provided `evaluate` method was able to obtain 75.4% accuracy with a response time around 5ms.



Directions

As detailed, the `evaluate` command does not work on this training data. A manual list of samples was created to validate the results. Some preliminary sample results are:

More Results

Other samples using the DIGITS UI by manually uploading images:

robocars01 Image Classification Model

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Predictions

Right	56.95%
Left	42.4%
Straight	0.65%

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robocars01 Image Classification Model

Predictions

Right	58.7%
Left	38.15%
Straight	3.14%

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robocars01 Image Classification Model

Predictions

Left	67.02%
Right	32.97%
Straight	0.02%

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robocars01 Image Classification Model

Predictions

Left	57.24%
Right	42.7%
Straight	0.07%

robocars01 Image Classification Model

Predictions

Left	63.38%
Right	36.52%
Straight	0.1%

robocars01 Image Classification Model

Predictions

Straight	100.0%
Right	0.0%
Left	0.0%

robocars01 Image Classification Model

Predictions

Straight	78.66%
Right	16.33%
Left	5.01%

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robocars01 Image Classification Model

Predictions

Straight	100.0%
Right	0.0%
Left	0.0%

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Using the selected list of validation samples got the following results:

All classifications

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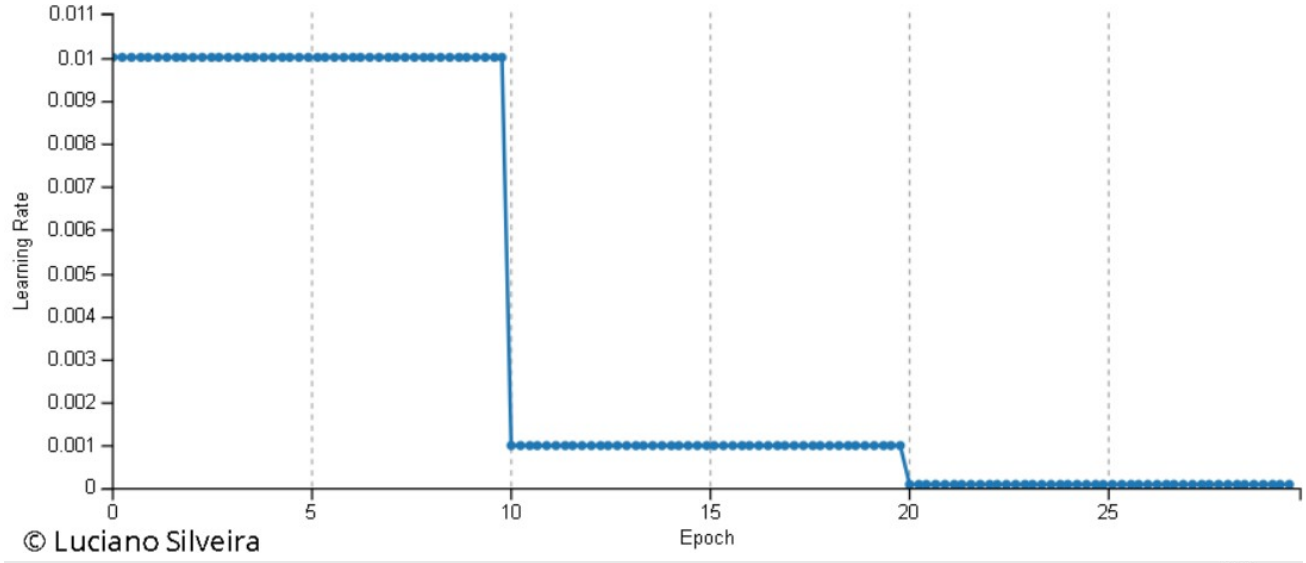
	Path	Top predictions					
1	/home/workspace/validation01/Straight/2763_cam-image_array_.jpg	Straight	100.0%	Right	0.0%	Left	0.0%
2	/home/workspace/validation01/Straight/2806_cam-image_array_.jpg	Straight	78.66%	Right	16.33%	Left	5.01%
3	/home/workspace/validation01/Straight/2817_cam-image_array_.jpg	Straight	100.0%	Right	0.0%	Left	0.0%
4	/home/workspace/validation01/Straight/2867_cam-image_array_.jpg	Straight	99.99%	Right	0.01%	Left	0.0%
