

# Speed Limit Signs: An Image Classification Problem

A SELECTION OF HIGHLIGHTS FROM OUR FULL REPORT

November 16, 2021

*Only some  
models are  
shown due to  
time constraints*

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\*Both authors contributed equally to the project. Presentation will be shared between both presenters, who participated fully in every phase of the project in all aspects of the data science pipeline.

# Speed limit sign classification



“Speed”

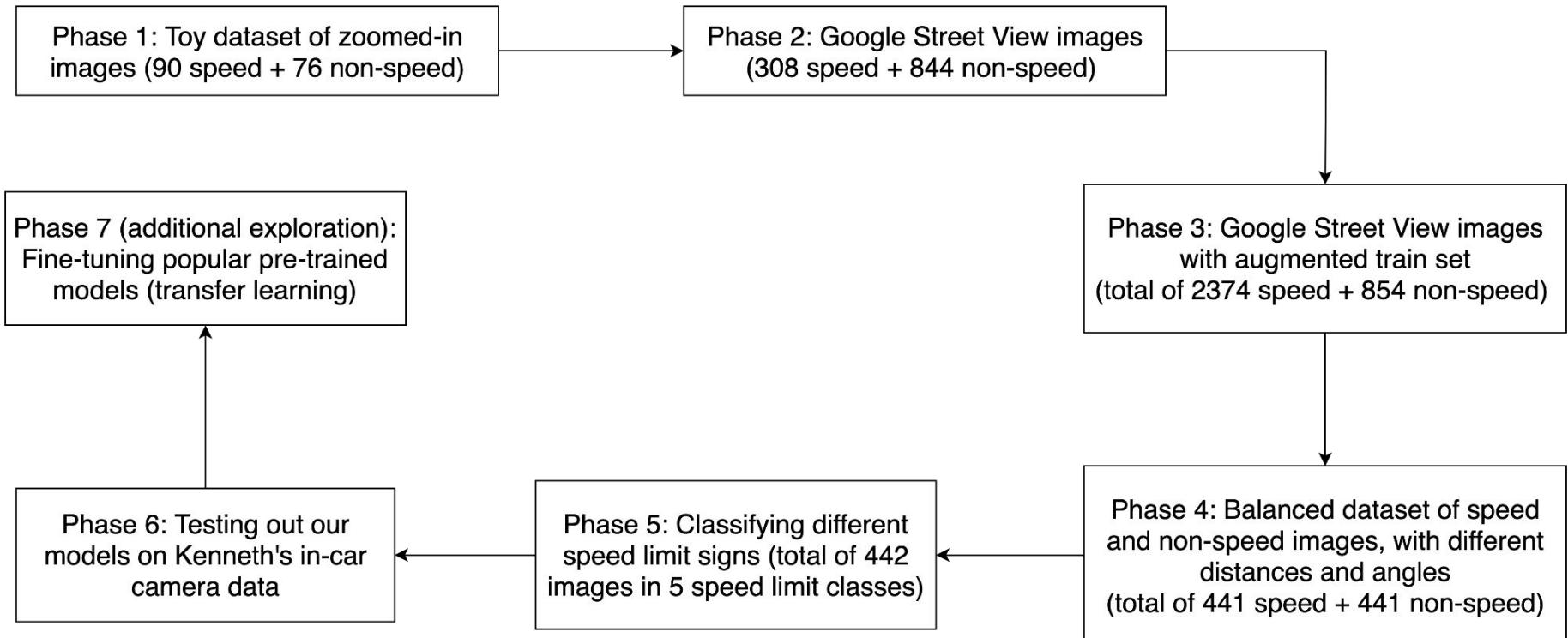


“Non-speed”

## PROBLEM STATEMENT

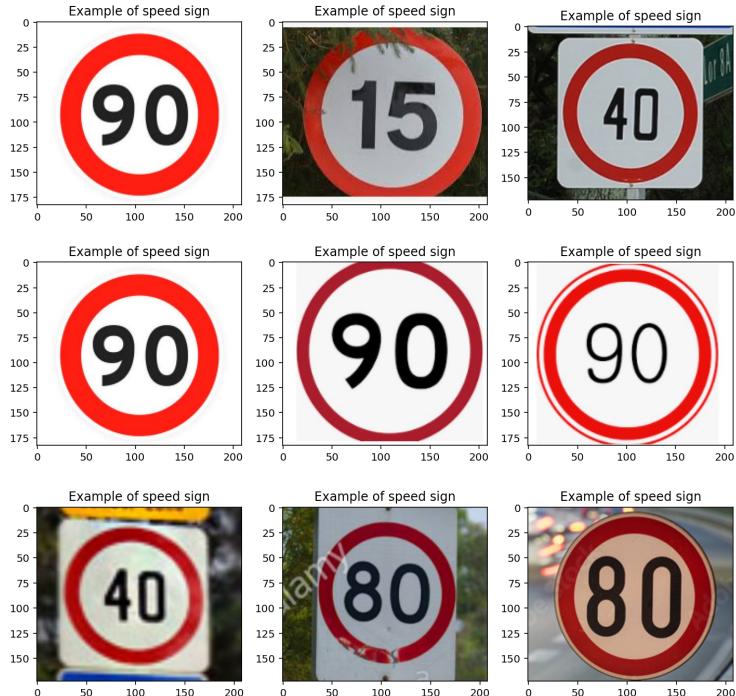
Train an image classifier to identify if an image has a speed limit sign.

