Dataset exploration:

For the traffic sign classifier project, the “traffic-sign-data” data set which contains test.p, validation.p and train.p is used.

After exploring the data set, it was found that

Number of training examples	34799
Number of testing examples	12630
Image data shape	(32, 32, 3)
Number of Classes	43

To better understand the dataset, an exploratory visualization of the data set is done.

Preprocessing:

Adaptive Histogram equalization:

1. Normalization maps the pixel values in the range 0-1 which is very helpful with gradient descent as it has practical impact on the speed of convergence and stability.
2. Histogram Equalization would reduce the impact of varying contrast and illumination in images and thus make the model more robust to the same.

Augmenting the training data:

1. The training data defined above was augmented to obtain 5000 samples per class. The additional data was generated to increase samples for training, which in turn would make training more robust.
2. The newly generated dataset includes normalized original data, and newly generated data (by randomly introducing rotation, x-translation, y-translation, sheer factor and zoom factor to the original data).
3. The new dataset is balanced and had already been pre-processed for normalizing contrast and illumination.

To prevent data leakage from test data set during training, the training data set is divided into training, validation and testing data.

Model Architecture:

If a well-known architecture was chosen:

What architecture was chosen?

Lenet 5 architecture is implemented. LeNet-5 has multiple layers and can be trained with the backpropagation algorithm. It can obtain effective representations of the original image, which makes it possible to recognize visual patterns directly from raw pixels with little-to-none preprocessing

Why did you believe it would be relevant to the traffic sign application?

The LeNet architecture with 5 layers is used in this project as the problem description is similar to character classification problem on which LeNet was applied

Lenet 5 architecture can handle translation, scaling, rotation, aspect ratio and stroke width of the characters in the images. This capability is needed for classifying traffic signs necessary since the positioning of the traffic signs in the image is never perfect

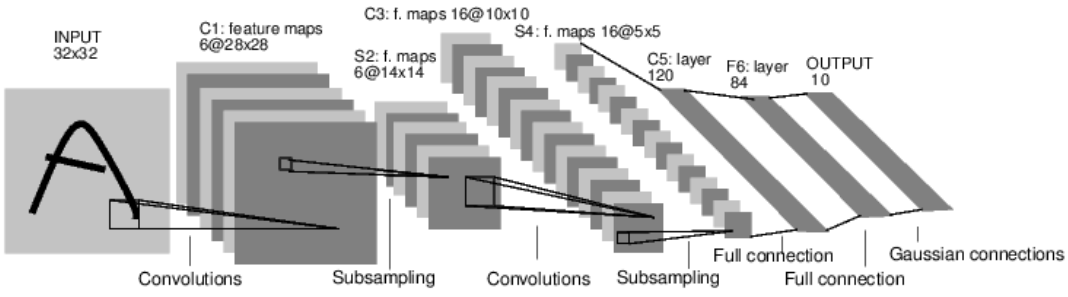
The text and shapes in the sign board is predicted in the same way by the Lenet 5 as predicting optical characters since it first detects basic components in the image like lines, curves etc which is common for both traffic signs and optical characters.

How does the final model's accuracy on the training, validation and test set provide evidence that the model is working well?

Dropouts were not introduced as the model did not overfit. The accuracy on the train, validation and test dataset are 99.4%,99.2% and 94.4% respectively which proves that the model is working fine.

Architecture:

The LeNet architecture only accepts 32x32xC images, where C is the number of color channels. As we have color images in this project, C value of 3 is chosen (RGB)



Layer 1:

Convolutional. The output shape is 28x28x6.

Activation. Rectified Linear Unit (ReLU)

Pooling. The output shape is 14x14x6.

Layer 2:

Convolutional. The output shape is 10x10x16.

Activation. Rectified Linear Unit (ReLU)

Pooling. The output shape is 5x5x16.

Flatten. Flatten the output shape of the final pooling layer such that it's 1D instead of 3D. The easiest way to do is by using tf.contrib.layers.flatten

Layer 3:

Fully Connected. It has 120 outputs.