5	/home/workspace/validation01/Straight/2920_cam-image_array_.jpg	Straight	100.0%	Right	0.0%	Left	0.0%
6	/home/workspace/validation01/Straight/2920_cam-image_array_.jpg	Straight	100.0%	Right	0.0%	Left	0.0%

```
Path    Top predictions
1       Straight/2763_cam-image_array_.jpg      Straight        100.0%  Right   0.0%    Left    0.0%
2       Straight/2806_cam-image_array_.jpg      Straight        78.66%  Right   16.33%  Left    5.01%
3       Straight/2817_cam-image_array_.jpg      Straight        100.0%  Right   0.0%    Left    0.0%
4       Straight/2867_cam-image_array_.jpg      Straight        99.99%  Right   0.01%   Left    0.0%
5       Straight/2920_cam-image_array_.jpg      Straight        100.0%  Right   0.0%    Left    0.0%
6       Straight/2920_cam-image_array_.jpg      Straight        100.0%  Right   0.0%    Left    0.0%
7       Left/2678_cam-image_array_.jpg  Left    63.38%  Right   36.52%  Straight        0.1%
8       Left/2744_cam-image_array_.jpg  Left    63.87%  Right   36.1%   Straight        0.03%
```

```
9       Left/2792_cam-image_array_.jpg  Left    70.39%  Right   29.6%   Straight        0.01%
10      Left/2852_cam-image_array_.jpg  Left    57.24%  Right   42.7%   Straight        0.07%
11      Left/2952_cam-image_array_.jpg  Right   52.54%  Left    47.05%  Straight        0.41%
12      Left/2996_cam-image_array_.jpg  Left    67.02%  Right   32.97%  Straight        0.02%
13      Right/2641_cam-image_array_.jpg Right   58.7%   Left    38.15%  Straight        3.14%
14      Right/2693_cam-image_array_.jpg Left    56.53%  Right   43.41%  Straight        0.06%
15      Right/2736_cam-image_array_.jpg Right   52.84%  Left    46.56%  Straight        0.6%
16      Right/3043_cam-image_array_.jpg Left    55.91%  Right   43.51%  Straight        0.58%
17      Right/3187_cam-image_array_.jpg Left    53.16%  Right   46.51%  Straight        0.33%
18      Right/3459_cam-image_array_.jpg Right   56.95%  Left    42.4%   Straight        0.65%
19      Right/3610_cam-image_array_.jpg Left    53.51%  Right   46.25%  Straight        0.24%
```

