Traffic Sign Recognition

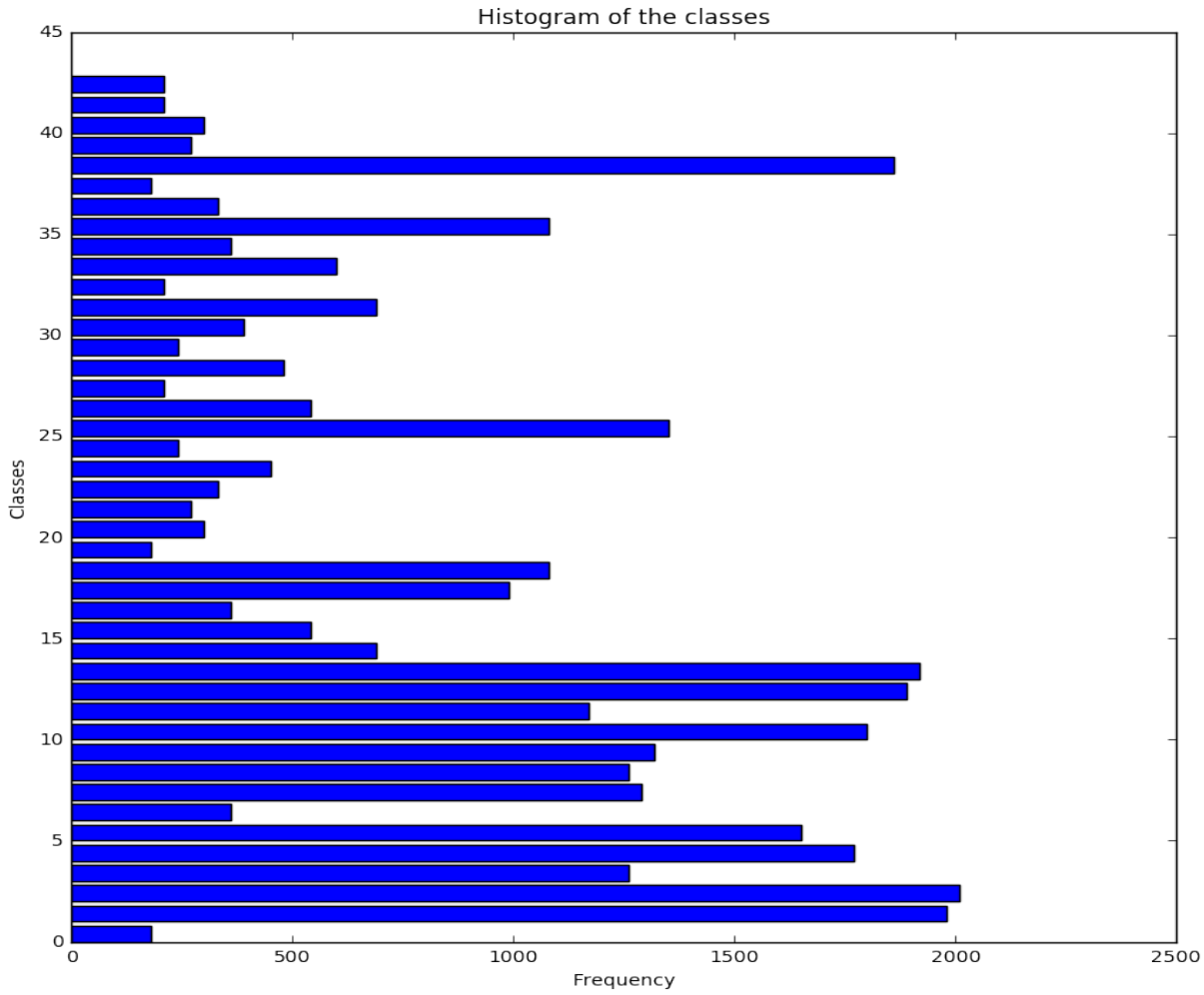
Data Set Summary & Exploration

Using basic array functions following parameters are explored:

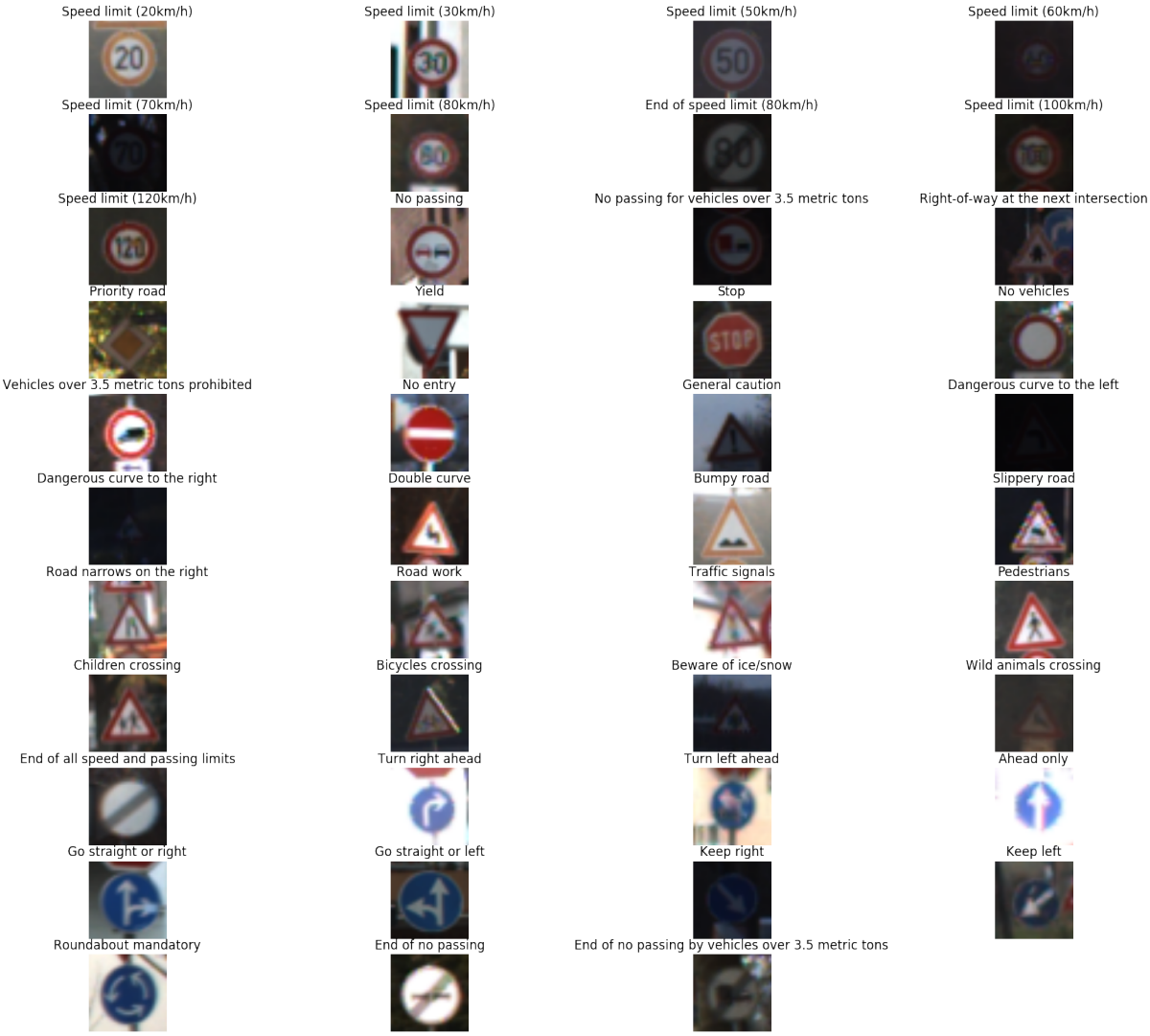
- Number of training samples: 34799
- Number of testing samples :12630
- Image data shape = (32, 32, 3)
- Number of classes = 43
- Validation Set = 4410 samples

Exploratory visualization of the dataset

Here is an exploratory visualization of the data set. It is a bar chart showing how the training data set is distributed.