Activation. Rectified Linear Unit (ReLU)

Layer 4: Fully Connected. It has 84 outputs.

Activation. Rectified Linear Unit (ReLU)

Layer 5: Fully Connected (Logits). It has 43 outputs.

Model Training:

Optimizer: AdamOptimizer for managing learning rate

Batch Size: 128

Just a small discrepancy between the code and the reported number of epochs. Please amend the write-up.

Epochs: 30

Variables initialized with normal distribution (mean=0, std dev=0.1)

Biases initialized with zeros

Testing on new images:

12 new images are downloaded from internet out of which 4 are from real life.

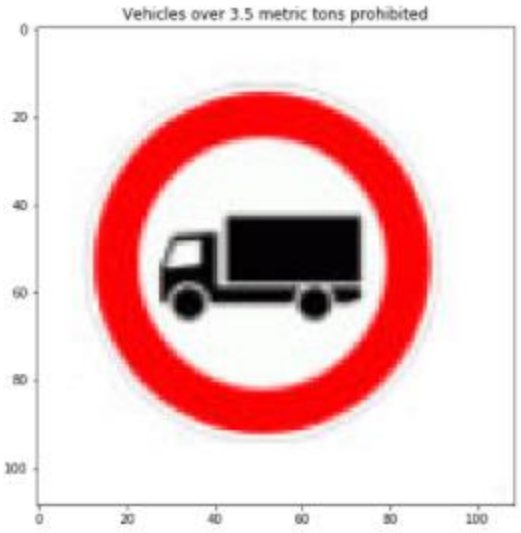
Discuss at least one characteristic of these new images that might make it easy / difficult for the classifier to classify them

The dataset provided to train the model is the German Traffic Signs Dataset. As the new images are of Germany Traffic Sign itself, it should not be difficult for model to predict.

Performance on new images:

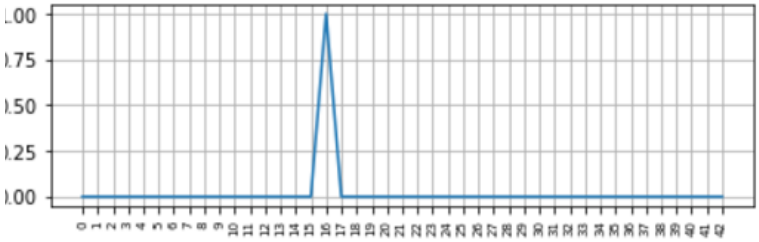
Be sure to also compare the accuracy of the model when tested on the new images to its accuracy in the original test set.

11/12 are being classified correctly.



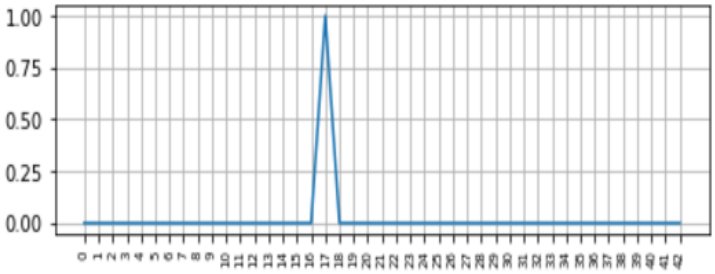
Correct class: Vehicles over 3.5 metric tons prohibited(label 16)

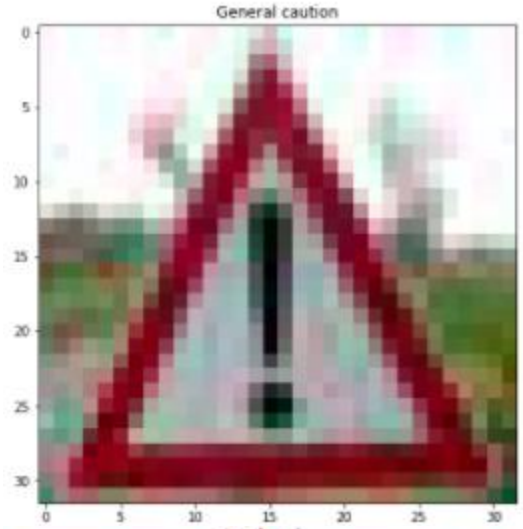
Predicted class: Vehicles over 3.5 metric tons prohibited (label 16)