# OVERALL PROJECT STRUCTURE

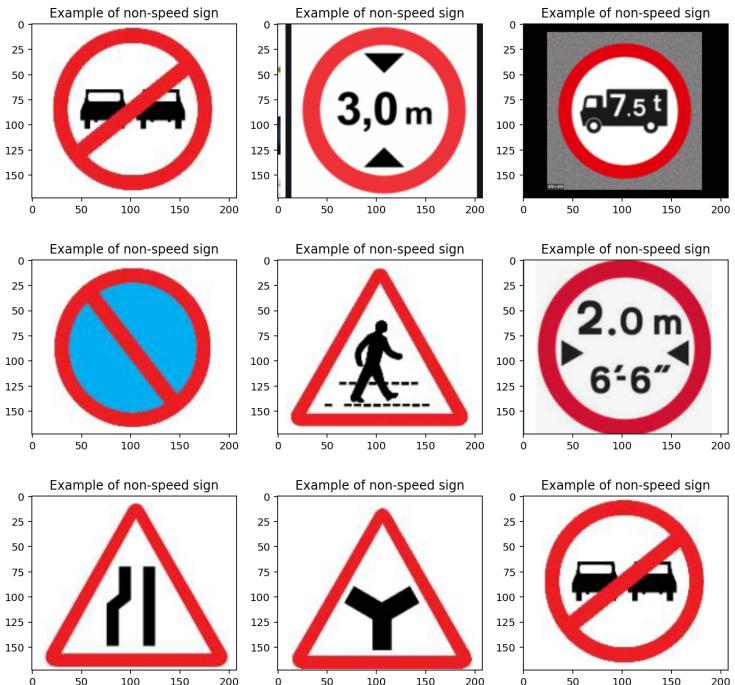


# Phase 1: Dataset of Zoomed-in Road Sign Images

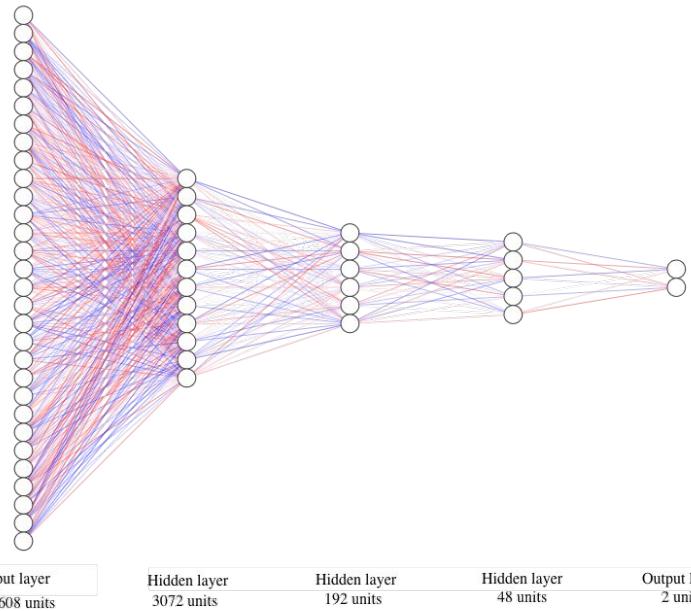
**SPEED (90 images)**



**NONSPEED (76 images)**

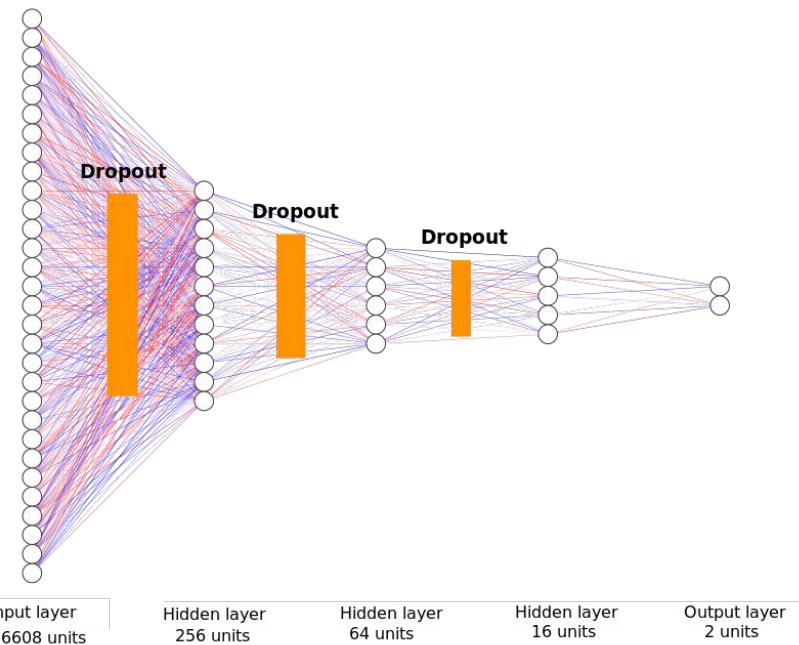


# Phase 1: Models



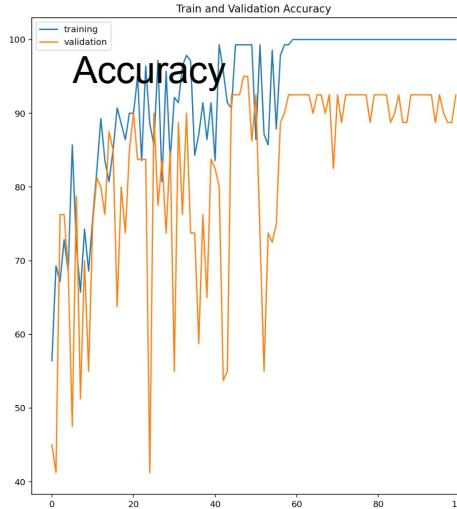
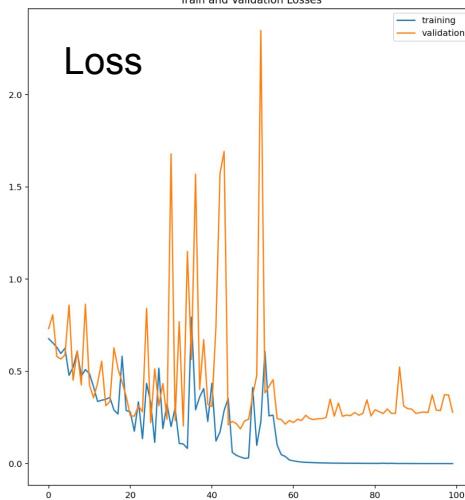
**Model 1a**

Parameters: 604,582,226  
Architecture: MLP

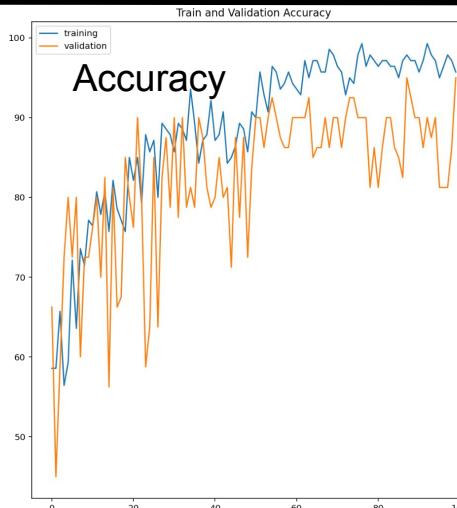
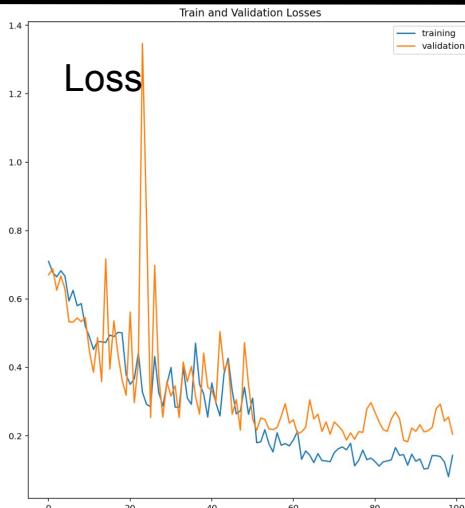