Following picture shows a sample from each class with the labels.

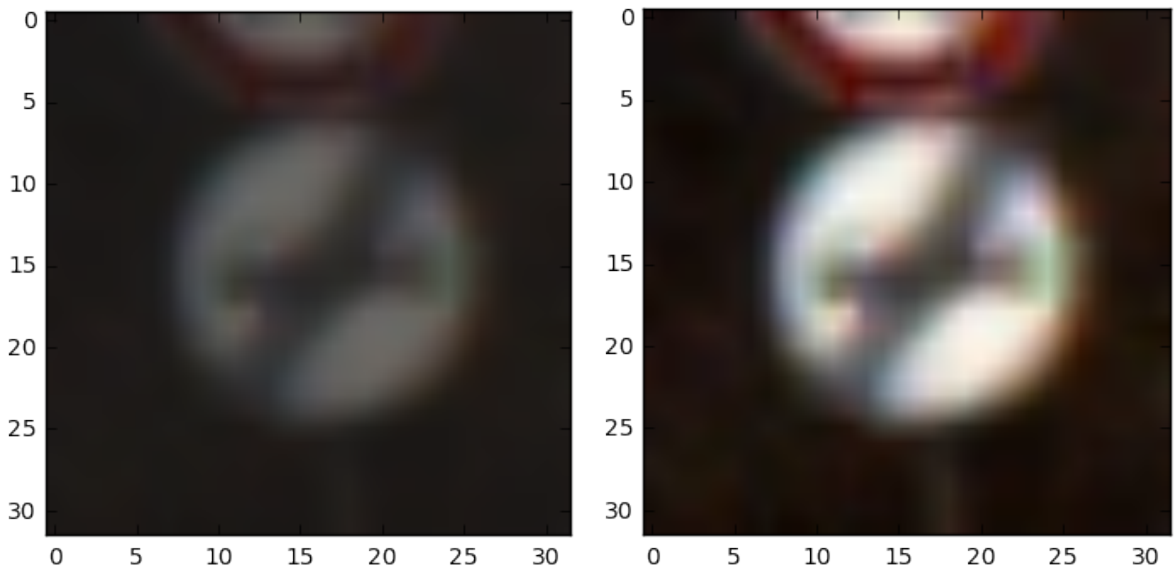


Design and Test a Model Architecture

Preprocessing of the data

First the images are normalized by use of OPENCB normalize function.

Following figure shows before and after normalization of the image.