Correct class: No Entry(label 17)

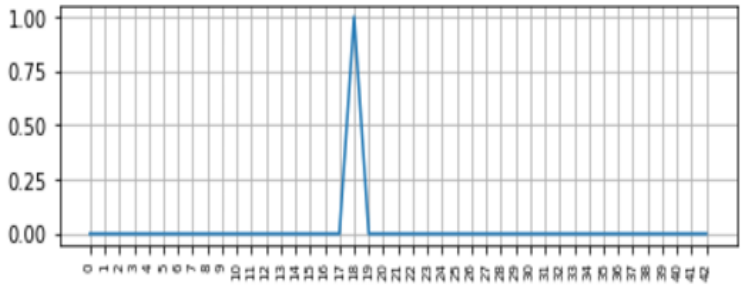
Predicted class: No Entry(label 17)

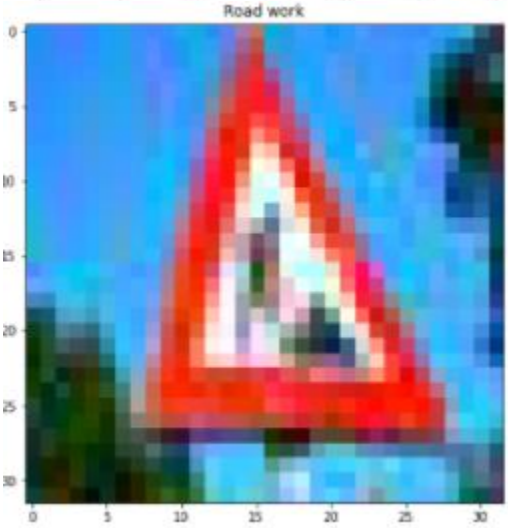




Correct class: General Caution (label 18)

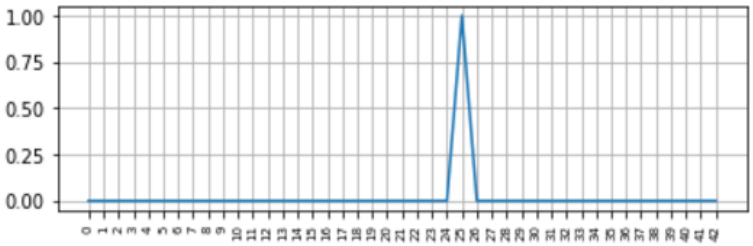
Predicted class: General Caution (label 18)

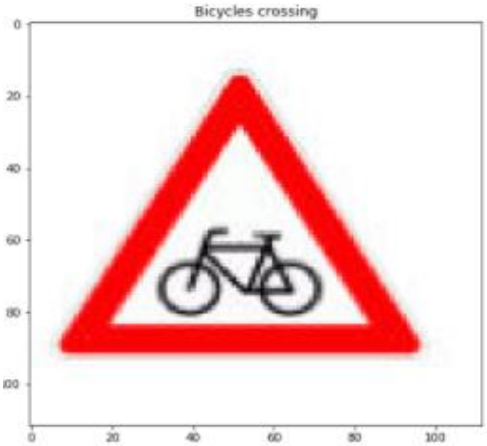




Correct class: Road Work (label 25)

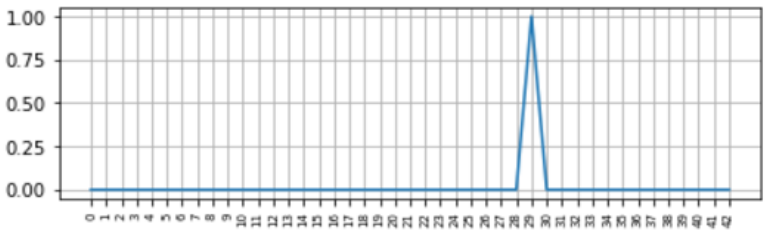
Predicted class: Road Work (label 25)

