Advancing Road Safety: Traffic Sign Recognition

Modified LeNet-5 CNN Classification on GTSRB Dataset

Introduction to GTSRB

- **German Traffic Sign Recognition Benchmark**

- Introduced in 2011: large, lifelike dataset capturing real-world variability.

- 43 classes, 51,839 images
- Image sizes: 15x15 to 250x250 pixels
- Train, Test, Meta (csv files for class reference)

- From video sequences on German roads
- Reflects actual sign frequency on roads

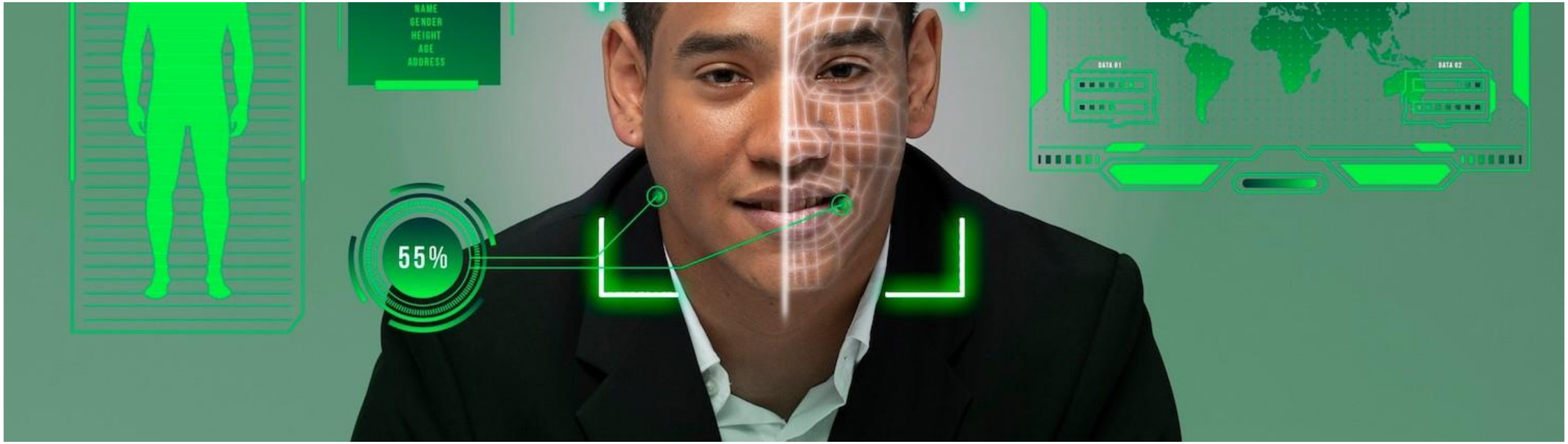
- natural class imbalance, varying illumination, and occlusions

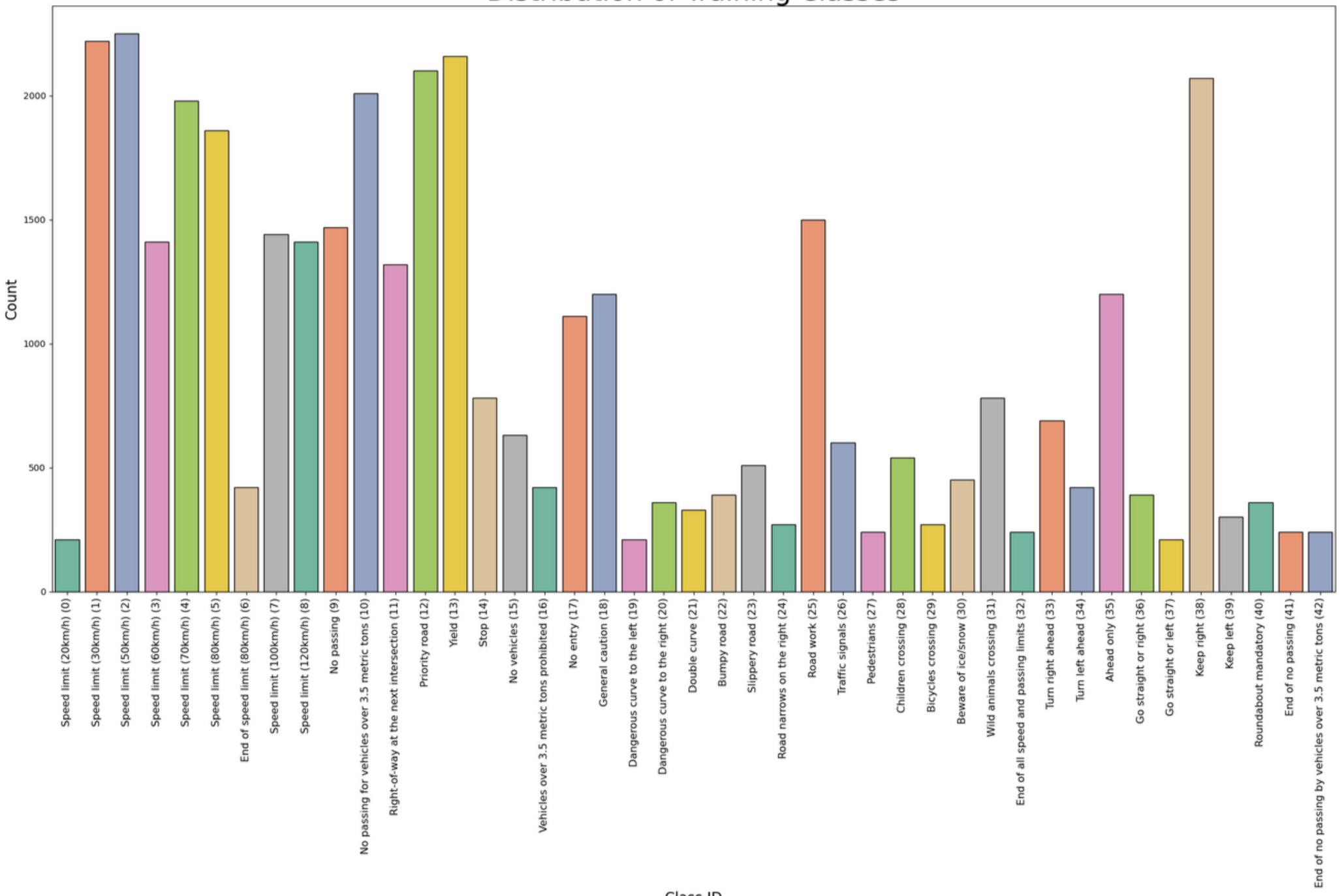
Why Traffic Sign Recognition?

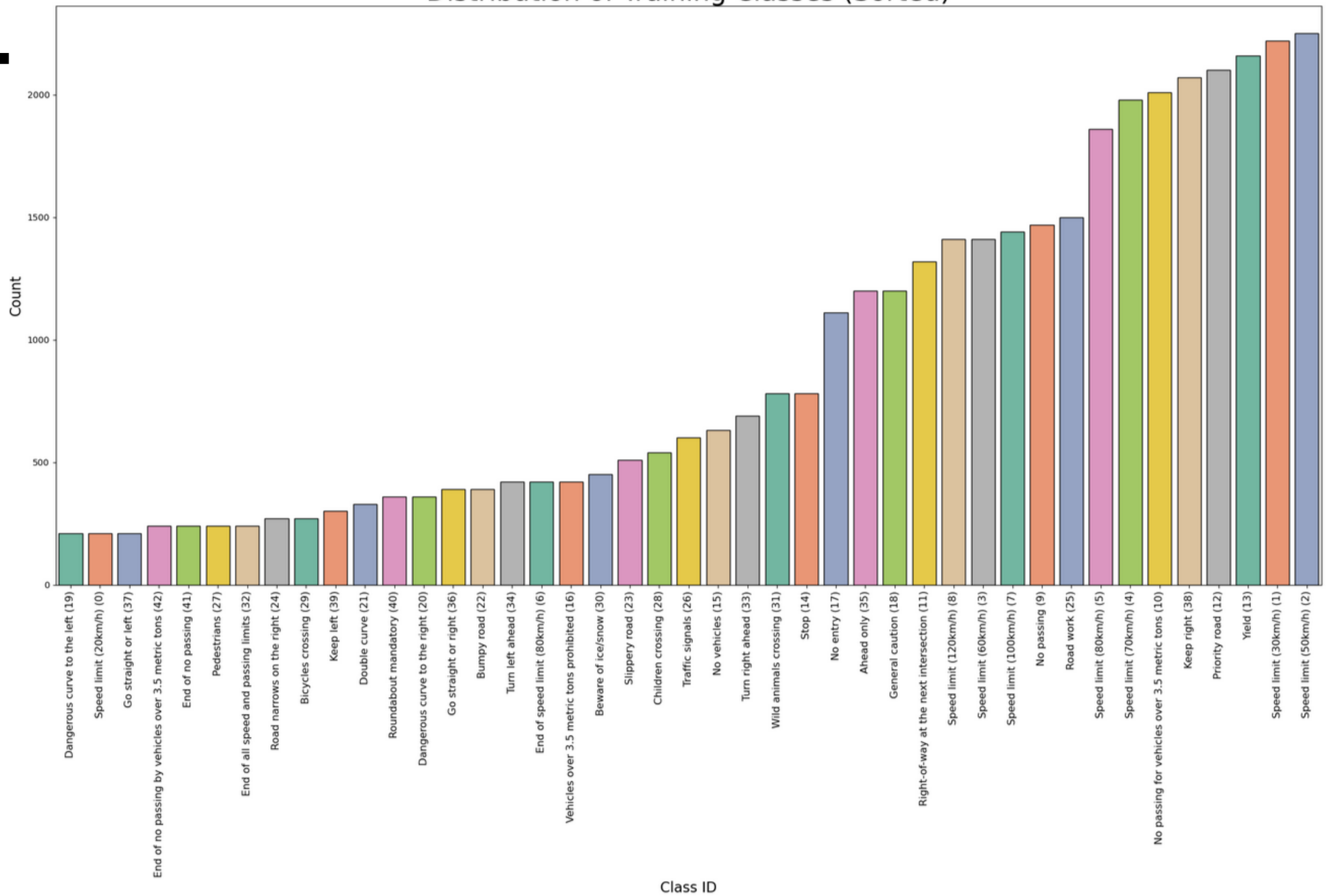
- ADAS Integration: Real-time speed limit detection and warning
- Traffic Monitoring: Automated sign inventory and maintenance