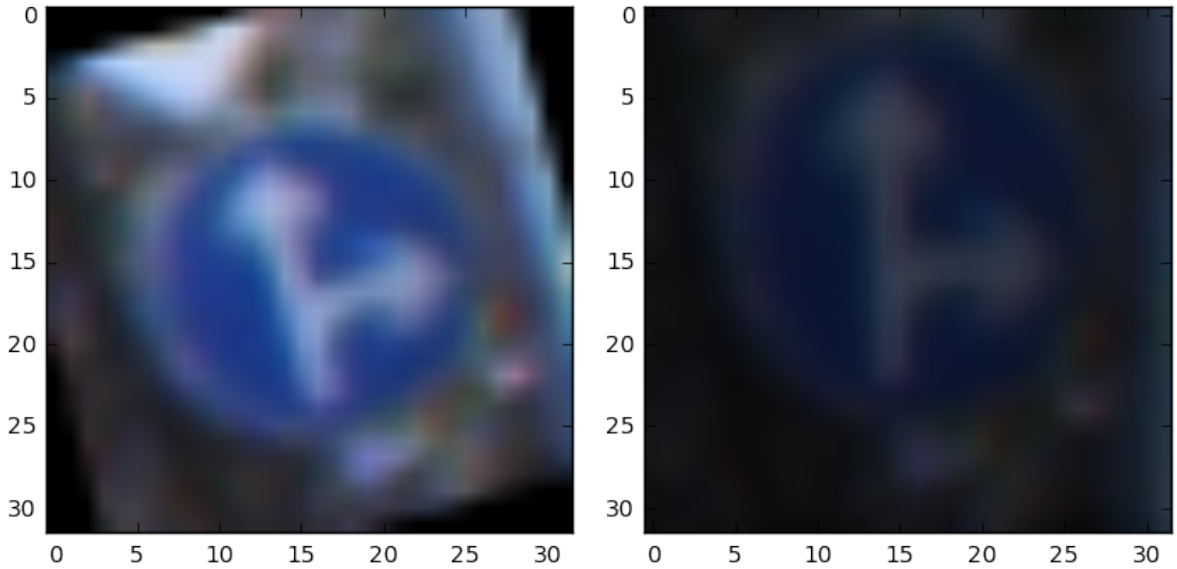


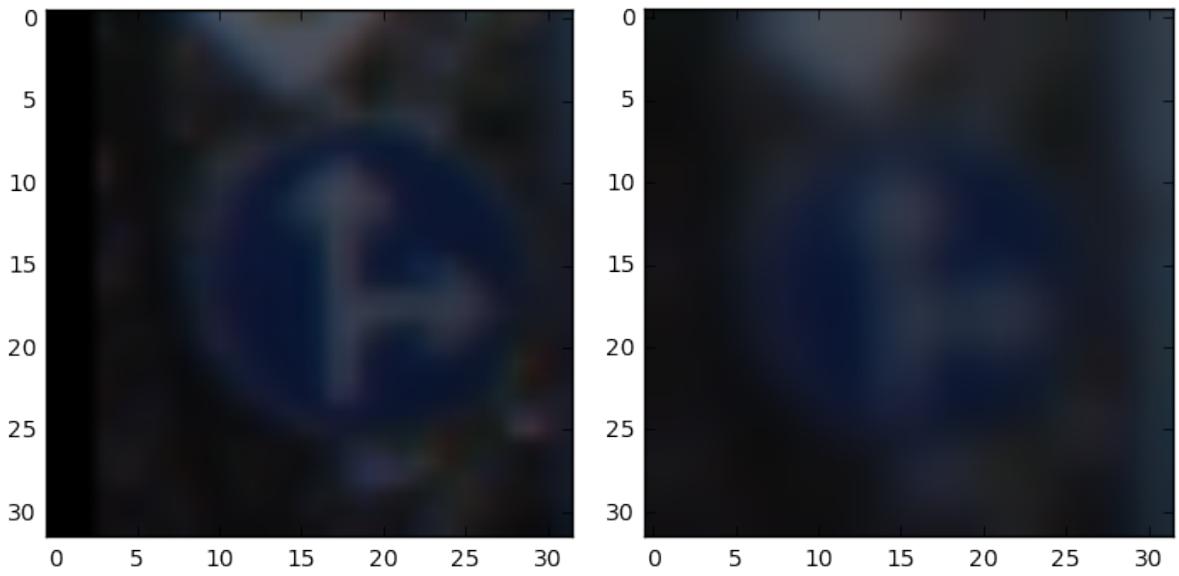
After normalization step, new images are created from the training set generated to be able have nearly same number of images in each class. Total samples kept at a minimum but number of images are still random.

Four different operations applied to the test images to create additional images. Namely