**Model 1c**

Parameters: 50,349,426  
Architecture: MLP



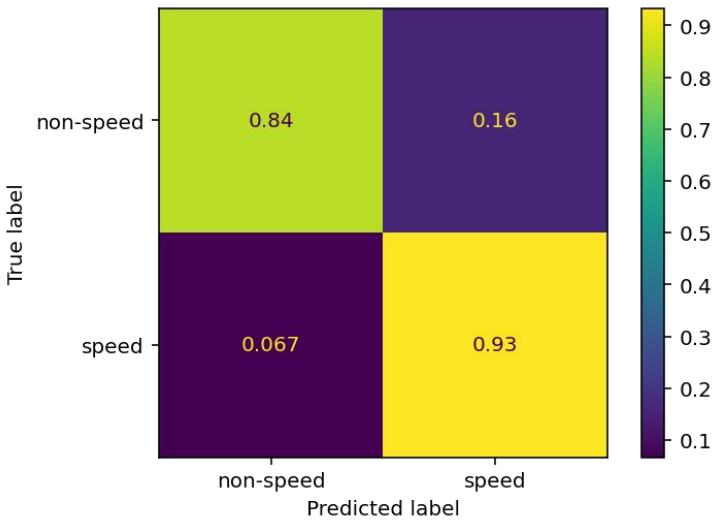
**Model 1a**  
Performance metrics  
on validation data  
 Accuracy 0.907  
 F1 score 0.903  
 Precision 0.881  
 Recall 0.964  
 AUC 0.935



Loss function: Cross Entropy Loss  
 Optimizer: Stochastic Gradient Descent

**Model 1c**  
Performance metrics  
on validation data  
 Accuracy 0.943  
 F1 score 0.964  
 Precision 0.936  
 Recall 1.0  
 AUC 0.893

# Model 1a



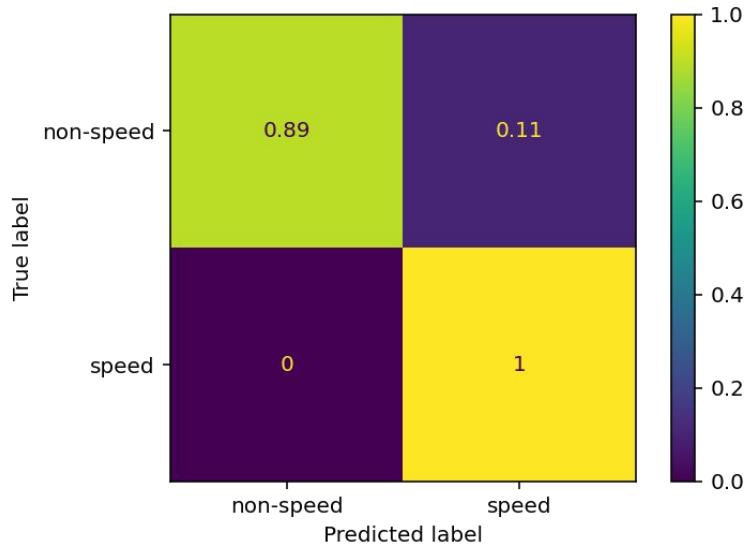
## Performance metrics on validation data

Accuracy 0.907  
F1 score 0.903  
Precision 0.881  
Recall 0.964  
AUC 0.935

**Number of trainable parameters**  
50,349,426

# Model 1c

(fewer parameters; with dropout)