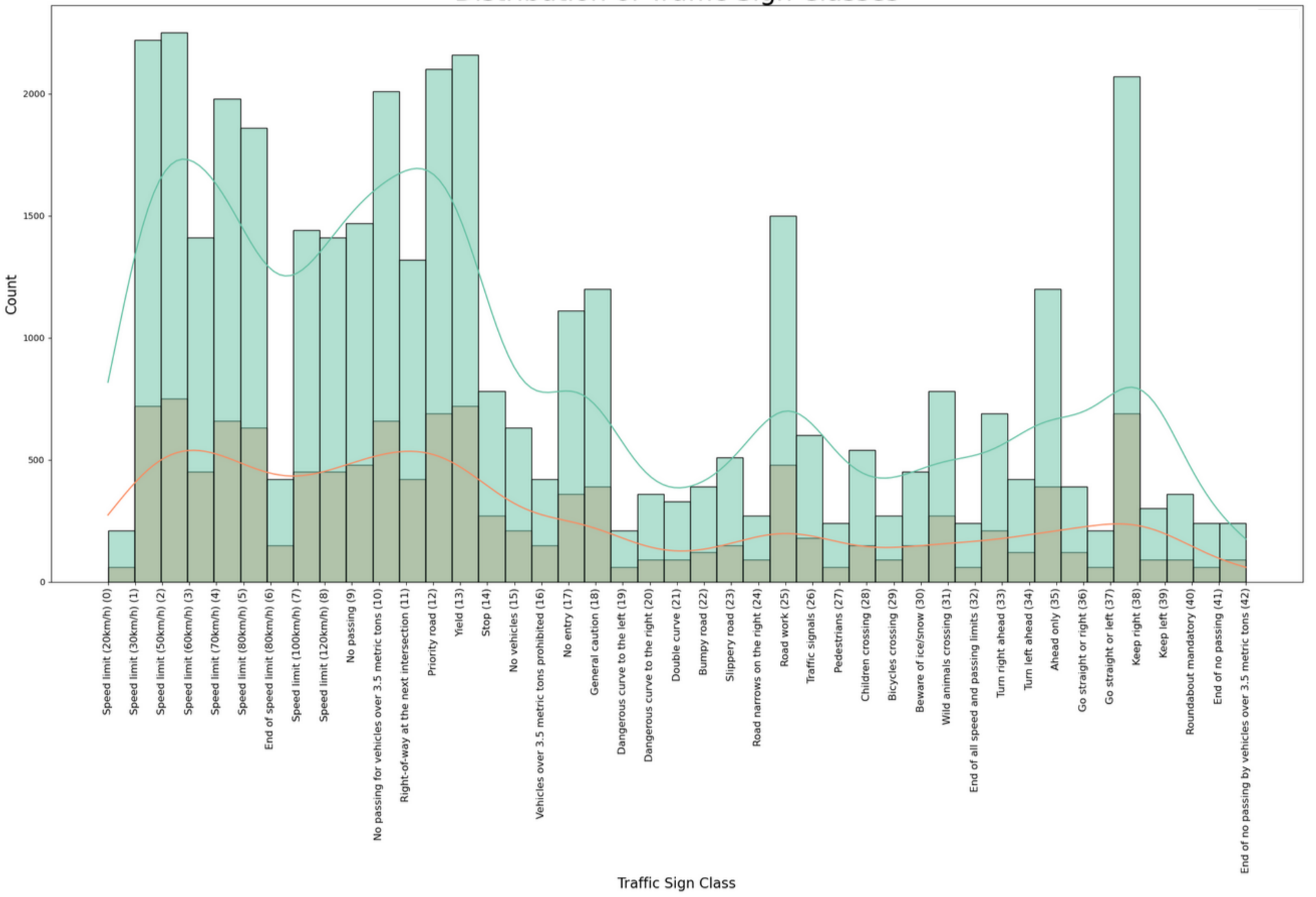
- GPS Enhancement: Context-aware navigation instructions
- Potential for reducing accidents

- Keras/Tensorflow help simulate the sign monitoring system with CNN architecture!




Distribution of Training Classes
Count
0
500
1000
1500
2000
Speed limit (20km/h) (0)
Speed limit (30km/h) (1)
Speed limit (50km/h) (2)
Speed limit (60km/h) (3)
Speed limit (70km/h) (4)
Speed limit (80km/h) (5)
End of speed limit (80km/h) (6)
Speed limit (100km/h) (7)
Speed limit (120km/h) (8)
No passing (9)
No passing for vehicles over 3.5 metric tons (10)
Right-of-way at the next intersection (11)
Priority road (12)
Yield (13)
Stop (14)
No vehicles (15)
Vehicles over 3.5 metric tons prohibited (16)
No entry (17)
General caution (18)
Dangerous curve to the left (19)
Dangerous curve to the right (20)
Double curve (21)
Bumpy road (22)
Slippery road (23)
Road narrows on the right (24)
Road work (25)
Traffic signals (26)
Pedestrians (27)
Children crossing (28)
Bicycles crossing (29)
Beware of ice/snow (30)
Wild animals crossing (31)
End of all speed and passing limits (32)
Turn right ahead (33)
Turn left ahead (34)
Ahead only (35)
Go straight or right (36)
Go straight or left (37)
Keep right (38)
Keep left (39)
Roundabout mandatory (40)
End of no passing (41)
End of no passing by vehicles over 3.5 metric tons (42)
Class ID


Distribution of Training Classes (Sorted)
Count
0
500
1000
1500
2000
Class ID
Dangerous curve to the left (19)
Speed limit (20km/h) (0)
Go straight or left (37)
End of no passing by vehicles over 3.5 metric tons (42)
End of no passing (41)
Pedestrians (27)
End of all speed and passing limits (32)
Road narrows on the right (24)
Bicycles crossing (29)
Keep left (39)
Double curve (21)
Roundabout mandatory (40)
Dangerous curve to the right (20)
Go straight or right (36)
Bumpy road (22)
Turn left ahead (34)
End of speed limit (80km/h) (6)
Vehicles over 3.5 metric tons prohibited (16)
Beware of ice/snow (30)
Slippery road (23)
Children crossing (28)
Traffic signals (26)
No vehicles (15)
Turn right ahead (33)
Wild animals crossing (31)
Stop (14)
No entry (17)
Ahead only (35)
General caution (18)
Right-of-way at the next intersection (11)
Speed limit (120km/h) (8)
Speed limit (60km/h) (3)
Speed limit (100km/h) (7)
No passing (9)
Road work (25)
Speed limit (80km/h) (5)
Speed limit (70km/h) (4)
No passing for vehicles over 3.5 metric tons (10)
Keep right (38)
Priority road (12)
Yield (13)
Speed limit (30km/h) (1)
Speed limit (50km/h) (2)


Distribution of Traffic Sign Classes
Count
0
500
1000
1500
2000
Speed limit (20km/h) (0)
Speed limit (30km/h) (1)
Speed limit (50km/h) (2)
Speed limit (60km/h) (3)
Speed limit (70km/h) (4)
Speed limit (80km/h) (5)
End of speed limit (80km/h) (6)
Speed limit (100km/h) (7)
Speed limit (120km/h) (8)
No passing (9)
No passing for vehicles over 3.5 metric tons (10)
Right-of-way at the next intersection (11)
Priority road (12)
Yield (13)
Stop (14)
No vehicles (15)
Vehicles over 3.5 metric tons prohibited (16)
No entry (17)
General caution (18)
Dangerous curve to the left (19)
Dangerous curve to the right (20)
Double curve (21)
Bumpy road (22)
Slippery road (23)
Road narrows on the right (24)
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Traffic signals (26)
Pedestrians (27)
Children crossing (28)
Bicycles crossing (29)
Beware of ice/snow (30)
Wild animals crossing (31)
End of all speed and passing limits (32)
Turn right ahead (33)
Turn left ahead (34)
Ahead only (35)
Go straight or right (36)
Go straight or left (37)
Keep right (38)
Keep left (39)
Roundabout mandatory (40)
End of no passing (41)
End of no passing by vehicles over 3.5 metric tons (42)
Traffic Sign Class