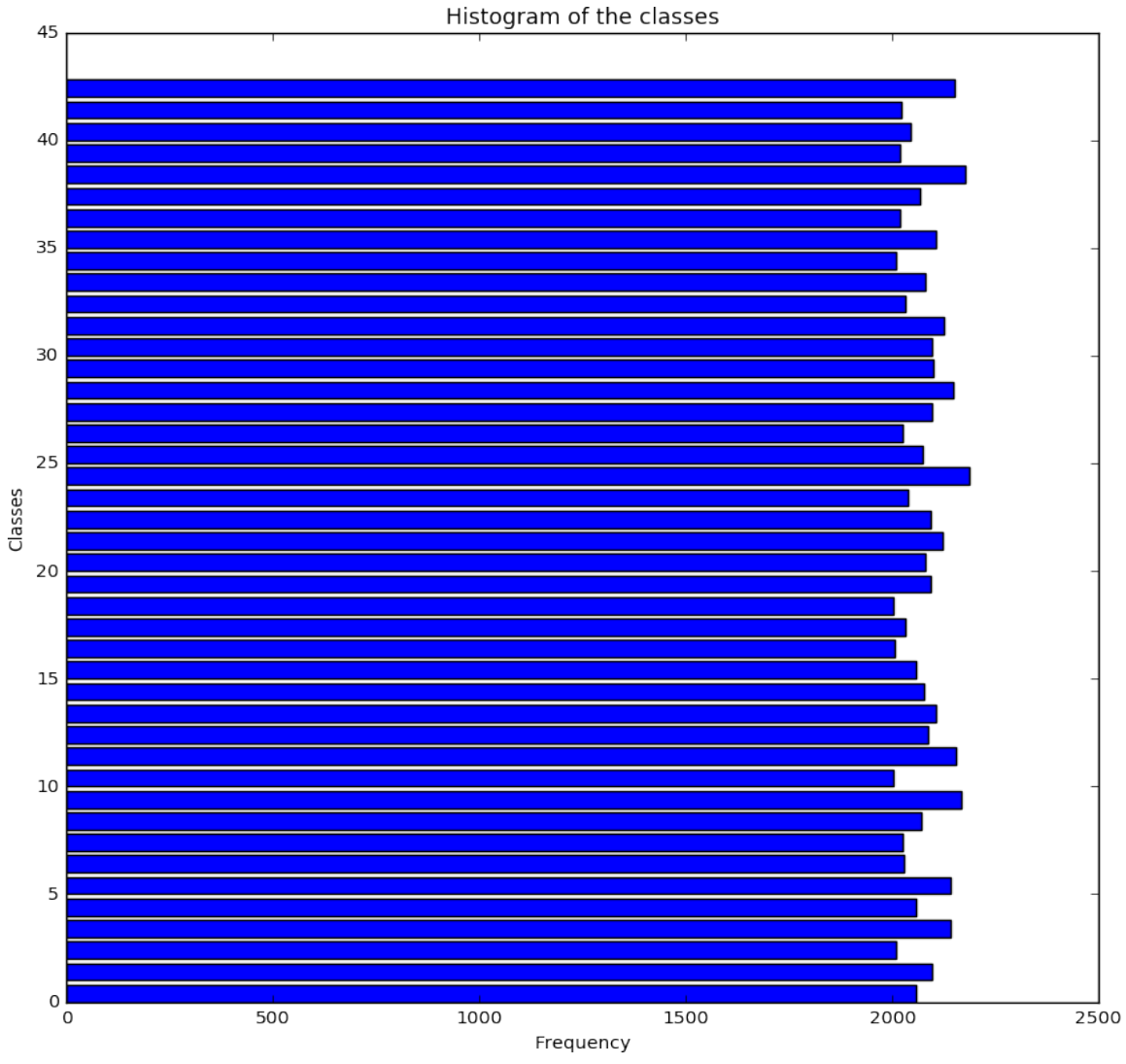
- Random rotation
- Random perspective
- Random shift
- Random blur

Following are some example images after random conversions





The difference between the original data set and the augmented data set is the following



Final model architecture

Following basic Lenet-5 architecture in the class is used with only two additional dropout, and small changes to reflect the characteristics of the traffic signs input changed to 32x32x3 and output changes updated to produce 43 classes.