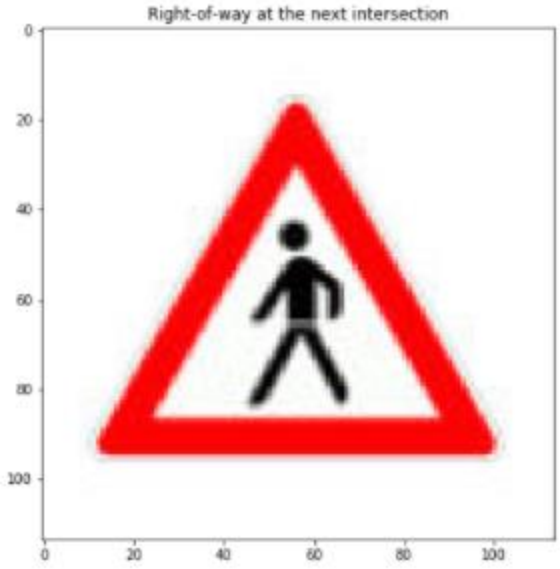




Correct class: Bicycle crossing (label 29)

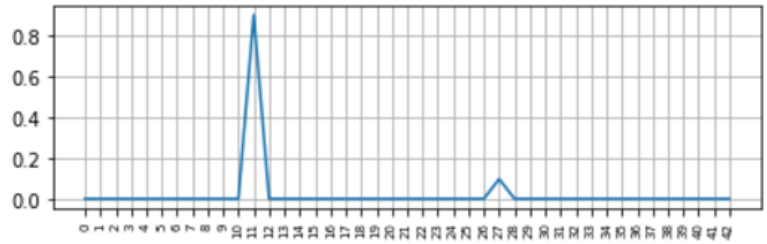
Predicted class: Bicycle crossing (label 29)



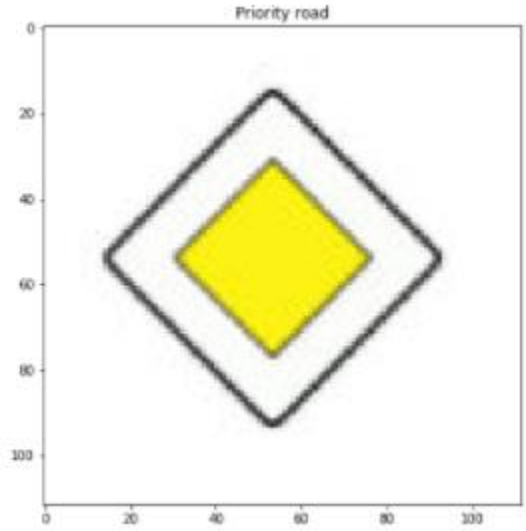


Correct class: Pedestrians (label 27)

Predicted class: Right-of-way at the next intersection (label 11)

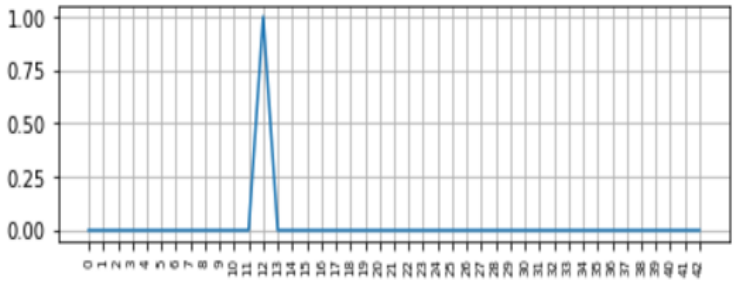


It has the correct prediction (pedestrians- label 27) in the top 5 predictions



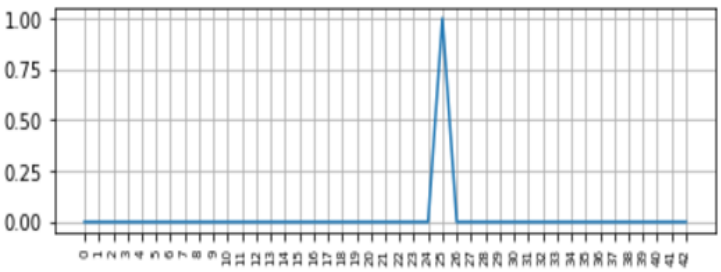
Correct class: Priority Road (label 12)