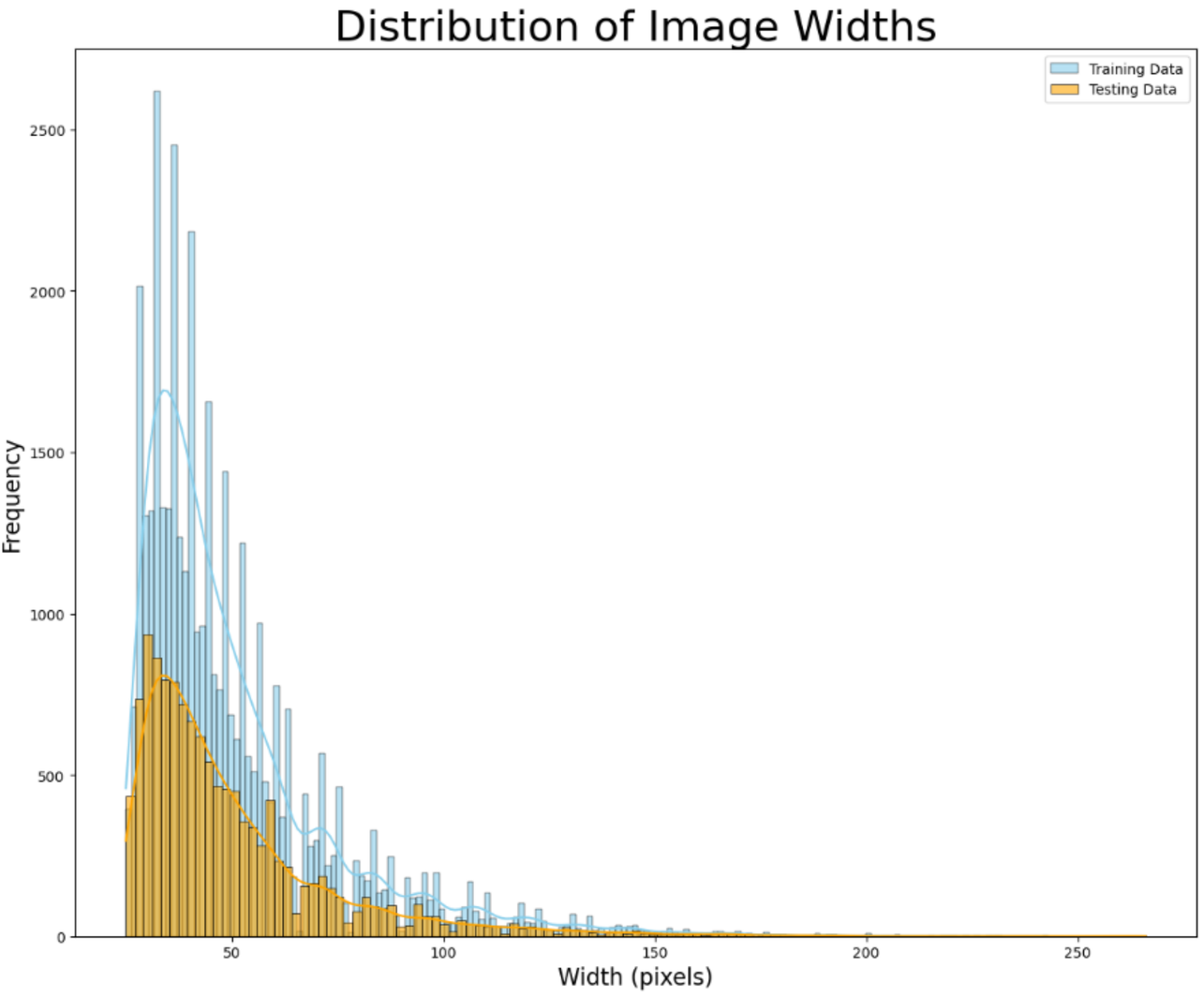
Top Ten Traffic Sign Classes

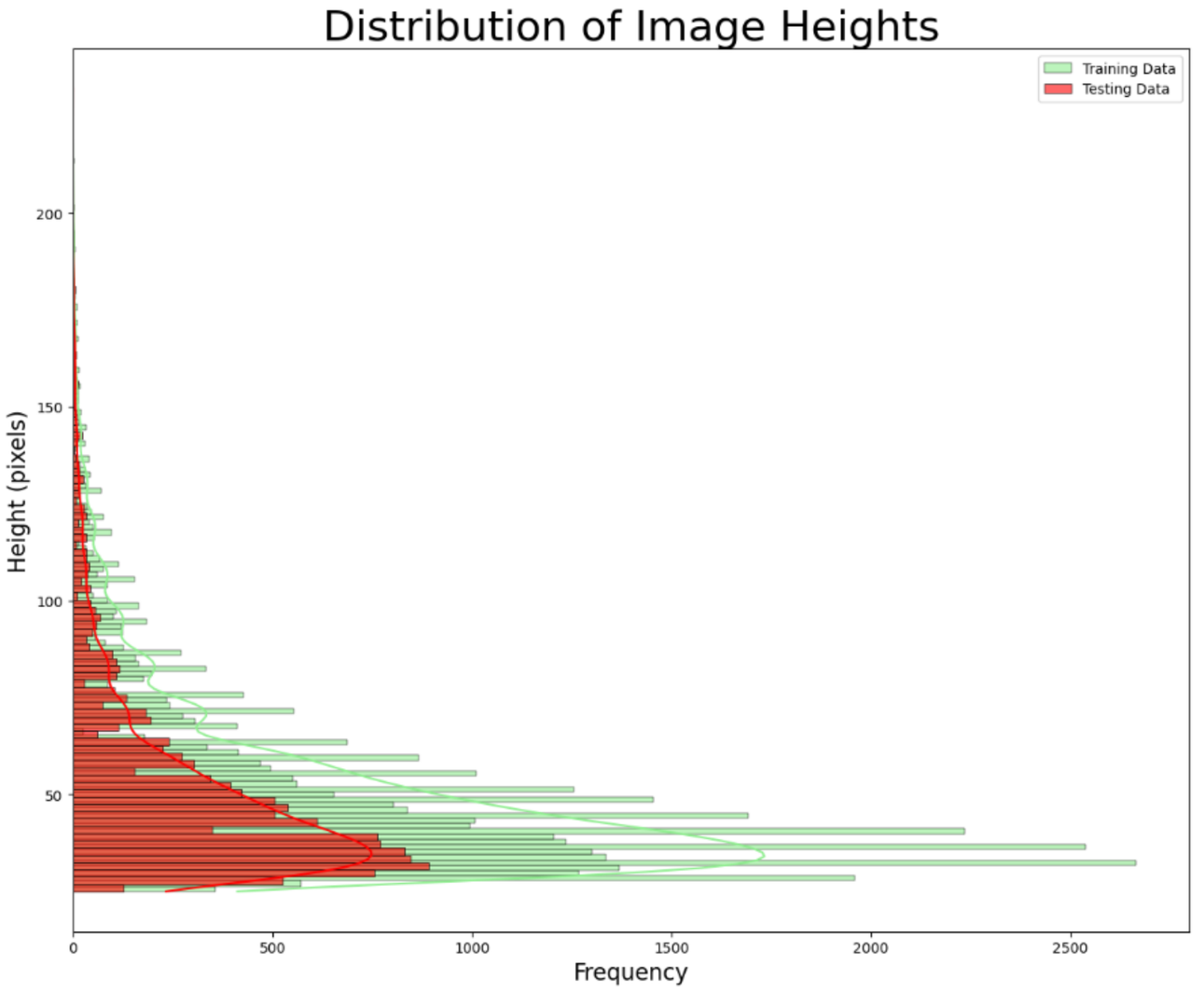
ClassId	Train Count	Train Percentage	Test Count	Test Percentage	SignName
2	2250	5.738478	750	5.938242	Speed limit (50km/h)
1	2220	5.661965	720	5.700713	Speed limit (30km/h)
13	2160	5.508939	720	5.700713	Yield
12	2100	5.355913	690	5.463183	Priority road
38	2070	5.279400	690	5.463183	Keep right
10	2010	5.126374	660	5.225653	No passing for vehicles over 3.5 metric tons
4	1980	5.049861	660	5.225653	Speed limit (70km/h)
5	1860	4.743809	630	4.988124	Speed limit (80km/h)
25	1500	3.825652	480	3.800475	Road work
9	1470	3.749139	480	3.800475	No passing

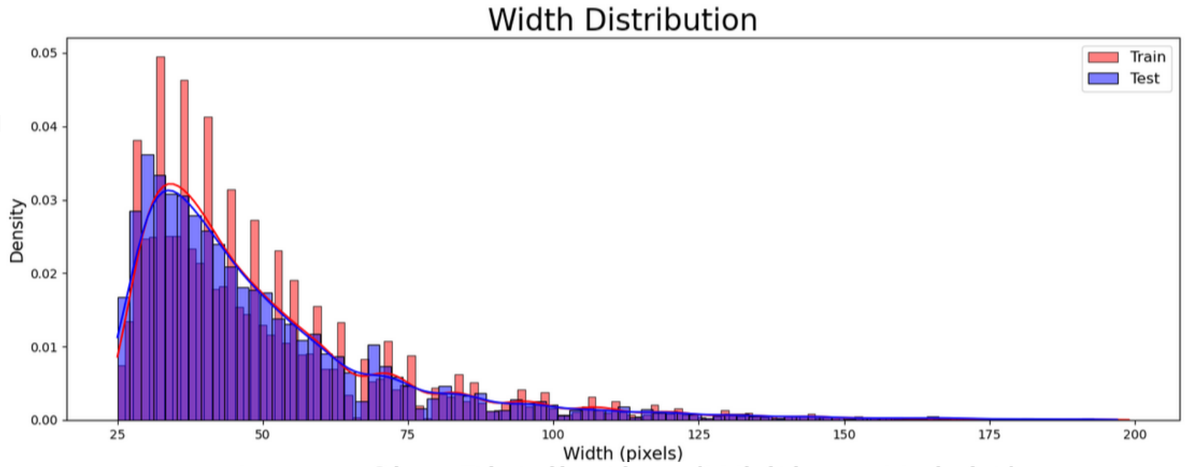
Bottom Ten Traffic Sign Classes

ClassId	Train Count	Train Percentage	Test Count	Test Percentage	SignName
19	210	0.535591	60	0.475059	Dangerous curve to the left
0	210	0.535591	60	0.475059	Speed limit (20km/h)
37	210	0.535591	60	0.475059	Go straight or left
42	240	0.612104	90	0.712589	End of no passing by vehicles over 3.5 metric ...
41	240	0.612104	60	0.475059	End of no passing
27	240	0.612104	60	0.475059	Pedestrians
32	240	0.612104	60	0.475059	End of all speed and passing limits
24	270	0.688617	90	0.712589	Road narrows on the right
29	270	0.688617	90	0.712589	Bicycles crossing
39	300	0.765130	90	0.712589	Keep left