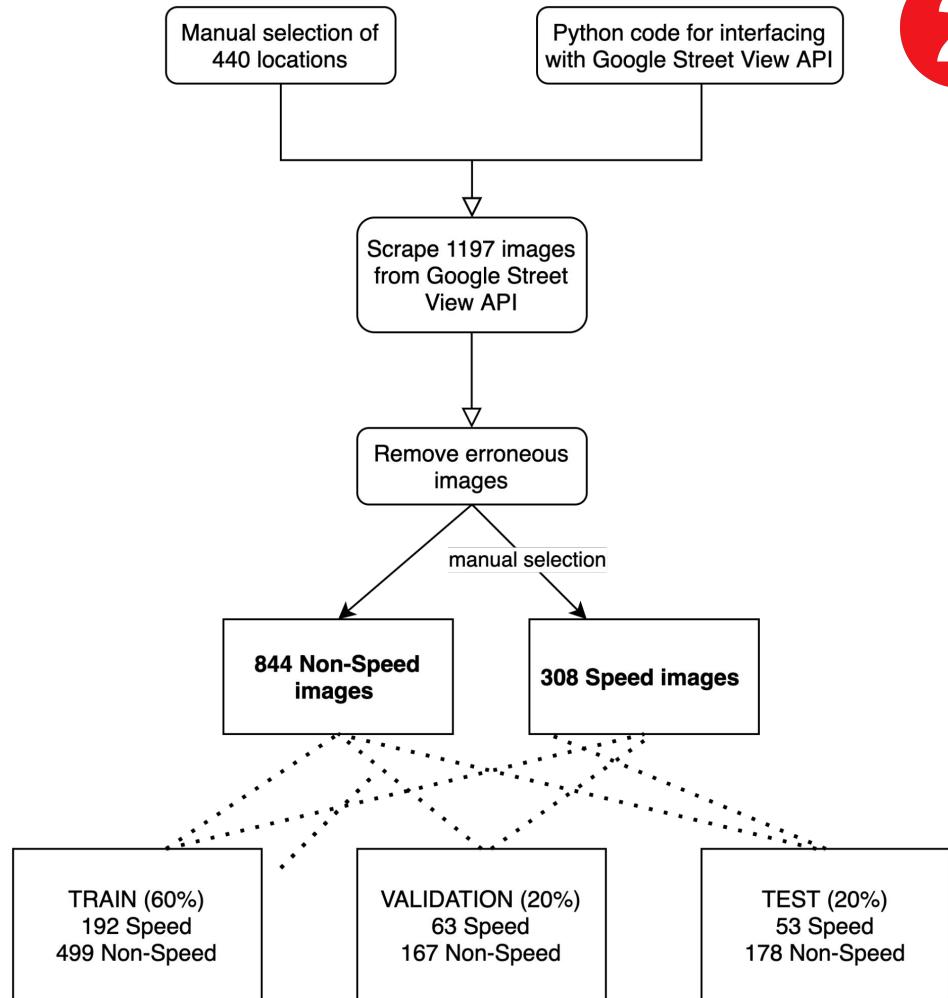


## Performance metrics on validation data

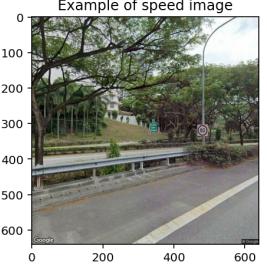
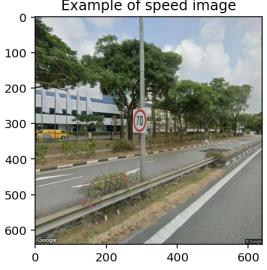
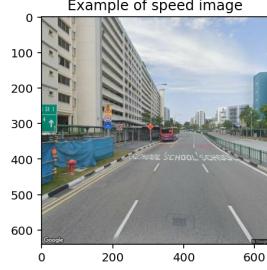
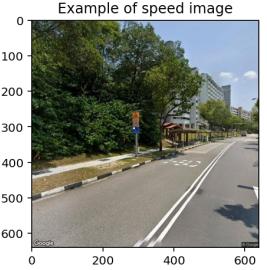
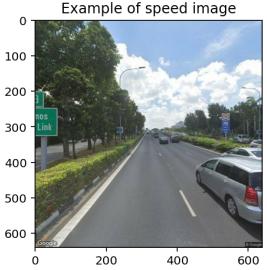
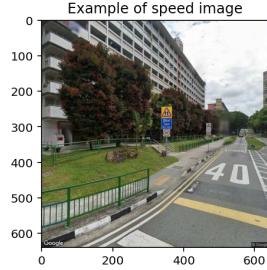
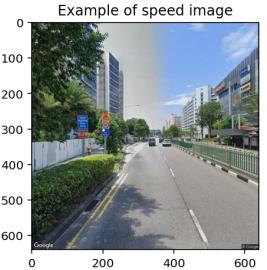
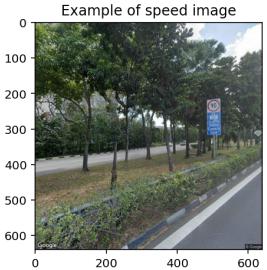
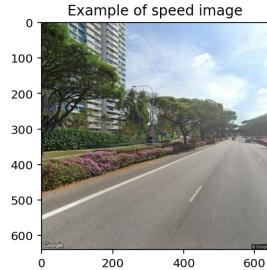
Accuracy 0.943  
F1 score 0.964  
Precision 0.936  
Recall 1.0  
AUC 0.893

**Number of trainable parameters**  
604,582,226

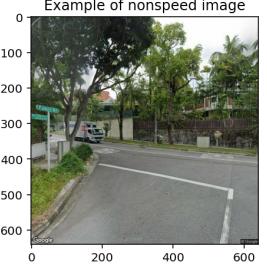
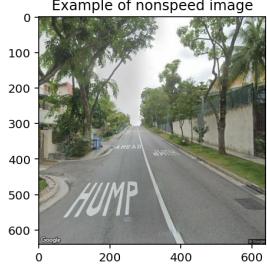
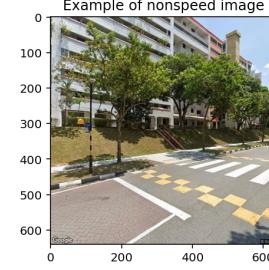
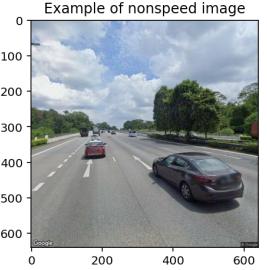
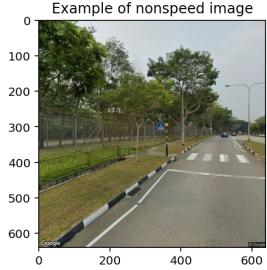
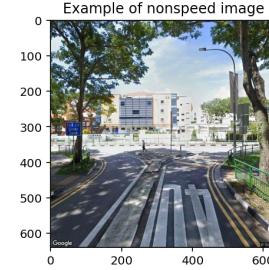
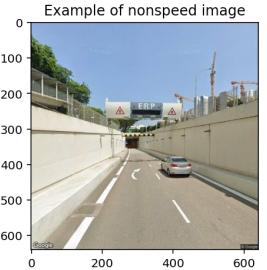
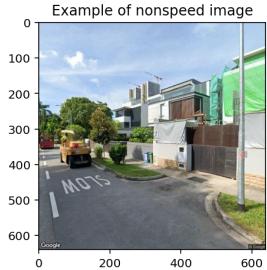
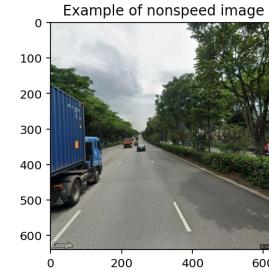
## Phase 2: Data collection



# Phase 2



Speed (308 images)

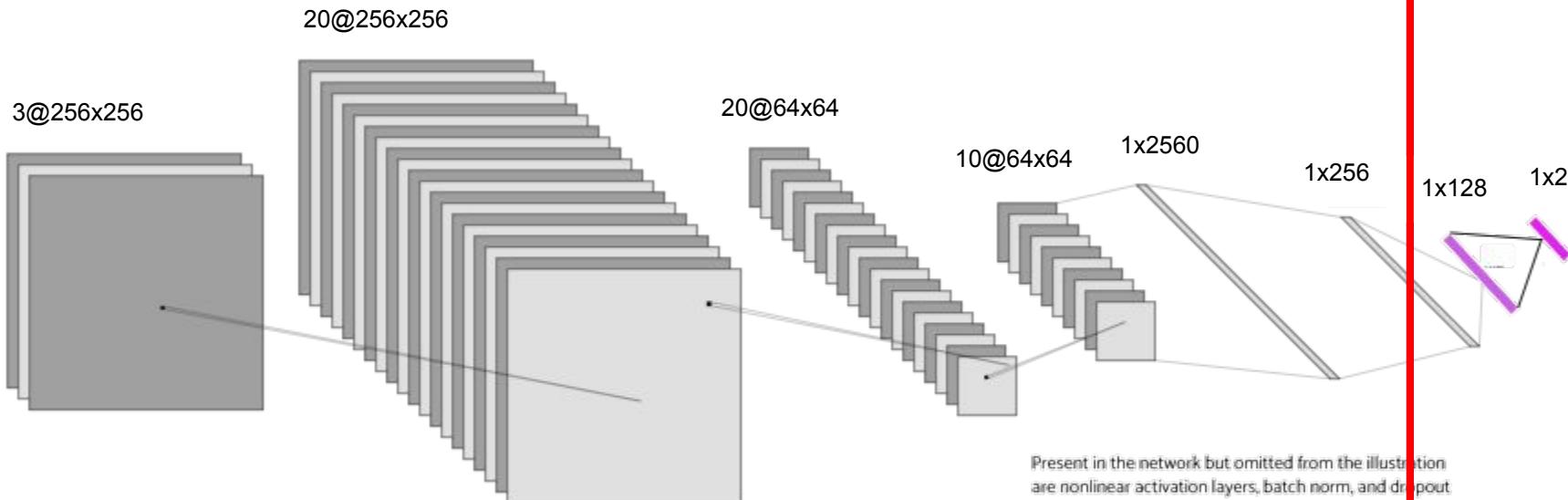


Nonspeed (844 images)