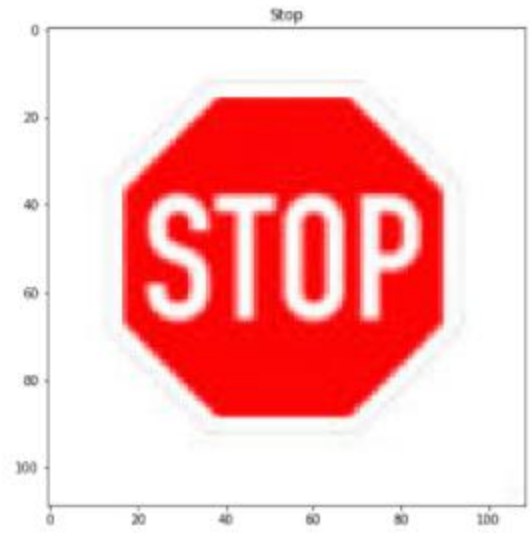
Predicted class: Priority Road (label 12)



Correct class: Road Work (label 25)

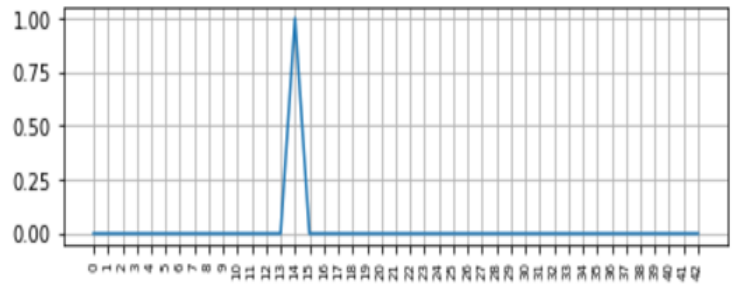
Predicted class: Road Work (label 25)

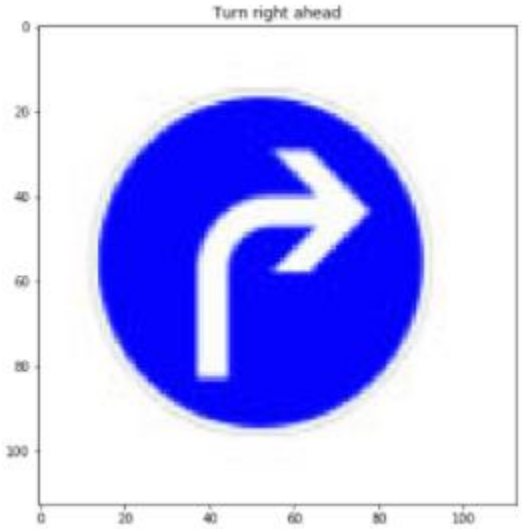




Correct class: Stop (label 14)

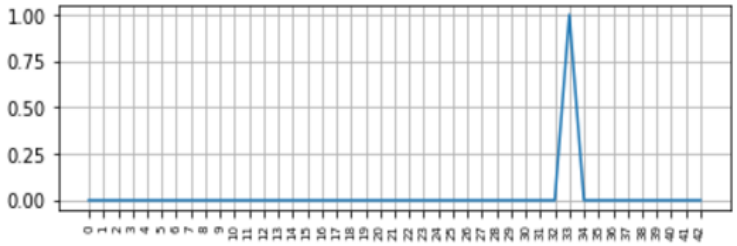
Predicted class: Stop (label 14)