CSV Metadata

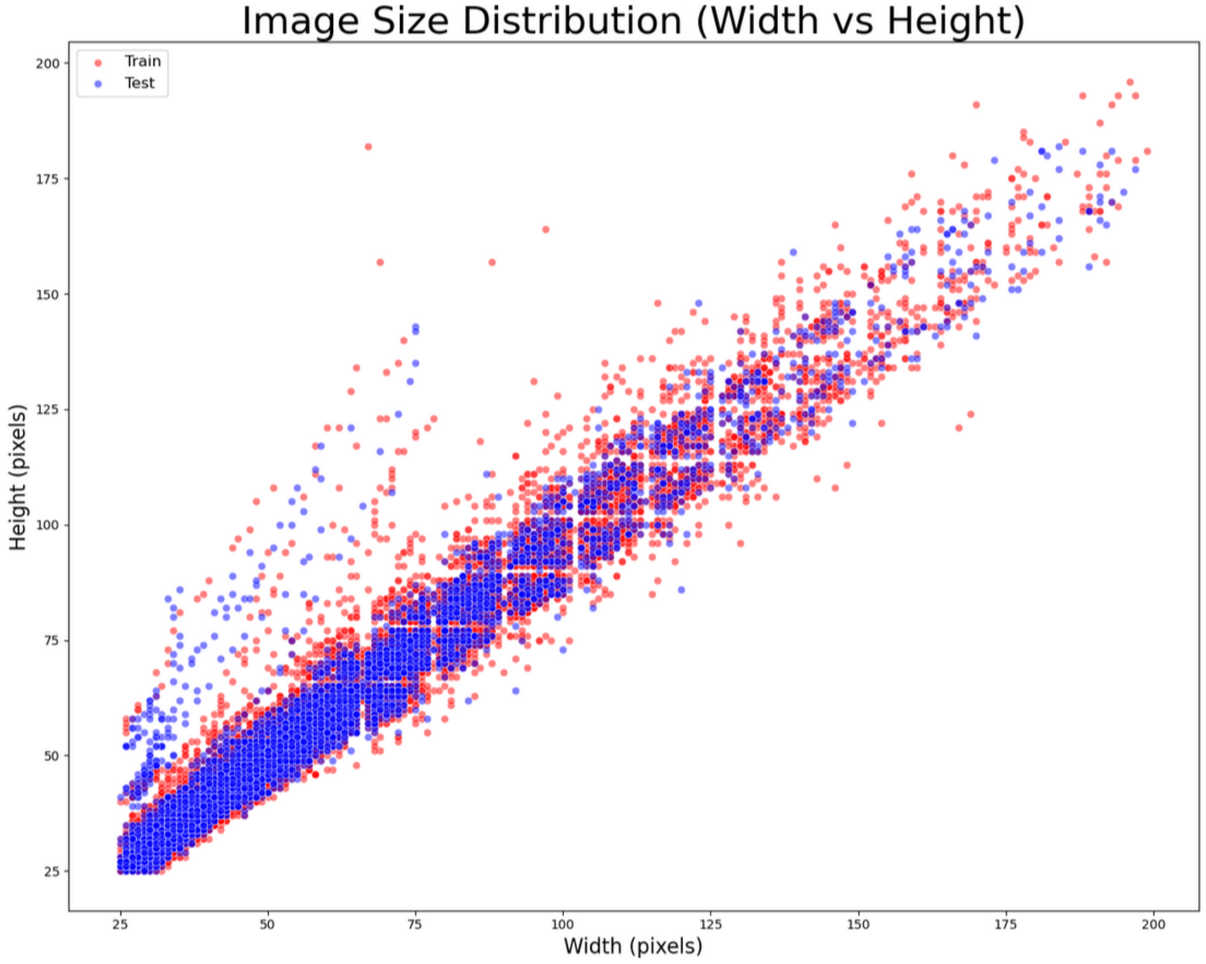


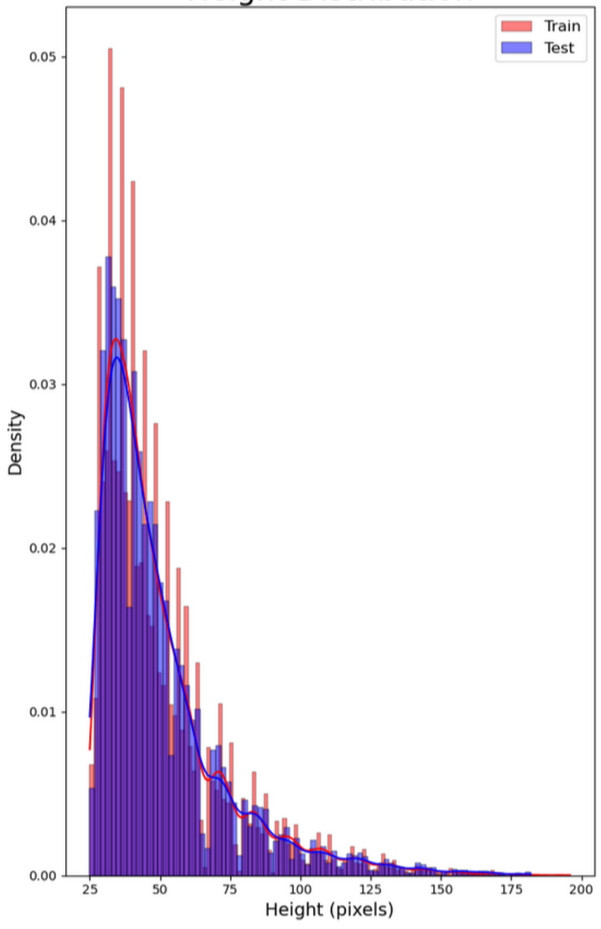


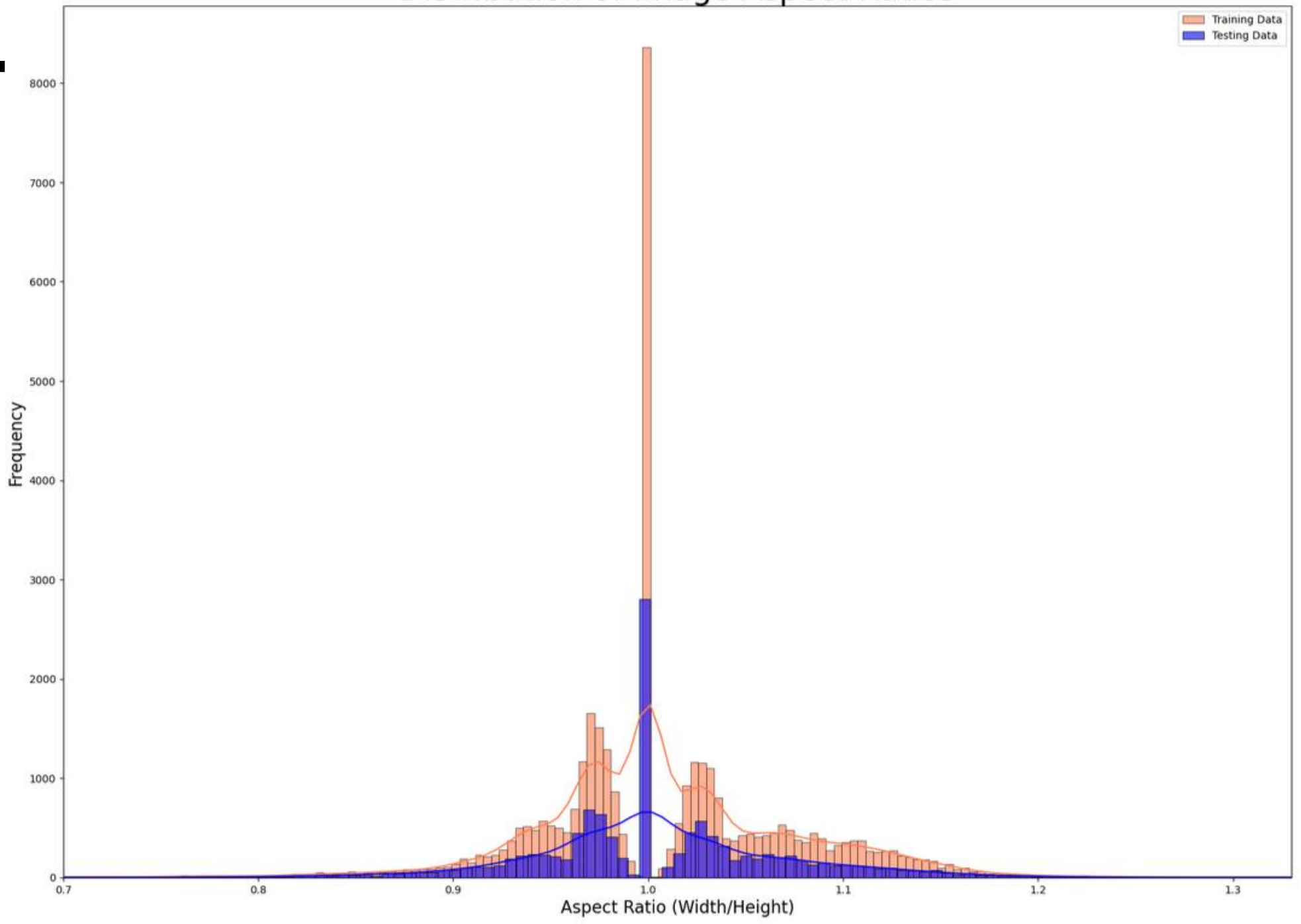


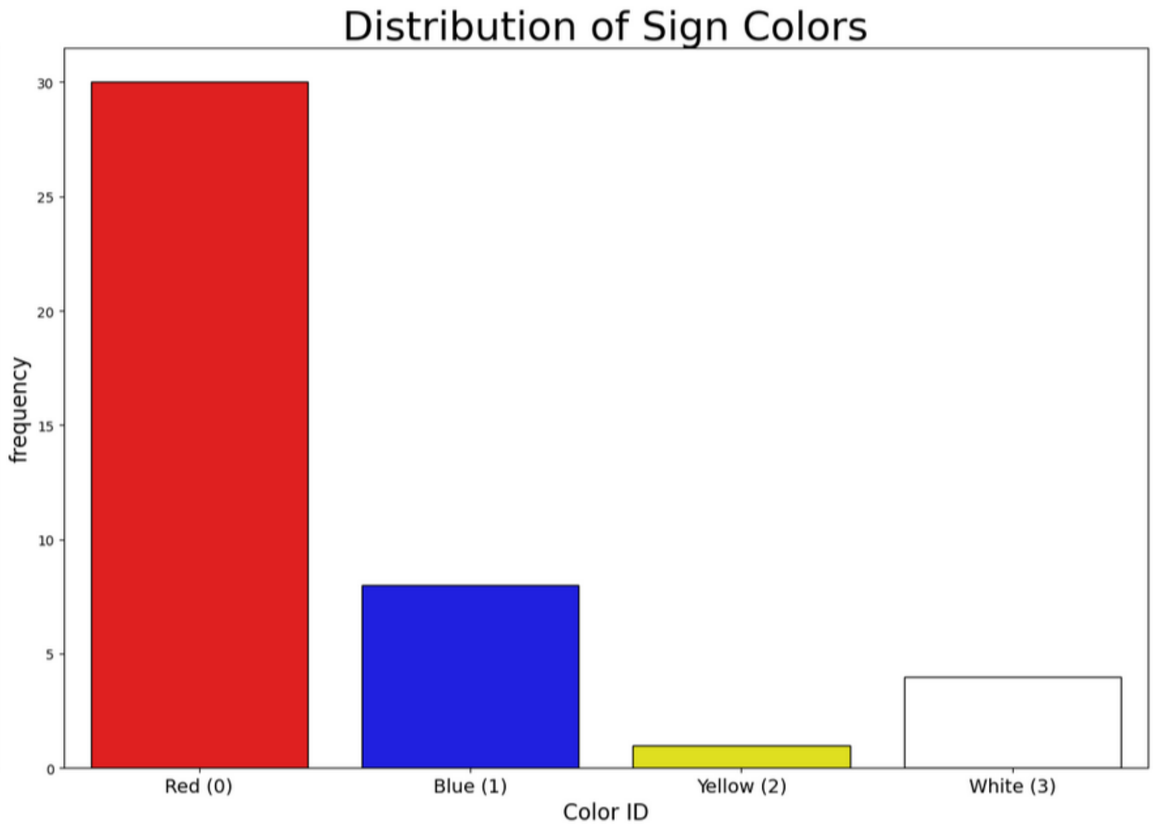
Train set:
Mean Width: 50.72
Mean Height: 50.23
Std Width: 23.93
Std Height: 22.80

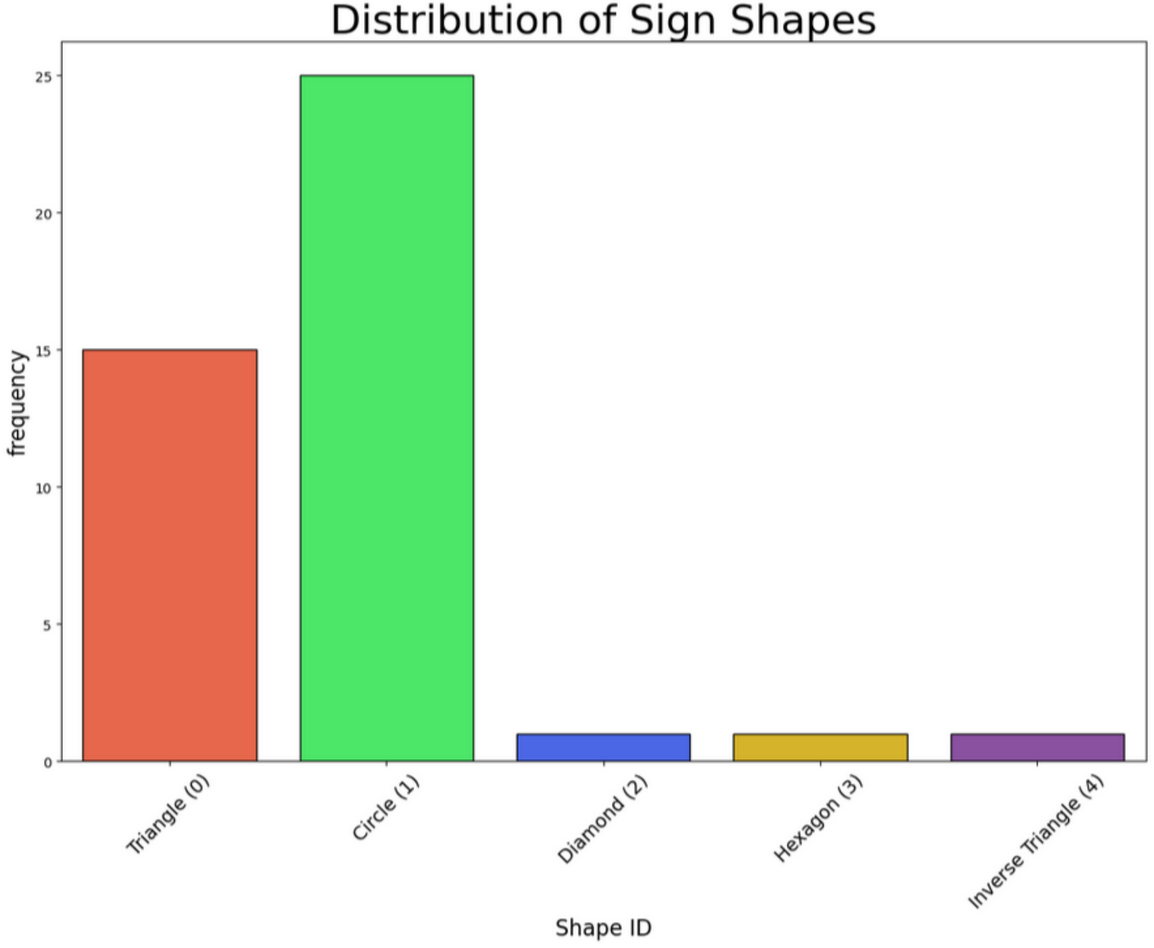
Test set:
Mean Width: 50.33
Mean Height: 50.22
Std Width: 24.44
Std Height: 23.21