# Model 2d

PRETRAINED ON PHASE 1 DATASET

ADDITIONAL LAYERS



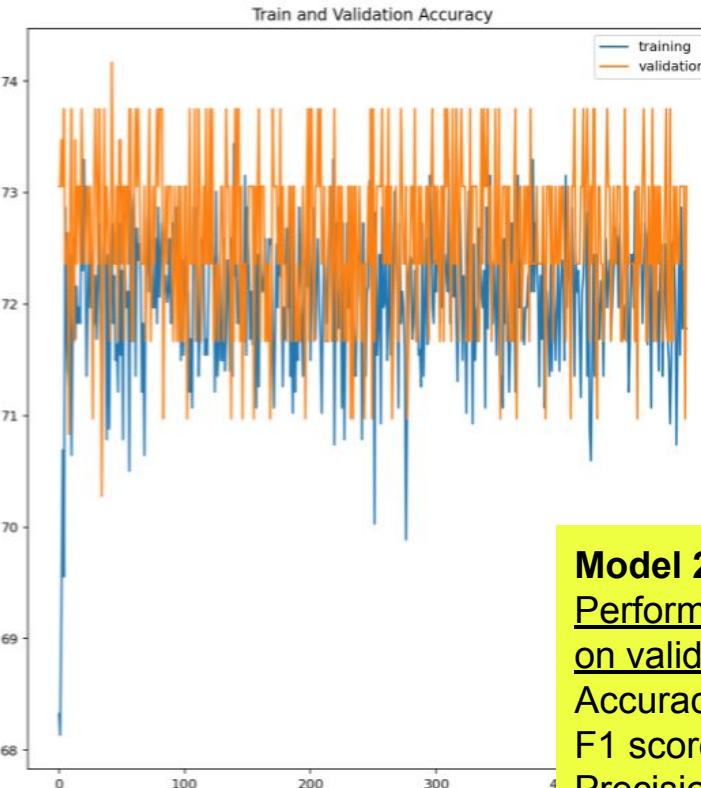
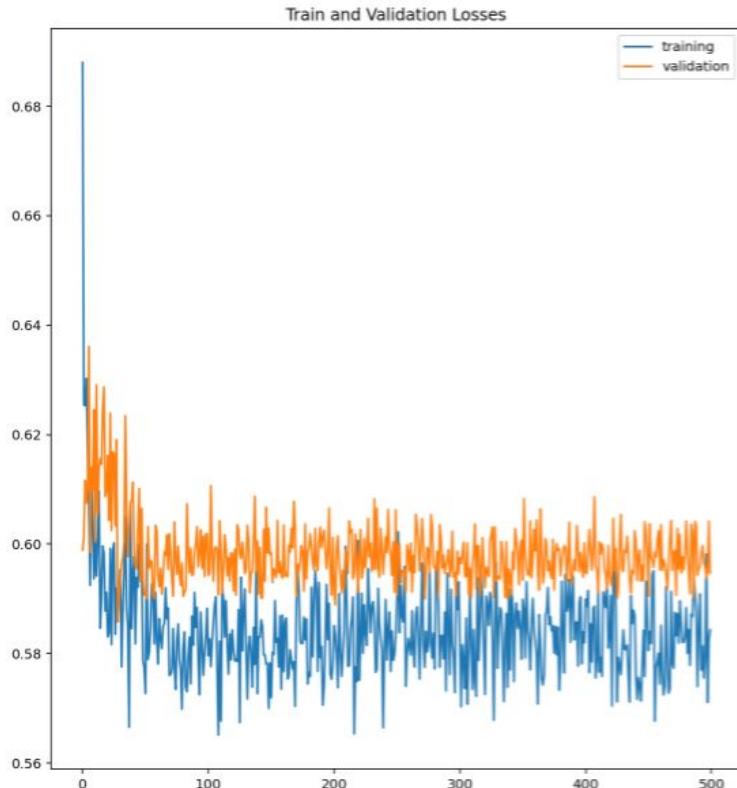
CONVOLUTION

MAXPOOL

CONVOLUTION

MAXPOOL

# Model 2d

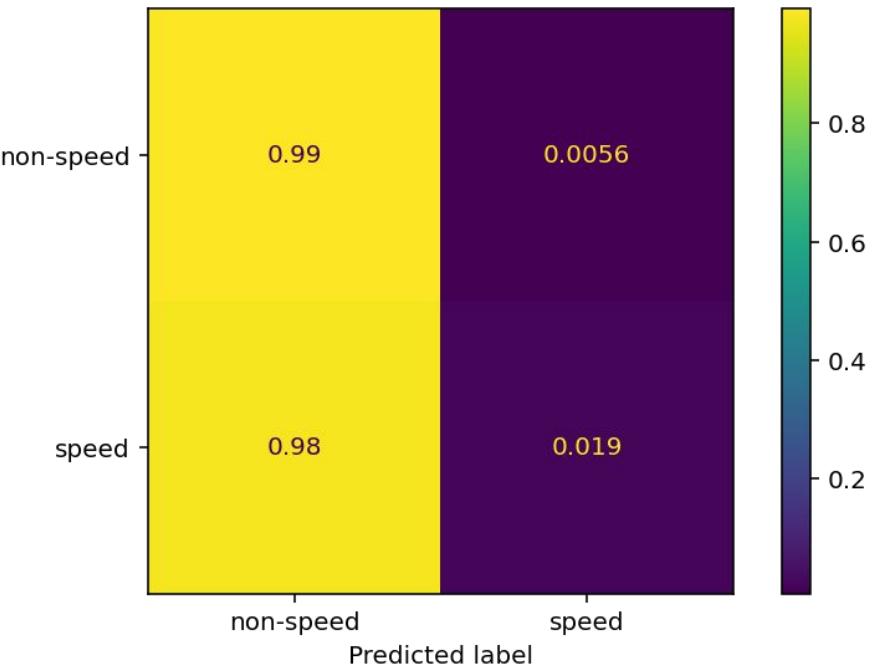


**Model 2D**  
Performance metrics  
on validation data  
Accuracy 0.774  
F1 score 0.014  
Precision 0.021  
Recall 0.011  
AUC 0.342