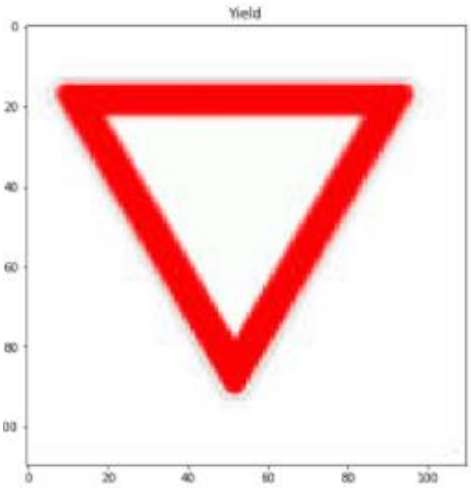




Correct class: Turn right ahead (label 33)

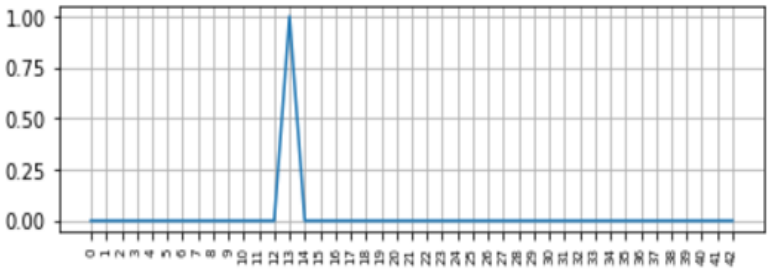
Predicted class: Turn right ahead (label 33)

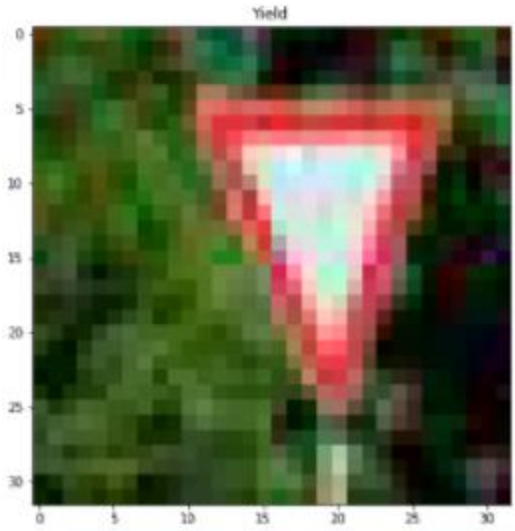




Correct class: Yield (label 13)

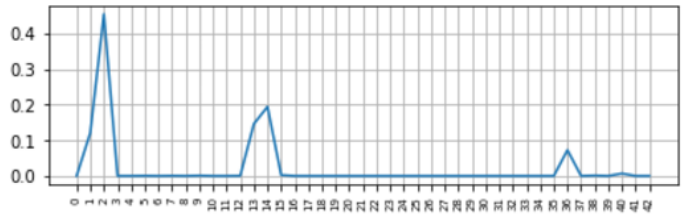
Predicted class: Yield (label 13)





Correct class: Yield (label 13)

Predicted class: Speed limit (50kph) (label 2)



The labels predicted are : Speed limit(30kph), Speed limit(50kph), yield, Stop, Go straight or right

(10/12)*100 => 83.33%

The accuracy on new images is 83.33% whereas the accuracy in the original test set is 94.4 %

You also need to discuss the certainties of the model's predictions in your write-up. Which predictions are the model certain of? Uncertain? In case the prediction was incorrect, did the correct prediction appear in the top five?

Below is the snapshot from the notebook output to illustrate the certainity. It can be seen that