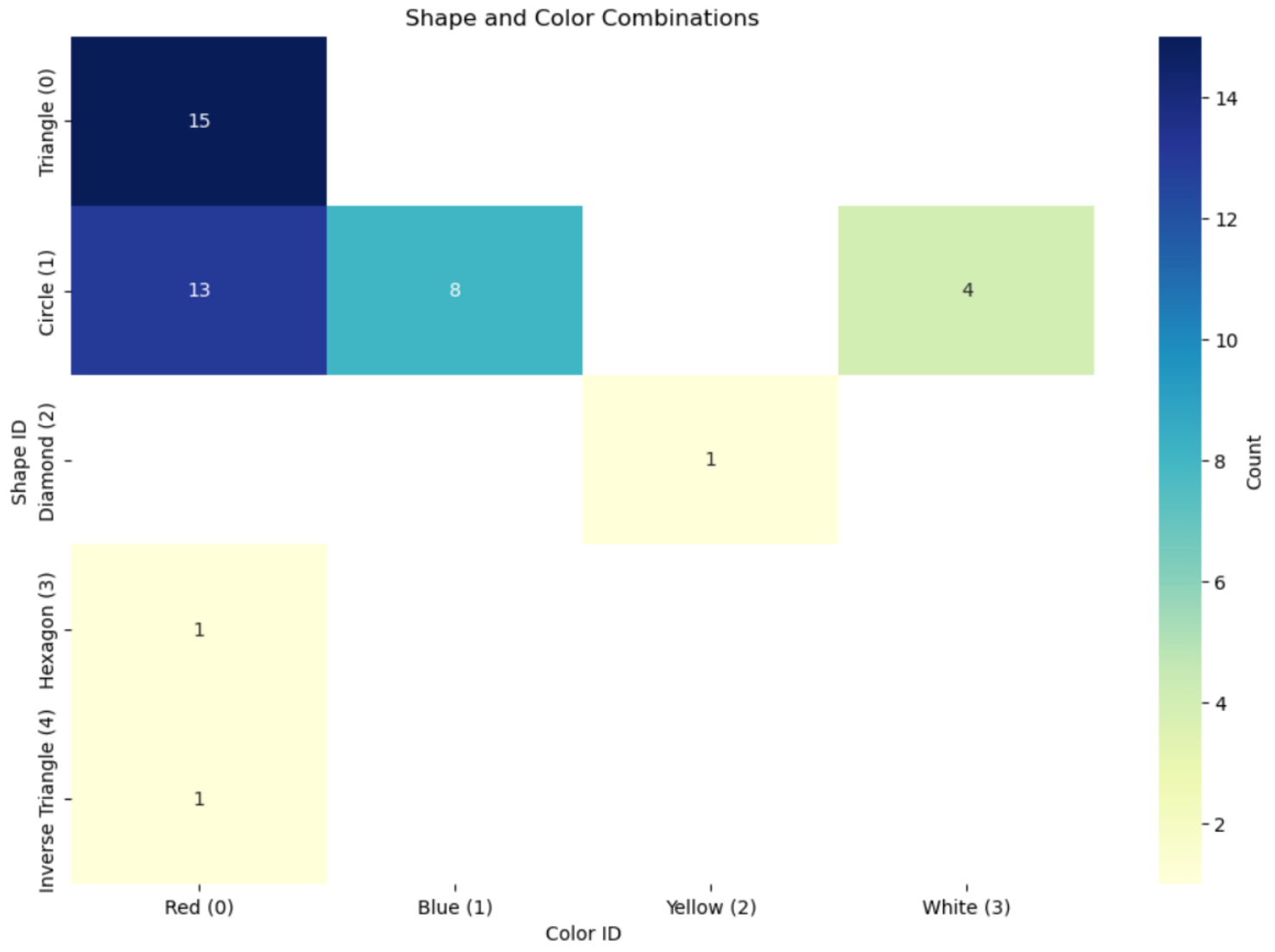


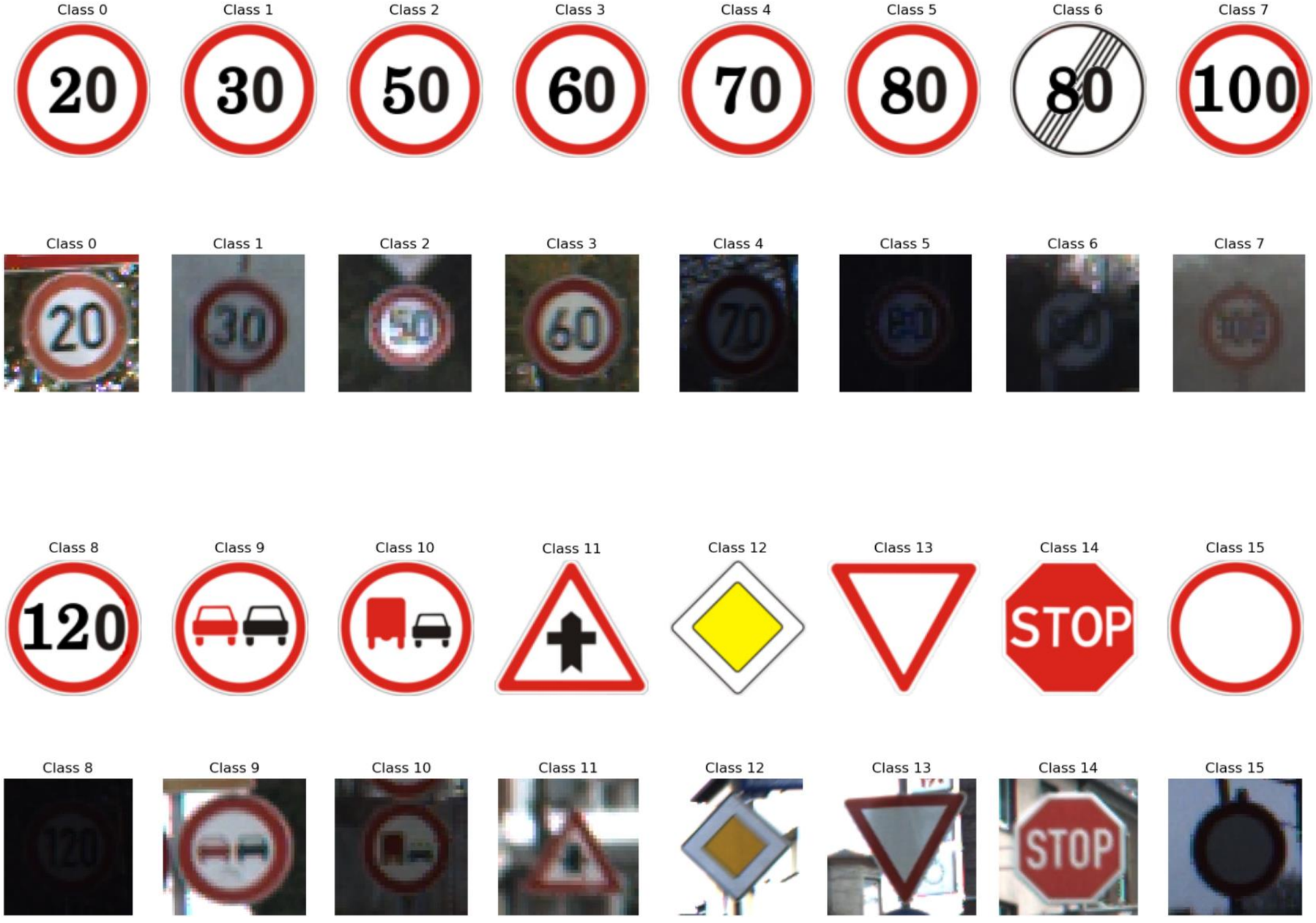



Distribution of Image Aspect Ratios
Training Data
Testing Data
Frequency
0
1000
2000
3000
4000
5000
6000
7000
8000
0.7
0.8
0.9
1.0
1.1
1.2
1.3
Aspect Ratio (Width/Height)


Distribution of Sign Colors
frequency
0
5
10
15
20
25
30
Red (0)
Blue (1)
Yellow (2)
White (3)
Color ID


Distribution of Sign Shapes
frequency
0
5
10
15
20
25
Triangle (0)
Circle (1)
Diamond (2)
Hexagon (3)
Inverse Triangle (4)
Shape ID


Shape and Color Combinations
Triangle (0)
Circle (1)
Diamond (2)
Hexagon (3)
Inverse Triangle (4)
Shape ID
15
13
8
4
1
1
1
Red (0)
Blue (1)
Yellow (2)
White (3)
Color ID
Count
14
12
10
8
6
4
2


Class 0
Class 1
Class 2
Class 3
Class 4
Class 5
Class 6
Class 7
Class 8
Class 9
Class 10
Class 11
Class 12
Class 13
Class 14
Class 15
STOP


Class 24
Class 25
Class 26
Class 27
Class 28
Class 29
Class 30
Class 31


Class 24
Class 25
Class 26
Class 27
Class 28
Class 29
Class 30
Class 31


Class 32
Class 33
Class 34
Class 35
Class 36
Class 37
Class 38
Class 39

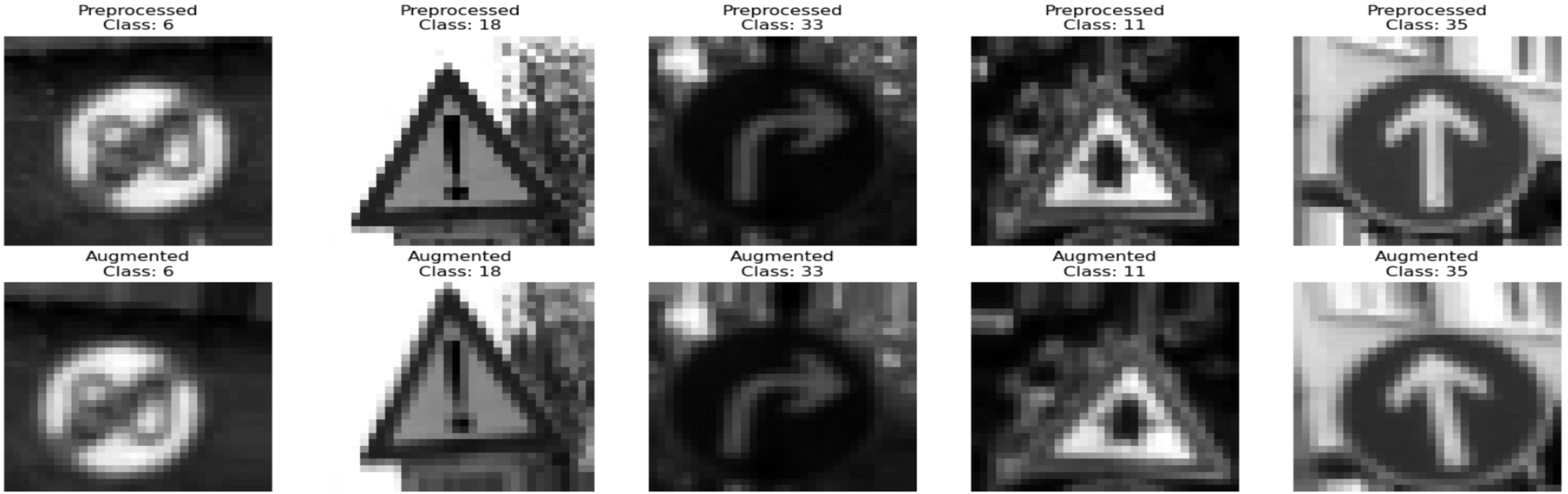

Class 32
Class 33
Class 34
Class 35
Class 36
Class 37
Class 38
Class 39

Data Augmentation Techniques

- Data augmentation is performed during training using Keras' ImageDataGenerator.
- Monochrome colorspace increases detection accuracy and improves model generalization.