## Model 2d

Model is just predicting NON-SPEED for every test data point

True label



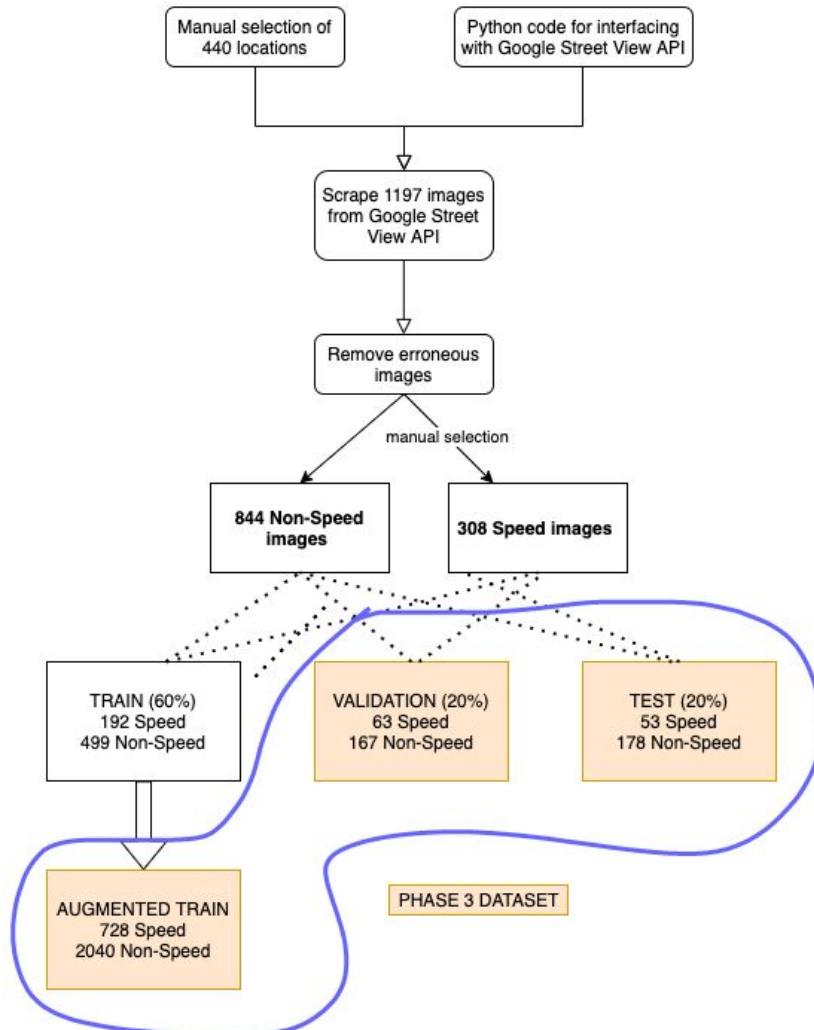
### Performance metrics on validation data

Accuracy 0.774  
F1 score 0.014  
Precision 0.021  
Recall 0.011  
AUC 0.342

### Number of trainable parameters

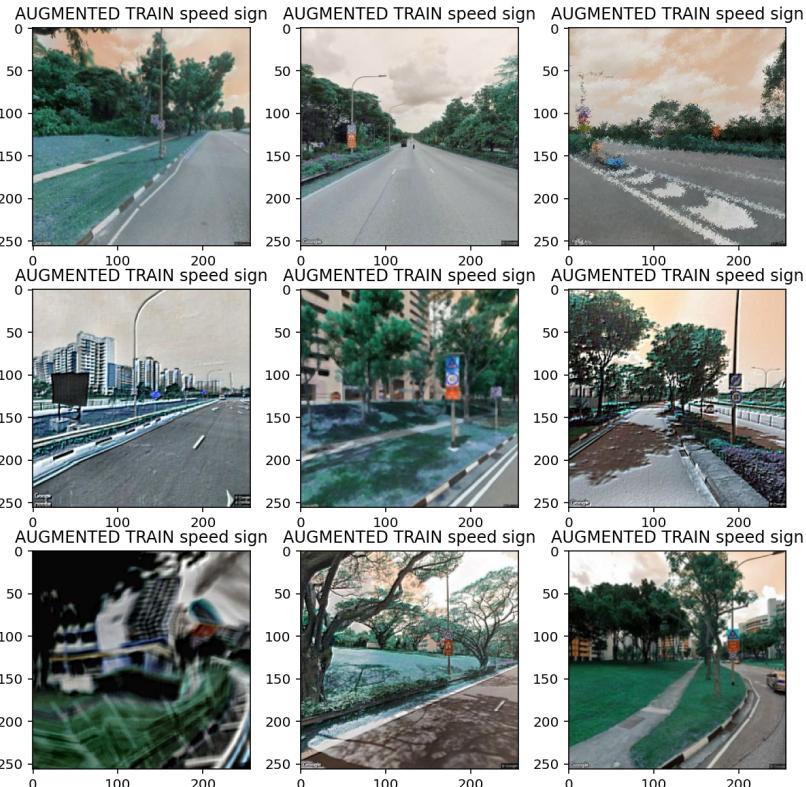
33,154

# Phase 3: Phase 2 + Augmented Train Images



# Phase 3: Examples of Augmented Train Images

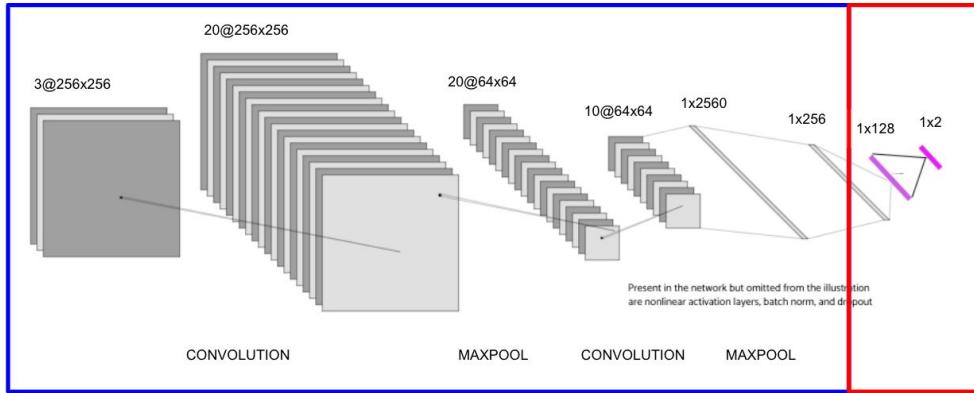
## SPEED (728 images)