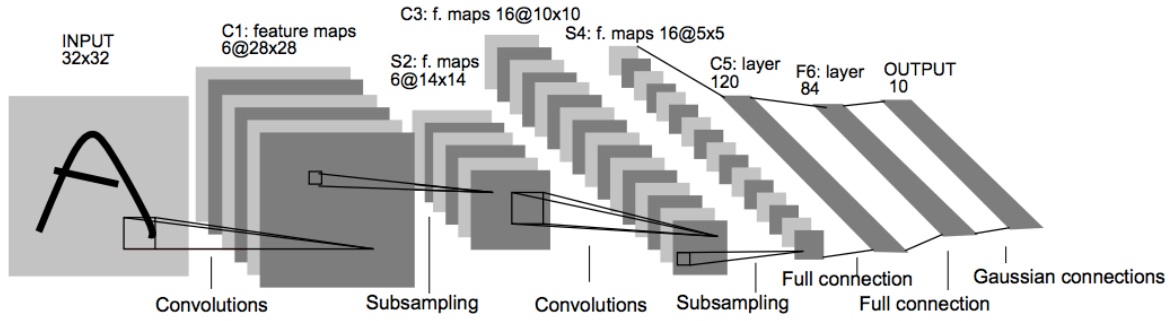


Fig. 2. Architecture of LeNet-5, a Convolutional Neural Network, here for digits recognition. Each plane is a feature map, i.e. a set of units whose weights are constrained to be identical.

My final model consisted of the following layers:

Layer	**Description**
Input	32x32x3 RGB image
Layer1: Convolution	1x1 stride, same padding, outputs 28x28x6
RELU	
Pooling	2x2 stride, outputs 14x14x6
Layer2: Convolution	1x1 strinde 10x10x16
RELU	
Flatten	Outputs 400
Fully Connected	Outputs 120
RELU	
Dropout	
Fully Connected	Output 83
Dropout	
Fully Connected	43

Training the network

Adam optimizer used to train the model. Following hyperparameters are used

- Batch size : 128
- Number of epochs : 35
- Learning rate : 0.001

Approach Used In Training

At the first step basic implementation learned in the class is used just small changes to handle RGB images. With this change validation accuracy was around 0.83.

Different Epoch's are test increasing number of epochs too much does not bring too much value. After 30 epoch there is only small increases in validation accuracy. Around 0.86.

After applying changes to the training set and normalization around 0.93 validation accuracy.

Applying dropout brought validation accuracy around 0,96 – 0,97.

My final model results were:

- validation set accuracy of 0.963
- test set accuracy of 0.942

Test a Model on New Images

First some test set from the competition available on the internet is used. But they look very similar to the training set.

Speed limit (100km/h)

Speed limit (60km/h)

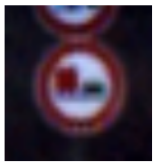
No passing

Ahead only

Speed limit (60km/h)

Speed limit (60km/h)

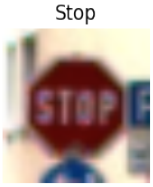
No passing for vehicles over 3.5 metric tons



Dangerous curve to the right

Speed limit (100km/h)

Stop



After 18 image set found. A CSV file for defining class of each image is prepared. These images normalized and converted to 32x32x3.

These images are clearer than the original images. Since the network is trained on more blurred images there may be difficulties to classify these images. Adding some blur to these images increases the correct prediction rate.

Model's prediction

Following were the results on these images

- correct matches: 14
- wrong matches: 4
- correct rate: 0.78

Most of the errors are on speed limit signs.