Keras ImageDataGenerator:

- Rotation: ±10 degrees
- Width/Height Shift: ±10%
- Zoom: ±10%
- Shear: 0.1 radians



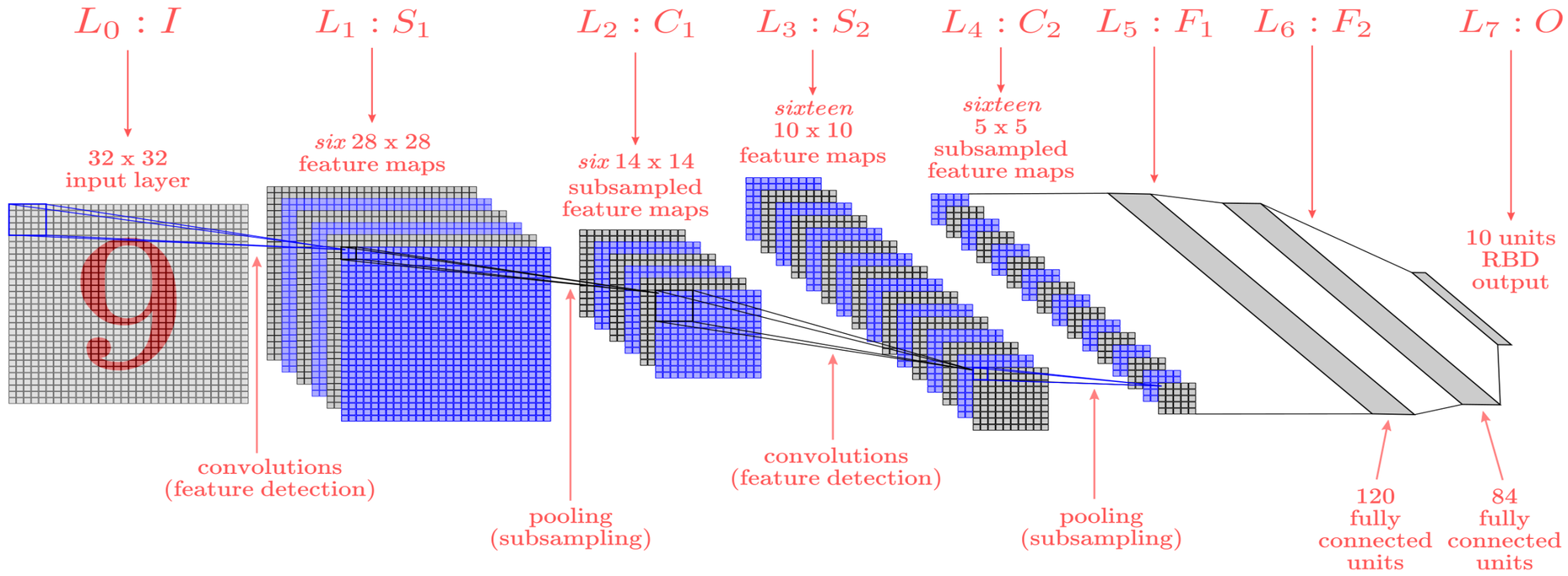

```
Preprocessing and data augmentation complete.
Training set shape: (31367, 32, 32, 1)
Validation set shape: (7842, 32, 32, 1)
```

LeNet-5 CNN Architecture

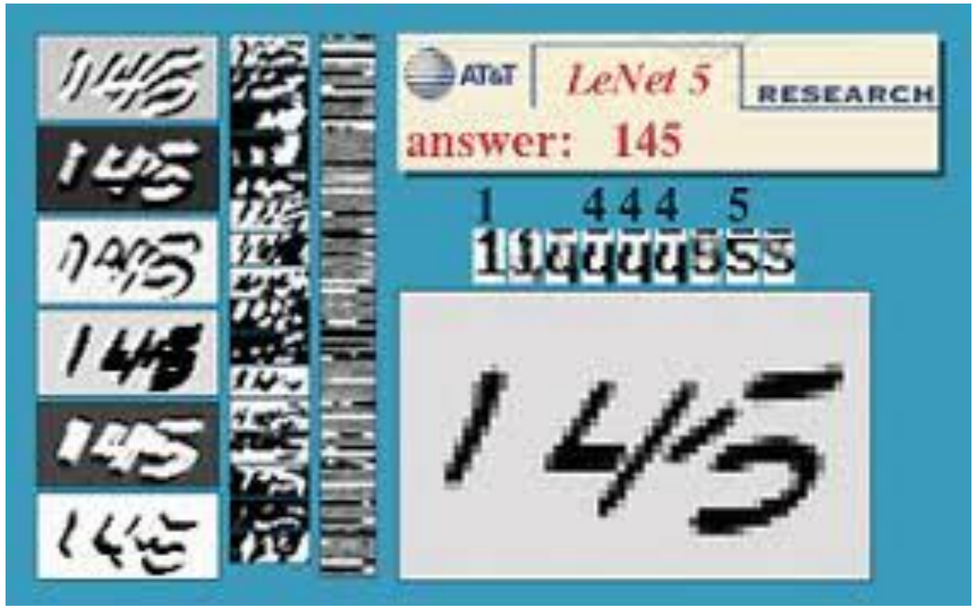
- Developed by Yann LeCun, Léon Bottou, Yoshua Bengio, and Patrick Haffner in 1998

- 2 convolutional layers, 2 subsampling layers, and 2 fully connected layers
- Designed for 32x32 pixel grayscale images

- LeNet-5 was revolutionary in using convolution for feature extraction. It demonstrated superior performance on the MNIST dataset, achieving a 0.95% error rate, a significant improvement over traditional methods.



Modified LeNet-5 CNN



Yann LeCun @ylecun · 16h
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108 43 1.3K 195K

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342 280 2.5K 337K

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Modified LeNet-5 CNN

- The original LeNet-5 had two convolutional layers; our modified version has three. This increased depth allows the network to learn more complex features specific to traffic signs.
- Increased the number of filters in the convolutional layers (32 and 64) compared to the original LeNet-5, allowing for more feature maps.
- A dropout layer with a rate of 0.5 was added before the final dense layer to prevent overfitting, a crucial consideration given our larger and more complex dataset.
- The final dense layer has 43 units, corresponding to the 43 classes in our traffic sign dataset, with a softmax activation for multi-class classification.
- Despite these modifications, our model remains relatively lightweight with only 124,139 parameters, making it suitable for real-time applications.

Forbidden Slide

Model: "sequential"

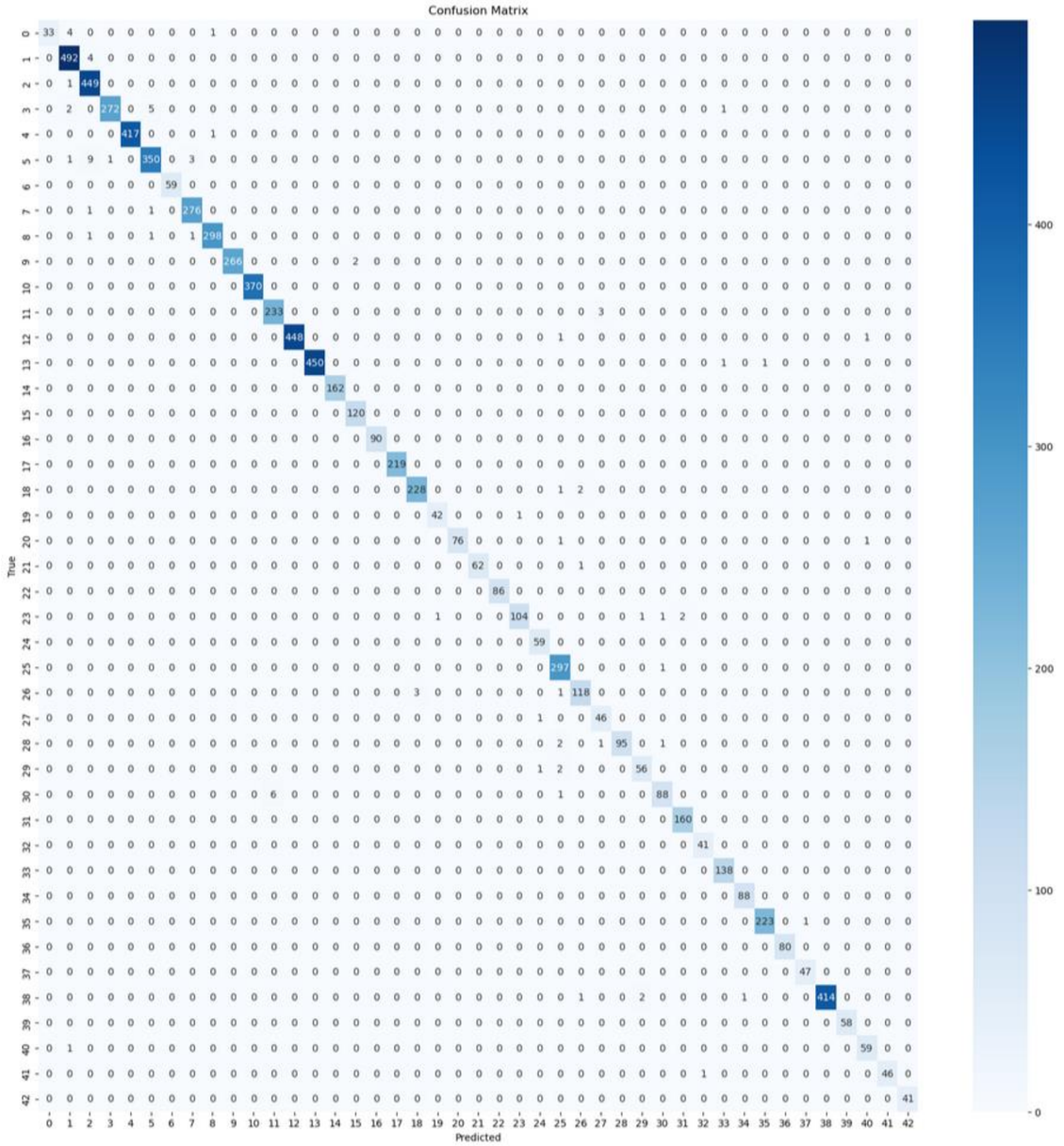
Layer (type)	Output Shape	Param #
conv2d (Conv2D)	(None, 30, 30, 32)	320
max_pooling2d (MaxPooling2D)	(None, 15, 15, 32)	0
conv2d_1 (Conv2D)	(None, 13, 13, 64)	18,496
max_pooling2d_1 (MaxPooling2D)	(None, 6, 6, 64)	0
conv2d_2 (Conv2D)	(None, 4, 4, 64)	36,928
flatten (Flatten)	(None, 1024)	0
dense (Dense)	(None, 64)	65,600
dropout (Dropout)	(None, 64)	0
dense_1 (Dense)	(None, 43)	2,795