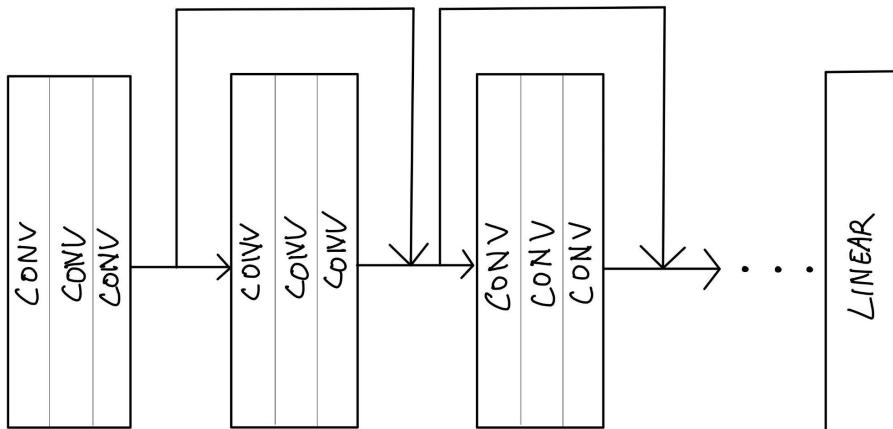
## NONSPEED (2040 images)



# Phase 3



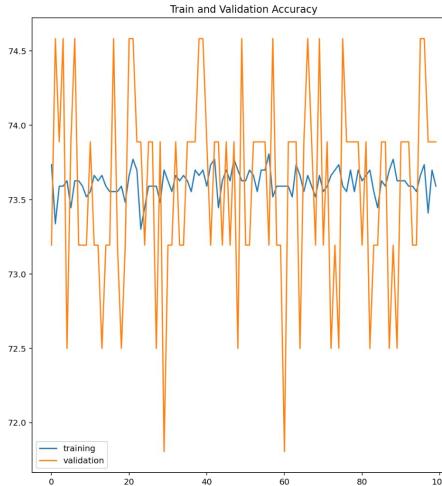
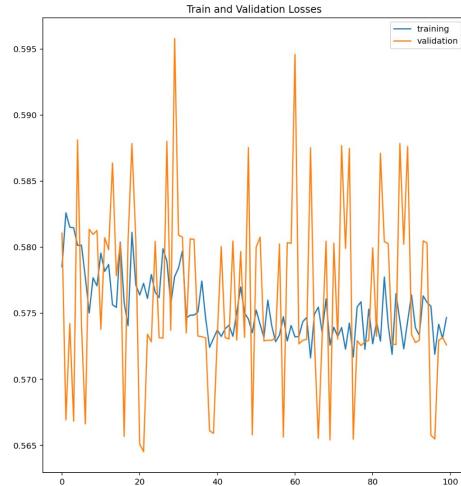
Model 3A  
Trainable Parameters: 33,154



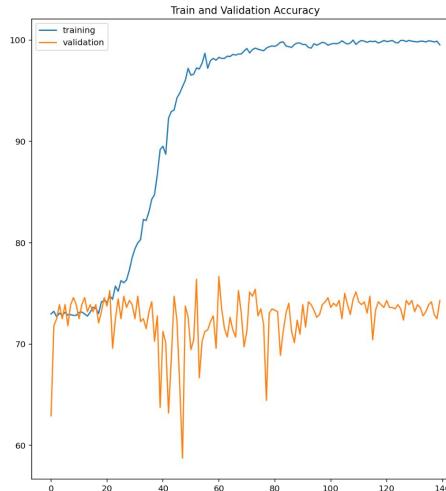
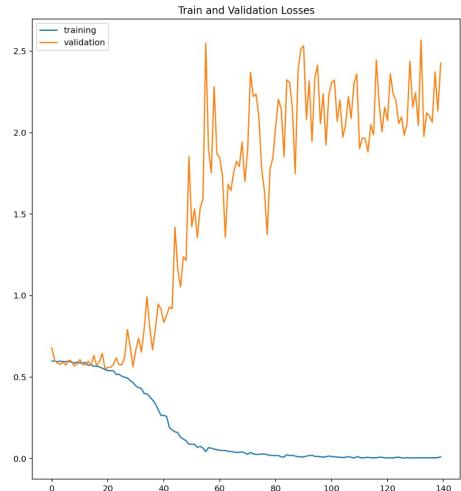
Model 3B  
Trainable Parameters: 23,512,130

Based on ResNet50  
[3,4,6,3], The expansion is always 4 times the input channels

Reference: <https://www.youtube.com/watch?v=DkNIBBBvcPs&t=369s>

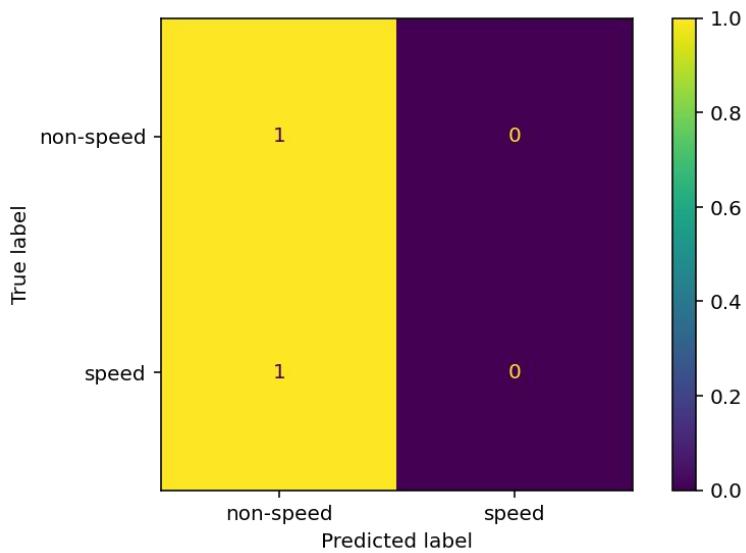


**Model 3A (CNN)**  
Performance metrics on validation data  
Accuracy 0.717  
F1 score 0.0  
Precision 0.0  
Recall 0.0  
AUC 0.413



**Model 3B (ResNet)**  
Performance metrics on validation data  
Accuracy 0.704  
F1 score 0.030  
Precision 0.054  
Recall 0.024  
AUC 0.391