- Misclassification percentage of End of speed limit (80km/h), Dangerous curve to the left, double curve, Pedestrians, Beware of ice/snow and End of no passing are very high(>=15%)
- Most of the classes are being misclassified as Speed limit (80km/h)
- Also, the model has accuracy and precision greater than 90% for most of the classes.

```
Class Speed limit (20km/h):
  Accuracy = 96.67%
  Precision = 95.08%
  Maximum Misclassified as: Speed limit (30km/h)
  Misclassification Percentage for above class: 1.67%

Class Speed limit (30km/h):
  Accuracy = 94.72%
  Precision = 97.29%
  Maximum Misclassified as: Speed limit (50km/h)
  Misclassification Percentage for above class: 2.36%

Class Speed limit (50km/h):
  Accuracy = 97.47%
  Precision = 96.06%
  Maximum Misclassified as: Speed limit (80km/h)
  Misclassification Percentage for above class: 1.07%

Class Speed limit (60km/h):
  Accuracy = 90.44%
  Precision = 97.60%
  Maximum Misclassified as: Speed limit (80km/h)
  Misclassification Percentage for above class: 7.11%

Class Speed limit (70km/h):
  Accuracy = 96.36%
  Precision = 97.55%
  Maximum Misclassified as: Speed limit (30km/h)
  Misclassification Percentage for above class: 1.06%

Class Speed limit (80km/h):
  Accuracy = 95.71%
  Precision = 89.33%
  Maximum Misclassified as: Speed limit (100km/h)
  Misclassification Percentage for above class: 1.43%

Class End of speed limit (80km/h):
  Accuracy = 76.00%
  Precision = 99.13%
  Maximum Misclassified as: End of no passing by vehicles over 3.5 metric tons
  Misclassification Percentage for above class: 21.33%

Class Speed limit (100km/h):
  Accuracy = 97.33%
  Precision = 96.90%
  Maximum Misclassified as: Speed limit (80km/h)
  Misclassification Percentage for above class: 0.67%
```

```
Class Speed limit (120km/h):
  Accuracy = 96.67%
  Precision = 98.19%
  Maximum Misclassified as: Speed limit (80km/h)
  Misclassification Percentage for above class: 2.22%

Class No passing:
  Accuracy = 99.58%
  Precision = 95.98%
  Maximum Misclassified as: No passing for vehicles over 3.5 metric tons
  Misclassification Percentage for above class: 0.42%

Class No passing for vehicles over 3.5 metric tons:
  Accuracy = 98.79%
  Precision = 98.34%
  Maximum Misclassified as: Speed limit (80km/h)
  Misclassification Percentage for above class: 0.45%

Class Right-of-way at the next intersection:
  Accuracy = 95.71%
  Precision = 82.38%
  Maximum Misclassified as: Beware of ice/snow
  Misclassification Percentage for above class: 1.43%

Class Priority road:
  Accuracy = 99.13%
  Precision = 99.71%
  Maximum Misclassified as: No vehicles
  Misclassification Percentage for above class: 0.43%

Class Yield:
  Accuracy = 98.75%
  Precision = 99.72%
  Maximum Misclassified as: No vehicles
  Misclassification Percentage for above class: 0.42%

Class Stop:
  Accuracy = 100.00%
  Precision = 97.47%

Class No vehicles:
  Accuracy = 96.67%
  Precision = 96.67%
  Maximum Misclassified as: No passing
  Misclassification Percentage for above class: 2.86%

Class Vehicles over 3.5 metric tons prohibited:
  Accuracy = 100.00%
  Precision = 98.68%
```

```
Class No entry:
  Accuracy = 97.78%
  Precision = 100.00%
  Maximum Misclassified as: Stop
  Misclassification Percentage for above class: 1.39%

Class General caution:
  Accuracy = 86.67%
  Precision = 95.48%
  Maximum Misclassified as: Right-of-way at the next intersection
  Misclassification Percentage for above class: 3.85%

Class Dangerous curve to the left:
  Accuracy = 78.33%
  Precision = 55.29%
  Maximum Misclassified as: Slippery road
  Misclassification Percentage for above class: 21.67%

Class Dangerous curve to the right:
  Accuracy = 91.11%
  Precision = 81.19%
  Maximum Misclassified as: No passing
  Misclassification Percentage for above class: 4.44%

Class Double curve:
  Accuracy = 62.22%
  Precision = 74.67%