Total params: 124,139 (484.92 KB)

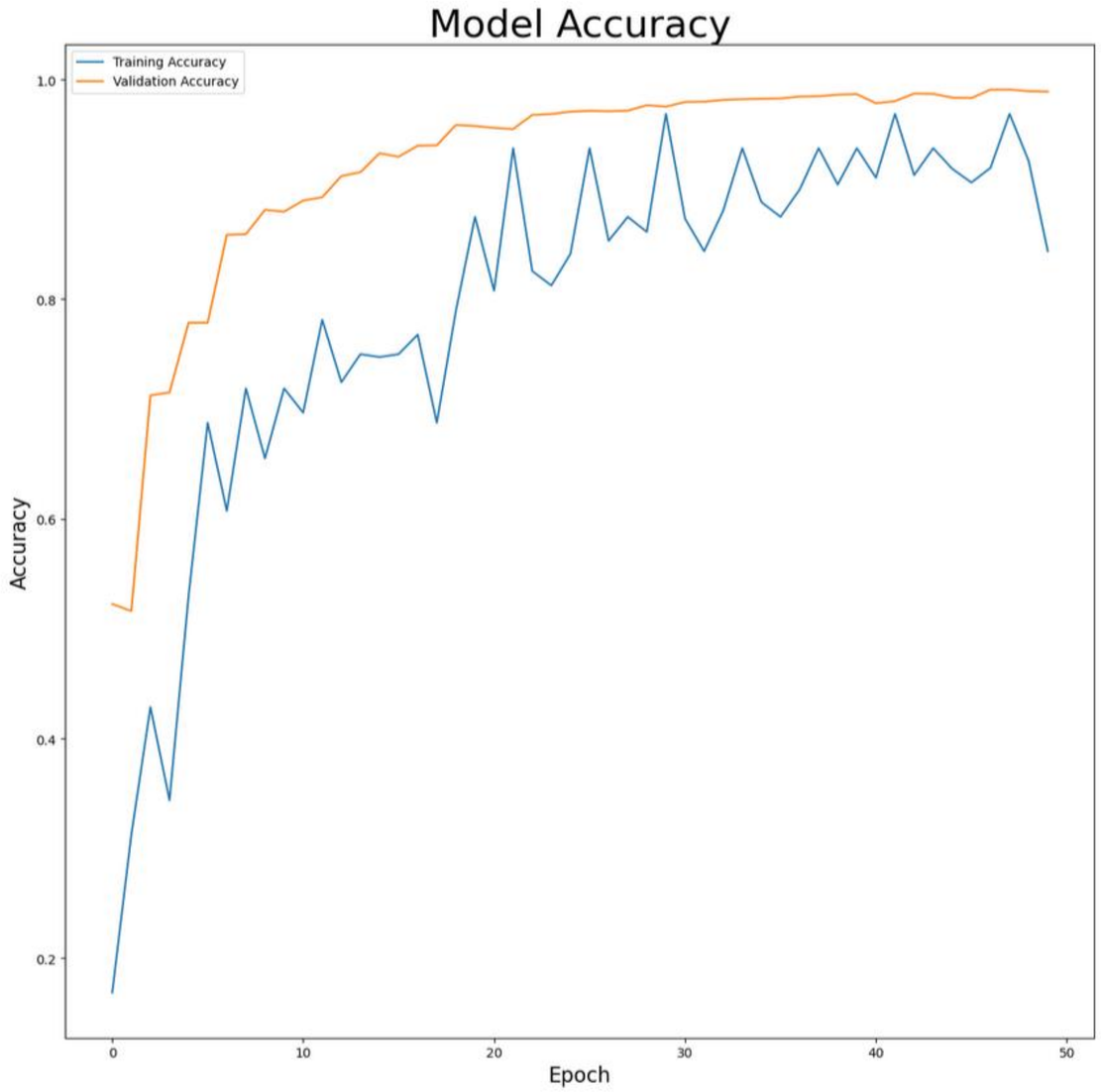
Trainable params: 124,139 (484.92 KB)

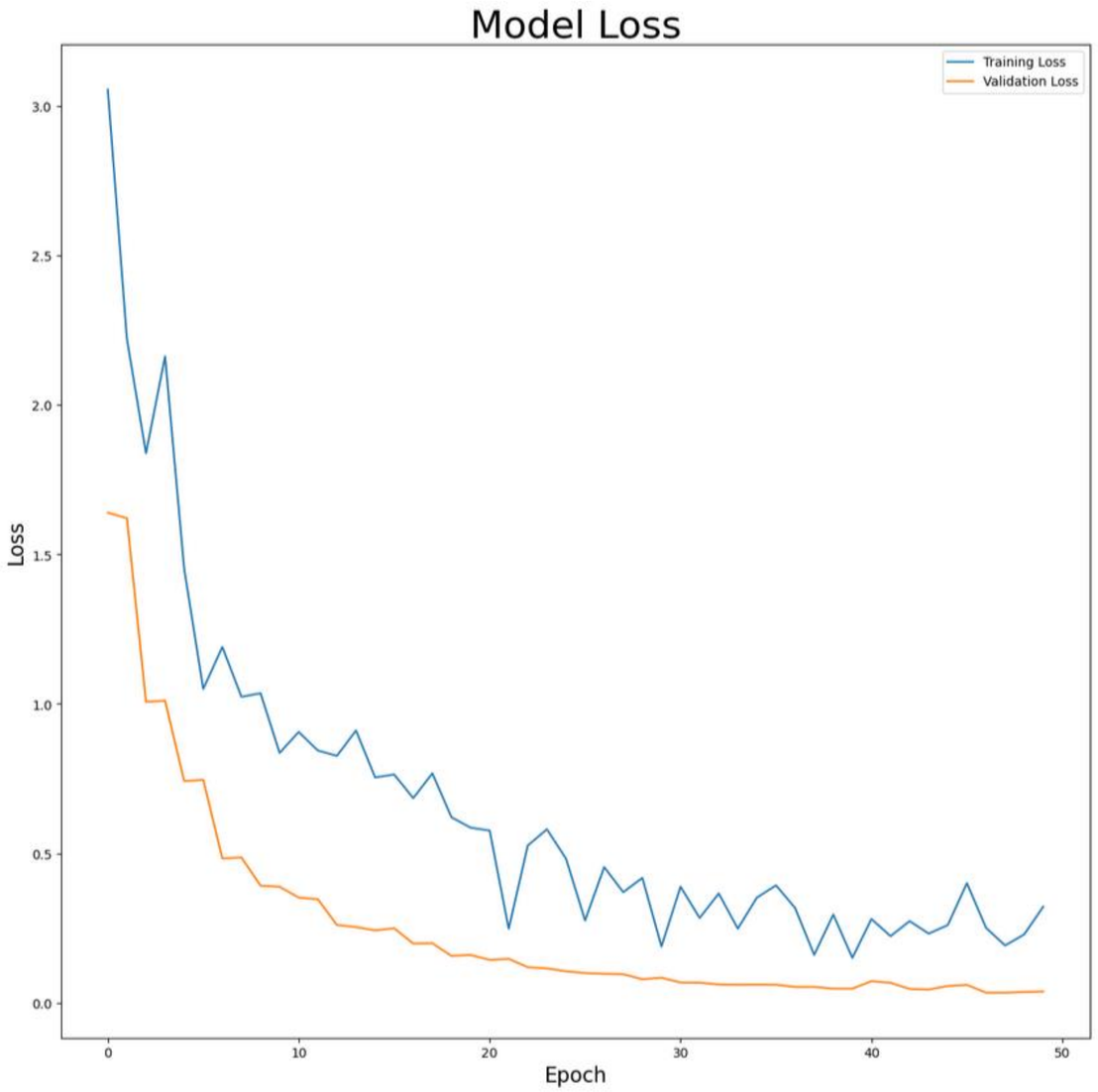
Non-trainable params: 0 (0.00 B)

```
Epoch 45/50
980/980 ━━━━━━━━━━━━━━━━━━━━ 26s 27ms/step - accuracy: 0.9202 - loss: 0.2591 - val_accuracy: 0.9836 - val_loss: 0.0563
Epoch 46/50
980/980 ━━━━━━━━━━━━━━━━━━━━ 1s 1ms/step - accuracy: 0.9062 - loss: 0.4002 - val_accuracy: 0.9832 - val_loss: 0.0599
Epoch 47/50
980/980 ━━━━━━━━━━━━━━━━━━━━ 26s 26ms/step - accuracy: 0.9181 - loss: 0.2547 - val_accuracy: 0.9908 - val_loss: 0.0342
Epoch 48/50
980/980 ━━━━━━━━━━━━━━━━━━━━ 1s 1ms/step - accuracy: 0.9688 - loss: 0.1918 - val_accuracy: 0.9909 - val_loss: 0.0341
Epoch 49/50
980/980 ━━━━━━━━━━━━━━━━━━━━ 26s 27ms/step - accuracy: 0.9256 - loss: 0.2280 - val_accuracy: 0.9894 - val_loss: 0.0364
Epoch 50/50
980/980 ━━━━━━━━━━━━━━━━━━━━ 1s 1ms/step - accuracy: 0.8438 - loss: 0.3218 - val_accuracy: 0.9890 - val_loss: 0.0377
```