Training Results

The training result are as follows:


Learning Rate
Epoch
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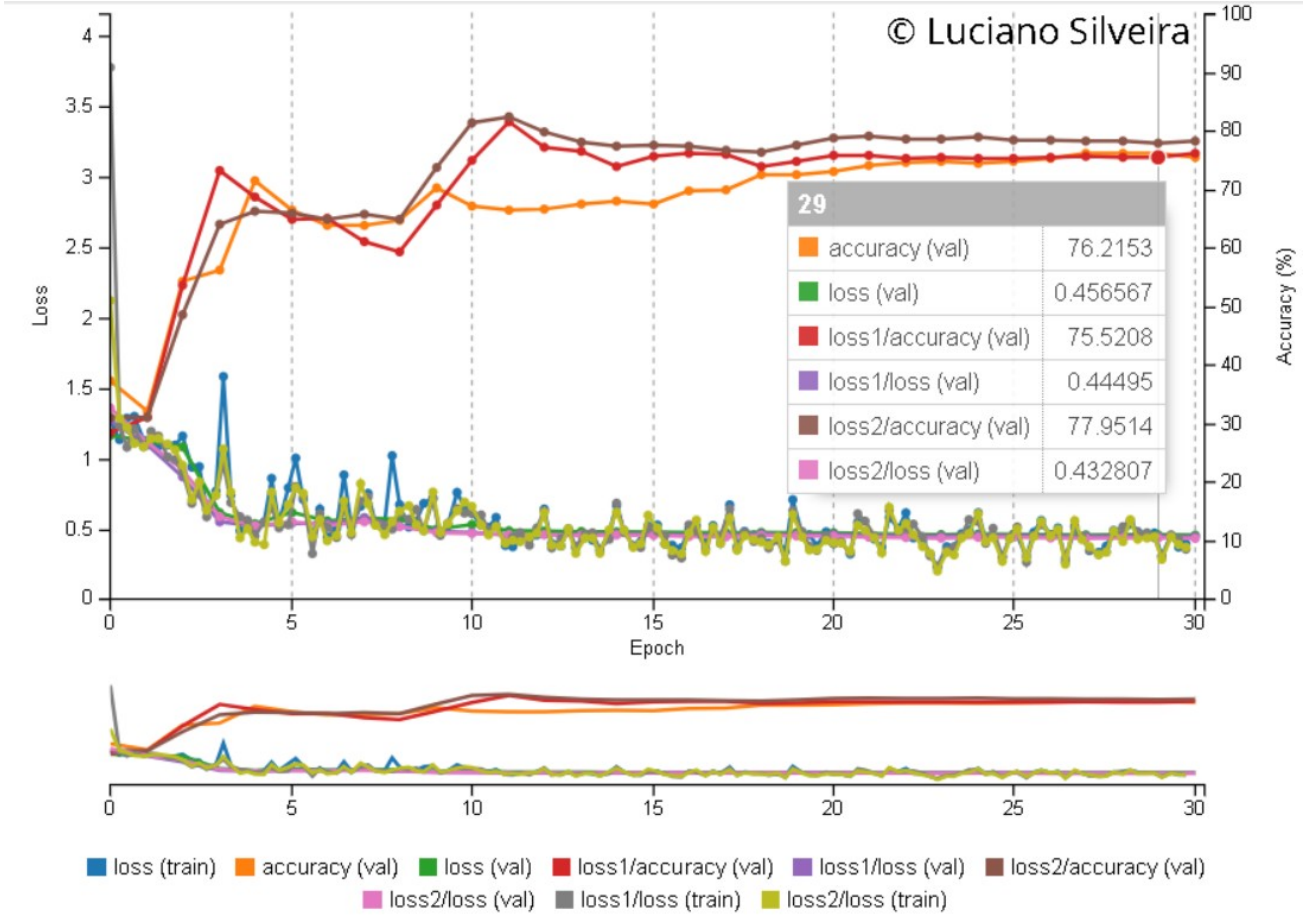
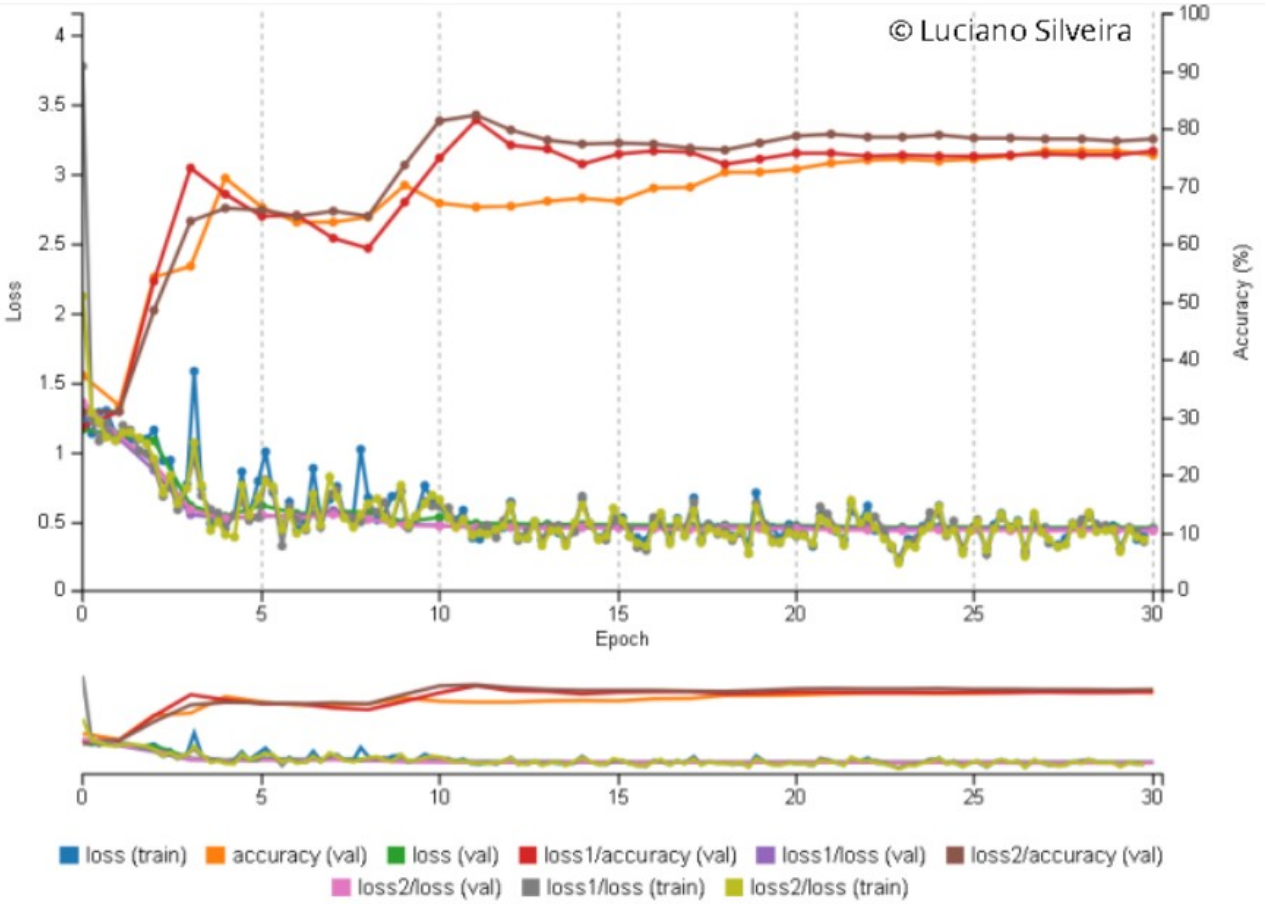