Top 5 probabilities

```
Correct image :  Roundabout mandatory
Turn right ahead: 0.9546
Roundabout mandatory: 0.0254
Keep left: 0.0194
End of speed limit (80km/h): 0.0004
Go straight or left: 0.0002
--------------------------------------------------
--------------------------------------------------
Correct image :  Stop
Stop: 0.9970
Bicycles crossing: 0.0015
Yield: 0.0010
Speed limit (30km/h): 0.0003
No vehicles: 0.0001
--------------------------------------------------
--------------------------------------------------
Correct image :  Road work
Road work: 1.0000
Bicycles crossing: 0.0000
Double curve: 0.0000
Wild animals crossing: 0.0000
Beware of ice/snow: 0.0000
--------------------------------------------------
--------------------------------------------------
Correct image :  Priority road
Priority road: 1.0000
Traffic signals: 0.0000
Yield: 0.0000
No vehicles: 0.0000
Right-of-way at the next intersection: 0.0000
--------------------------------------------------
--------------------------------------------------
Correct image :  General caution
General caution: 1.0000
Traffic signals: 0.0000
Pedestrians: 0.0000
Road work: 0.0000
Right-of-way at the next intersection: 0.0000
--------------------------------------------------
--------------------------------------------------
Correct image :  Speed limit (20km/h)
Speed limit (20km/h): 1.0000
Speed limit (30km/h): 0.0000
Speed limit (120km/h): 0.0000
Speed limit (70km/h): 0.0000
No vehicles: 0.0000
--------------------------------------------------
```

```
--------------------------------------------------
Correct image :  Speed limit (60km/h)
Speed limit (60km/h): 0.8522
Speed limit (50km/h): 0.1452
Speed limit (80km/h): 0.0026
No passing: 0.0000
No passing for vehicles over 3.5 metric tons: 0.0000
--------------------------------------------------
--------------------------------------------------
Correct image :  Keep right
Keep right: 1.0000
Go straight or right: 0.0000
Turn left ahead: 0.0000
Keep left: 0.0000
Ahead only: 0.0000
--------------------------------------------------
--------------------------------------------------
Correct image :  Go straight or left
Go straight or left: 1.0000
Ahead only: 0.0000
Roundabout mandatory: 0.0000
Road work: 0.0000
Turn right ahead: 0.0000
--------------------------------------------------
--------------------------------------------------
Correct image :  No passing
No passing: 0.9999
Vehicles over 3.5 metric tons prohibited: 0.0001
Speed limit (60km/h): 0.0000
Speed limit (20km/h): 0.0000
Children crossing: 0.0000
--------------------------------------------------
--------------------------------------------------
Correct image :  Dangerous curve to the left
Dangerous curve to the left: 0.9879
Slippery road: 0.0121
Wild animals crossing: 0.0000
Double curve: 0.0000
Bicycles crossing: 0.0000
--------------------------------------------------
--------------------------------------------------
Correct image :  Yield
Yield: 1.0000
Speed limit (30km/h): 0.0000
Priority road: 0.0000
No vehicles: 0.0000
Keep left: 0.0000
--------------------------------------------------
```

```
--------------------------------------------------
Correct image :  Speed limit (30km/h)
Speed limit (20km/h): 0.8353
Speed limit (60km/h): 0.0737
Speed limit (30km/h): 0.0477
Vehicles over 3.5 metric tons prohibited: 0.0248
Speed limit (80km/h): 0.0073
--------------------------------------------------
--------------------------------------------------
Correct image :  Go straight or right
Go straight or right: 1.0000
Turn left ahead: 0.0000
Ahead only: 0.0000
Turn right ahead: 0.0000
Keep right: 0.0000
--------------------------------------------------
--------------------------------------------------
Correct image :  Speed limit (50km/h)
Speed limit (30km/h): 0.6806
Roundabout mandatory: 0.1826
Right-of-way at the next intersection: 0.0508
Speed limit (70km/h): 0.0241
Pedestrians: 0.0186
--------------------------------------------------
--------------------------------------------------
Correct image :  No entry
No entry: 1.0000
Stop: 0.0000
Vehicles over 3.5 metric tons prohibited: 0.0000
No vehicles: 0.0000
Yield: 0.0000
--------------------------------------------------
--------------------------------------------------
Correct image :  Speed limit (100km/h)
Speed limit (120km/h): 0.9774
Keep left: 0.0063
Speed limit (20km/h): 0.0035
Speed limit (80km/h): 0.0030
Turn right ahead: 0.0030
--------------------------------------------------
--------------------------------------------------
Correct image :  End of all speed and passing limits
End of all speed and passing limits: 0.9954
End of speed limit (80km/h): 0.0044
End of no passing: 0.0002
End of no passing by vehicles over 3.5 metric tons: 0.0000
Priority road: 0.0000
```

How to improve

Following items may be considered.

1) Training set can be enriched to cover more signs.
2) A better architecture available can be used.
3) How the find ROI on the real world images should be worked.
4) Inputs from other sensors can be used as an input feature and this system can be used as a sensor fusion architecture.