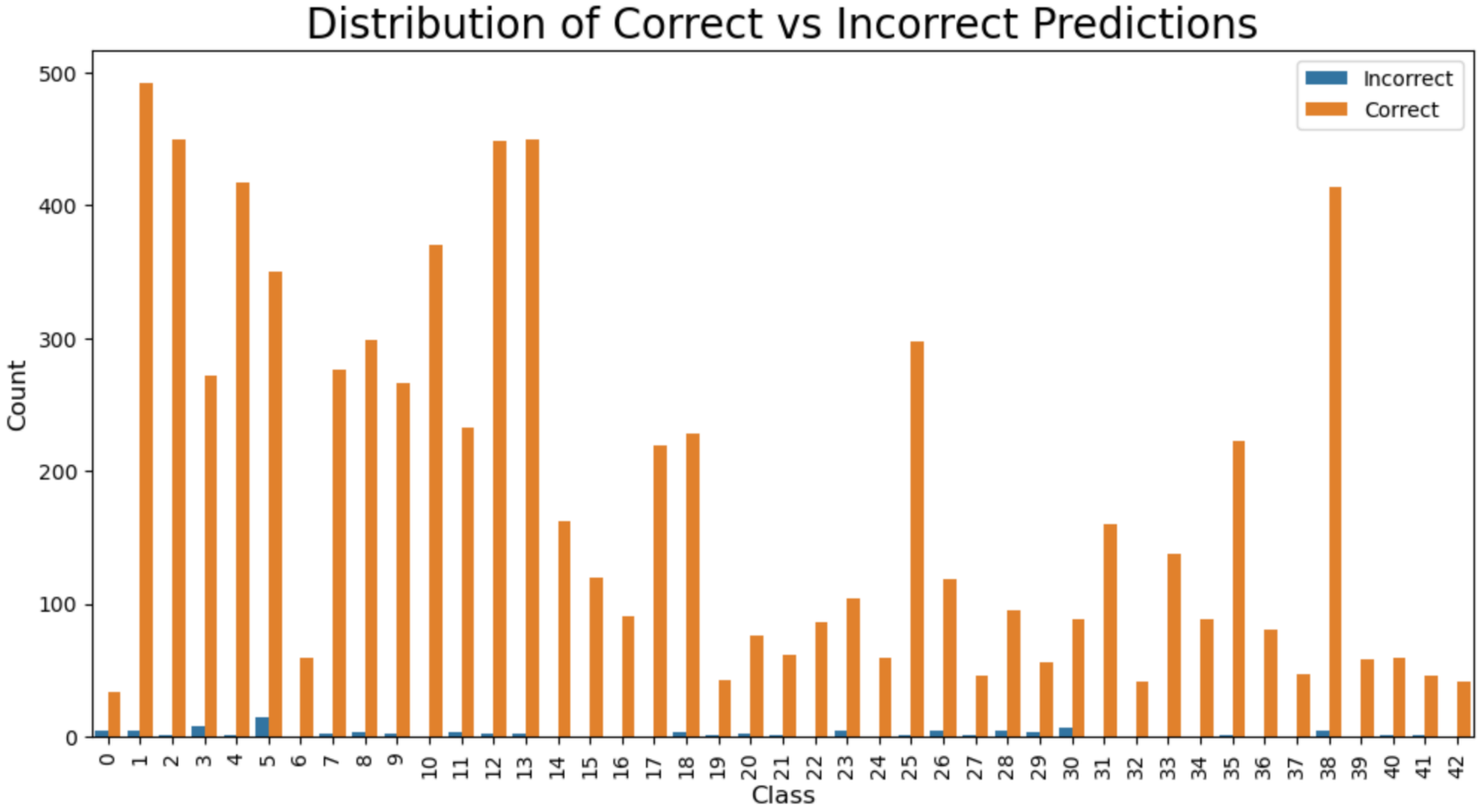


Plotting Model Metrics





Visualize Confusion Matrix



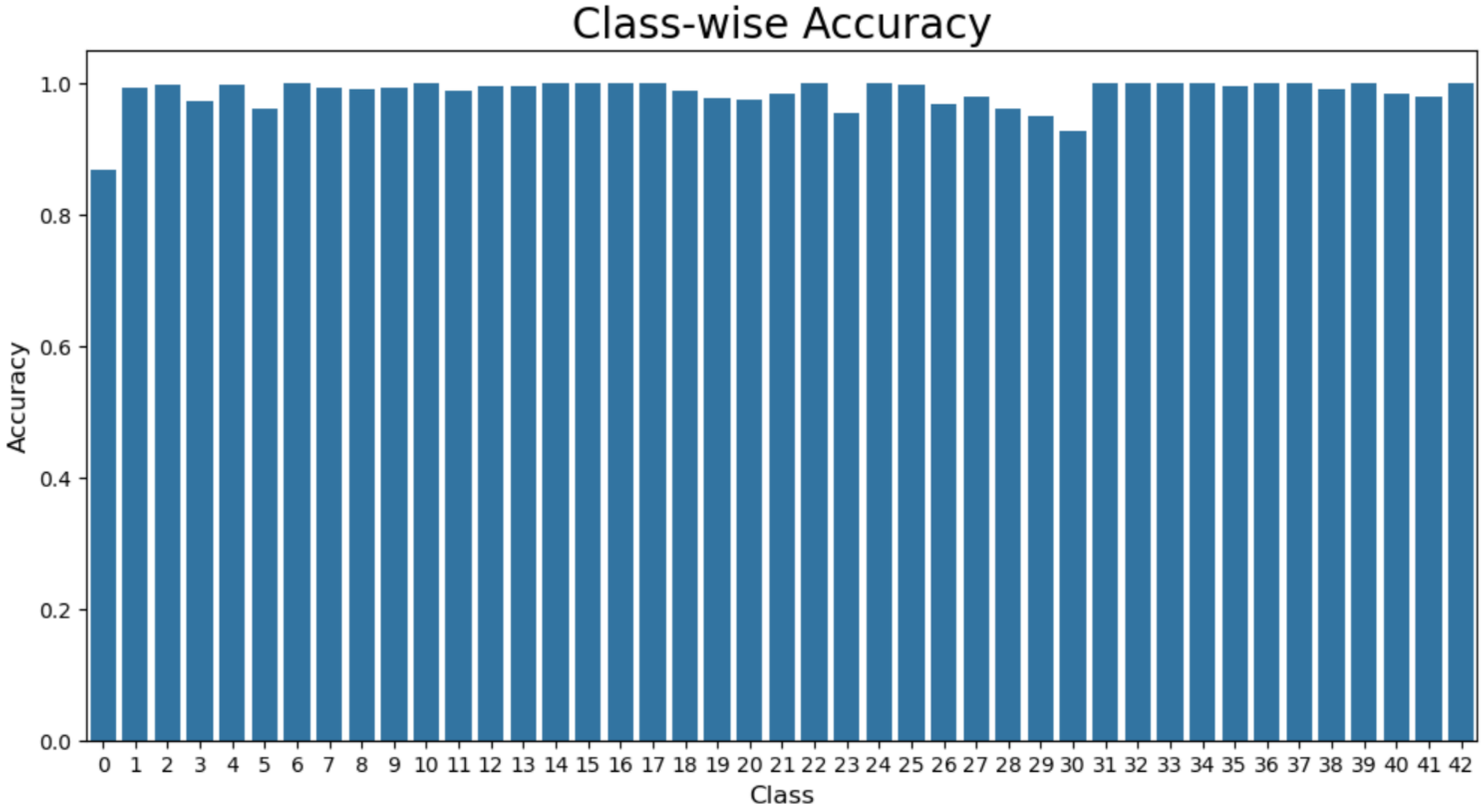
Similar Signs?

(1)

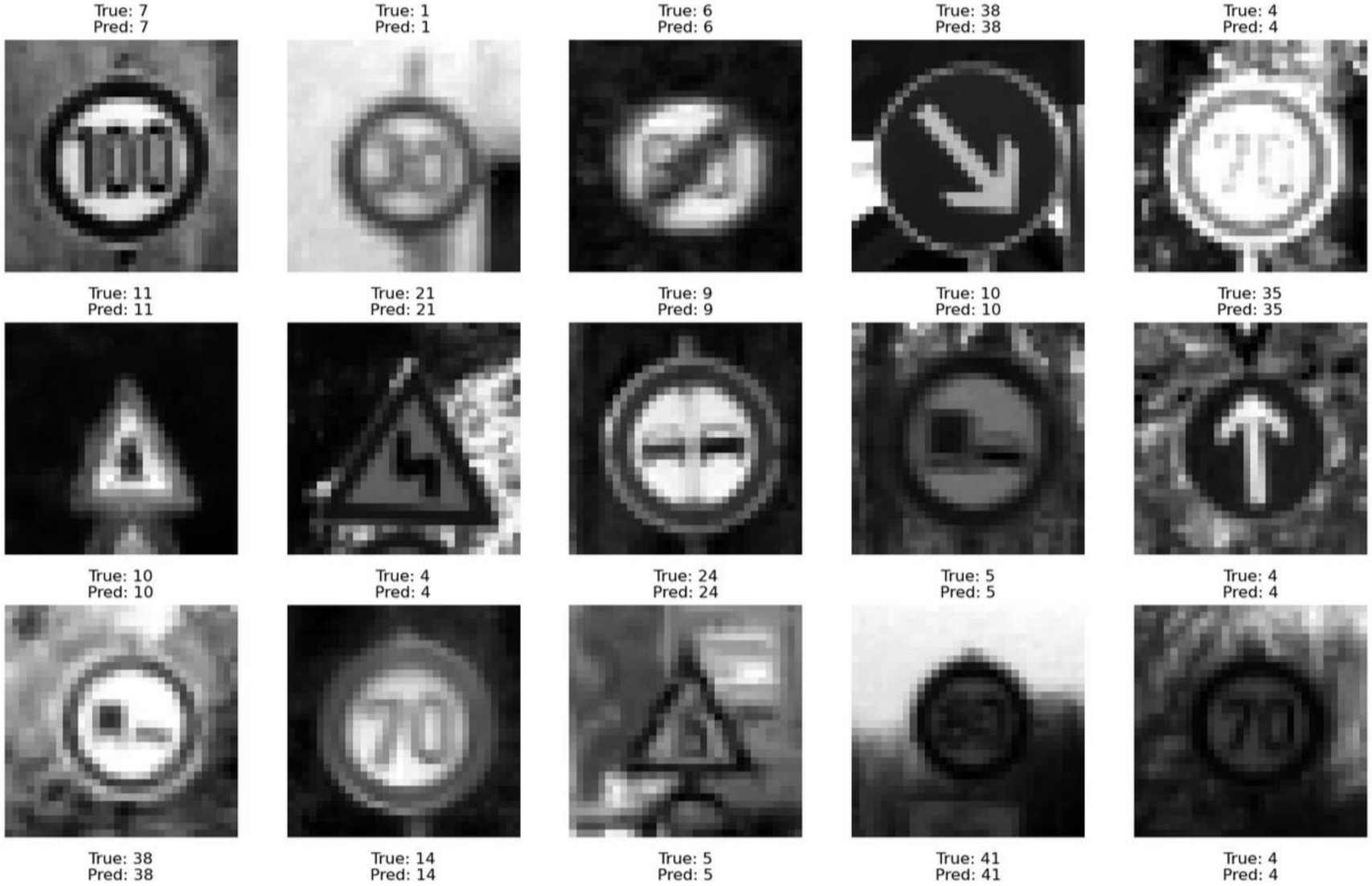
(0)

(18)

(26)



Actual vs Predicted Class ID



Future Use Cases

- Transfer Learning: Utilize EfficientNetB0 or MobileNetV2, pre-trained on ImageNet

- GPU Acceleration: Implement mixed precision training for 2-3x speedup
- YOLO v8 Integration: For real-time sign detection (expected 45 FPS on GPU)

- Significantly enhances both the accuracy and real-world applicability of the model.

Demonstration Overview

Streamlit App Features:

- Image upload and real-time classification
- Top-5 predictions with confidence scores

Webcam Capture:

- Continuous prediction on video stream
- Threshold-based classification display

- Streamlit app provides an intuitive interface for model interaction.

- The webcam feature, while sometimes inconsistent due to lighting and angle variations, demonstrates the potential for real-time applications.

Thanks!

Do you have any questions?