© Luciano Silveira
Loss
Accuracy (%)
Epoch
29
accuracy (val) 76.2153
loss (val) 0.456567
loss1/accuracy (val) 75.5208
loss1/loss (val) 0.44495
loss2/accuracy (val) 77.9514
loss2/loss (val) 0.432807
loss (train)
accuracy (val)
loss (val)
loss1/accuracy (val)
loss1/loss (val)
loss2/accuracy (val)
loss2/loss (val)
loss1/loss (train)
loss2/loss (train)



Discussion

The first model satisfactory met the given requirements; classification confidence of 75.4% and approximately avearge evaluation time of 5ms.

The second model got an accuracy of 76.2% for the training model. More data needs to be collected and classified to improve these values. This model will only work on the specified track as no processing is done on the images.

On the evaluation phase in particular the `Right` and `Left` classes got wrong values and in some cases a very close score:

robocars01 Image Classification Model

Predictions

Left	53.51%
Right	46.25%
Straight	0.24%

robocars01 Image Classification Model

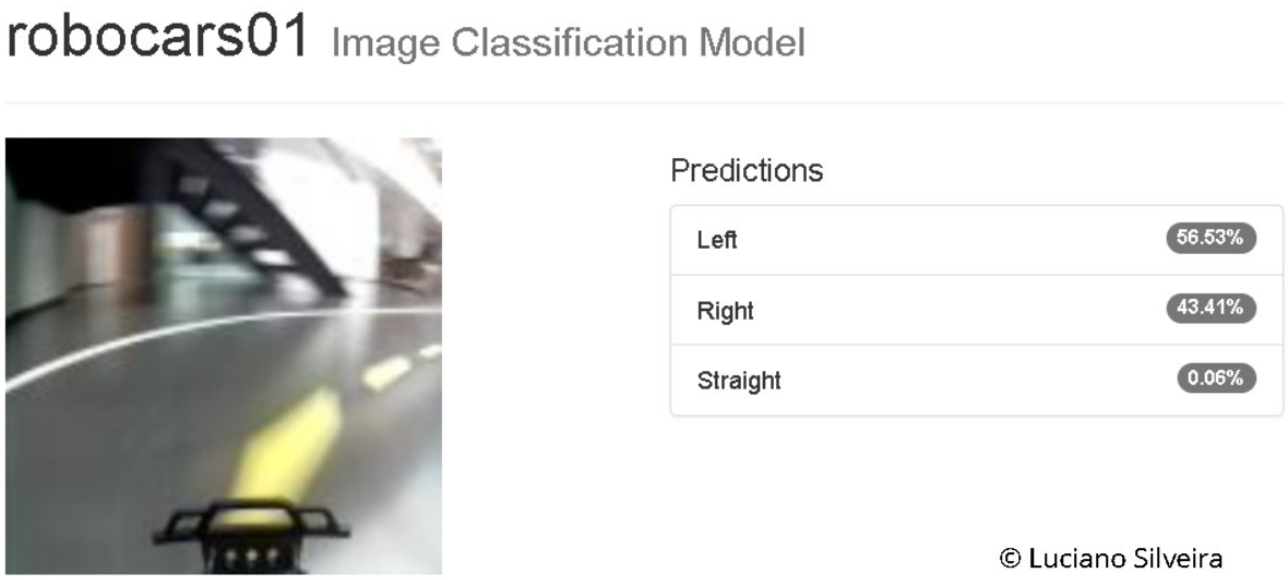
Predictions

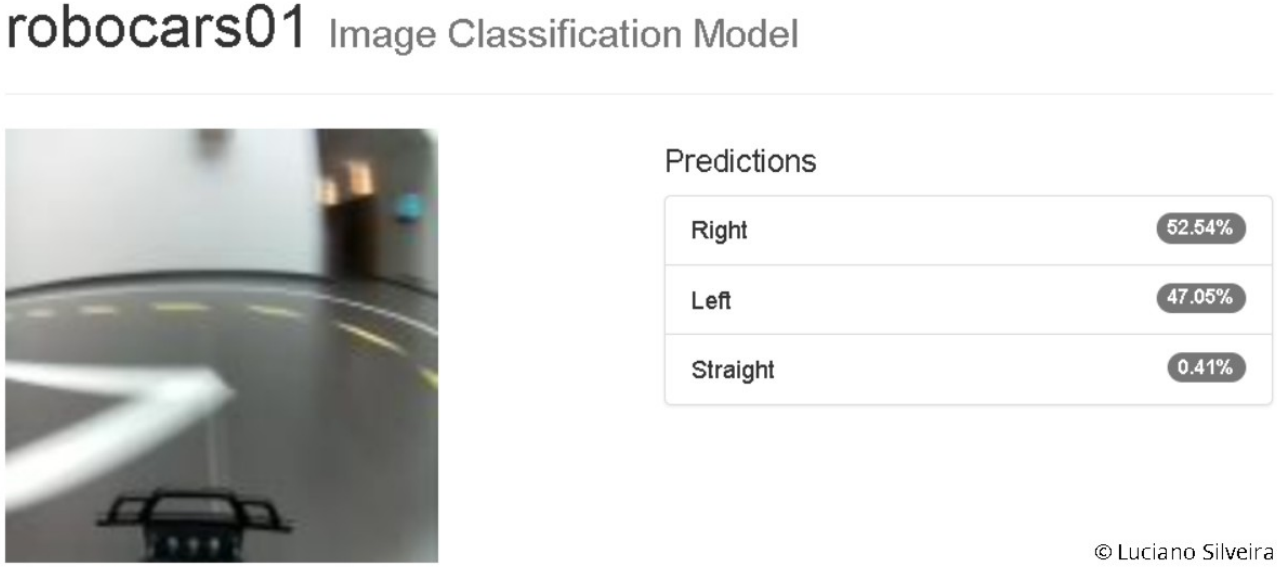
Left	53.16%
Right	46.51%
Straight	0.33%

robocars01 Image Classification Model

Predictions

Left	55.91%
Right	43.51%
Straight	0.58%





Conclusion / Future Work

For the first part of the project the results were satisfactory using the provided dataset (4GB) with thousand of sample images for each class.

The second part of the project got encouraging results but not enough to be used as a classification system. The dataset should be increased and polished and trained again. Some preprocessing can be done to the images; so as to improve it's classification

- crop the image to a region of interest
- use some pre-processing to normalize images
- change the image color scheme to HSV, Gray or a combination.
- change the image field of view with a birds view transformation to better aply the classification.

Links:

- detectnet
- Digits Getting Started
- Digits Classification
- watermark
- This repository

- Project Rubric