  Maximum Misclassified as: General caution
  Misclassification Percentage for above class: 11.11%

Class Bumpy road:
  Accuracy = 88.33%
  Precision = 99.07%
  Maximum Misclassified as: Road narrows on the right
  Misclassification Percentage for above class: 3.33%

Class Slippery road:
  Accuracy = 98.67%
  Precision = 66.37%
  Maximum Misclassified as: Right-of-way at the next intersection
  Misclassification Percentage for above class: 0.67%

Class Road narrows on the right:
  Accuracy = 83.33%
  Precision = 90.36%
  Maximum Misclassified as: Double curve
  Misclassification Percentage for above class: 4.44%
```

```
Class Road work:
  Accuracy = 81.88%
  Precision = 98.00%
  Maximum Misclassified as: Right-of-way at the next intersection
  Misclassification Percentage for above class: 8.75%

Class Traffic signals:
  Accuracy = 97.78%
  Precision = 90.72%
  Maximum Misclassified as: General caution
  Misclassification Percentage for above class: 1.11%

Class Pedestrians:
  Accuracy = 51.67%
  Precision = 62.00%
  Maximum Misclassified as: Double curve
  Misclassification Percentage for above class: 20.00%

Class Children crossing:
  Accuracy = 90.67%
  Precision = 96.45%
  Maximum Misclassified as: Bicycles crossing
  Misclassification Percentage for above class: 6.00%

Class Bicycles crossing:
  Accuracy = 97.78%
  Precision = 84.62%
  Maximum Misclassified as: Double curve
  Misclassification Percentage for above class: 1.11%

Class Beware of ice/snow:
  Accuracy = 53.33%
  Precision = 89.89%
  Maximum Misclassified as: Slippery road
  Misclassification Percentage for above class: 21.33%

Class Wild animals crossing:
  Accuracy = 99.63%
  Precision = 92.76%
  Maximum Misclassified as: Dangerous curve to the right
  Misclassification Percentage for above class: 0.37%

Class End of all speed and passing limits:
  Accuracy = 100.00%
  Precision = 95.24%

Class Turn right ahead:
  Accuracy = 99.52%
  Precision = 94.57%
  Maximum Misclassified as: Ahead only
  Misclassification Percentage for above class: 0.48%

Class Turn left ahead:
  Accuracy = 98.33%
  Precision = 88.06%
  Maximum Misclassified as: Go straight or right
```

```
Class Ahead only:
  Accuracy = 94.36%
  Precision = 98.92%
  Maximum Misclassified as: Turn left ahead
  Misclassification Percentage for above class: 2.56%

Class Go straight or right:
  Accuracy = 100.00%
  Precision = 95.24%

Class Go straight or left:
  Accuracy = 100.00%
  Precision = 93.75%

Class Keep right:
  Accuracy = 97.39%
  Precision = 99.85%
  Maximum Misclassified as: Roundabout mandatory
  Misclassification Percentage for above class: 1.30%

Class Keep left:
  Accuracy = 90.00%
  Precision = 98.78%
  Maximum Misclassified as: Turn right ahead
  Misclassification Percentage for above class: 8.89%

Class Roundabout mandatory:
  Accuracy = 95.56%
  Precision = 81.90%
  Maximum Misclassified as: Go straight or right
  Misclassification Percentage for above class: 2.22%

Class End of no passing:
  Accuracy = 78.33%
  Precision = 78.33%
  Maximum Misclassified as: End of no passing by vehicles over 3.5 metric tons
  Misclassification Percentage for above class: 16.67%

Class End of no passing by vehicles over 3.5 metric tons:
  Accuracy = 82.22%
  Precision = 63.25%
  Maximum Misclassified as: End of no passing
  Misclassification Percentage for above class: 13.33%
```

Reference:

- https://github.com/sumitbinnani/CarND-Traffic-Sign-Classifier-Project/blob/master/Traffic_Sign_Classifier.ipynb

- https://arxiv.org/pdf/1512.07108.pdf
- https://books.google.com.sg/books?id=AgyVCgAAQBAJ&pg=PA249&lpg=PA249&dq=traffic+sign+classifier+similarities+with+lenet+5&source=bl&ots=8nKcHVS4Ts&sig=fv3NRarArUgutg6aWChnds_DStY&hl=en&sa=X&ved=0ahUKEwjrgZPw8ODUAhVLro8KHXYVBmIQ6AEIXDAI#v=onepage&q=traffic%20sign%20classifier%20similarities%20with%20lenet%205&f=false
-