Model 3A

**Performance metrics on validation data**

Accuracy 0.717

F1 score 0.0

Precision 0.0

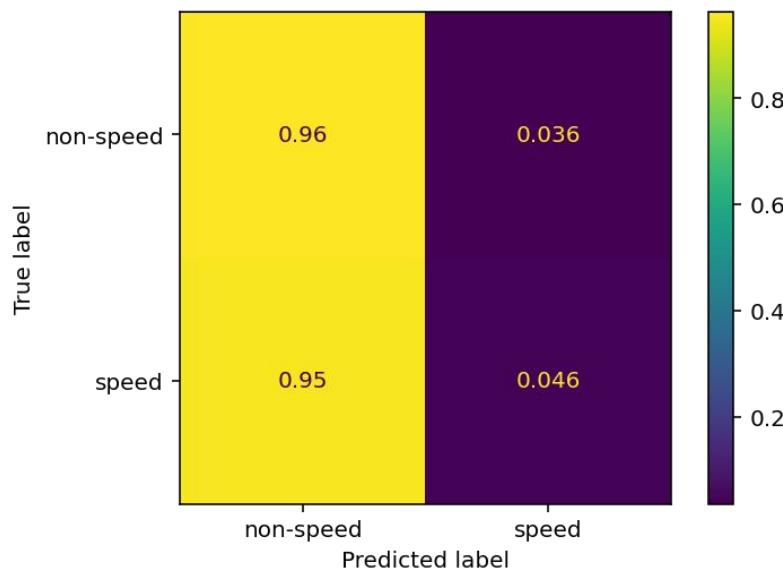
Recall 0.0

AUC 0.413

**Number of trainable parameters**

33,154

Model 3B

**Performance metrics on validation data**

Accuracy 0.704

F1 score 0.030

Precision 0.054

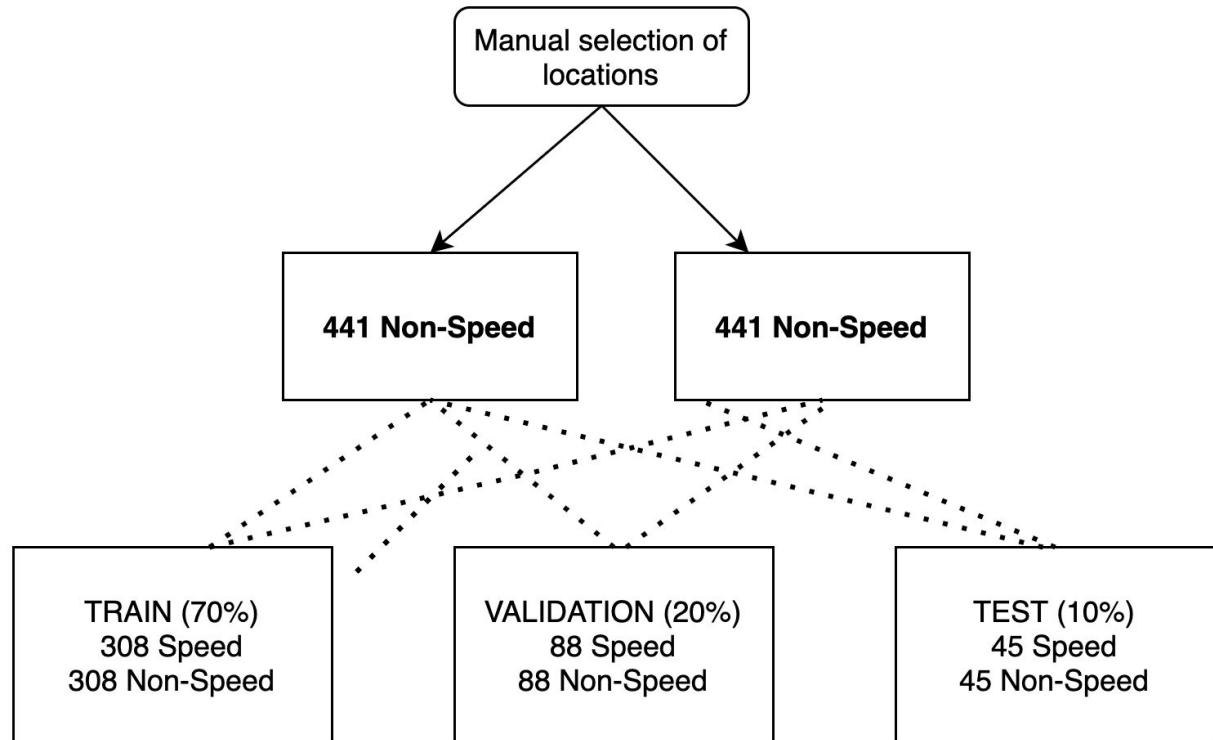
Recall 0.024

AUC 0.391

**Number of trainable parameters**

23,512,130

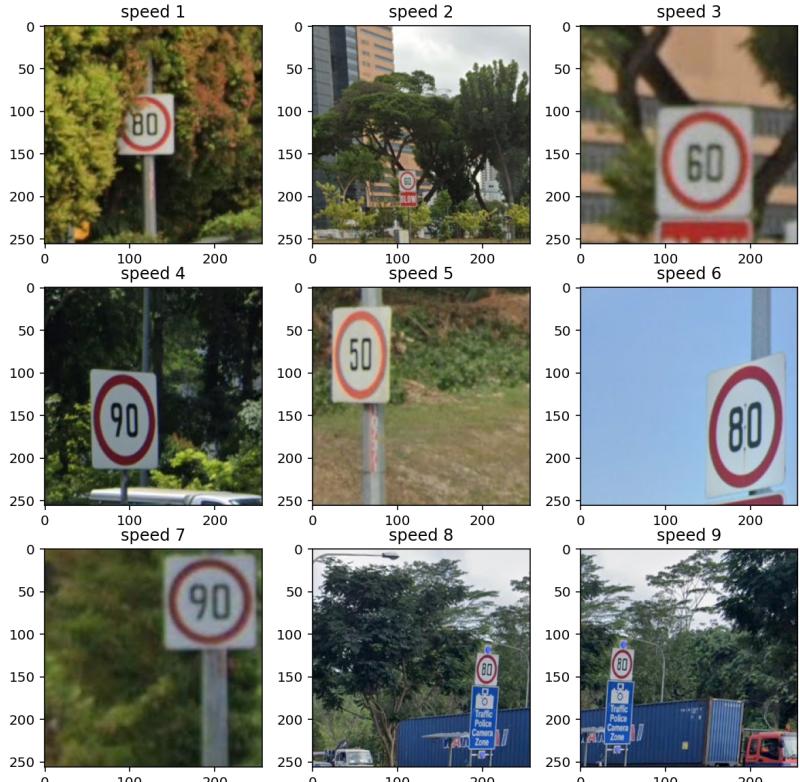
# Phase 4: Balanced dataset of screenshotted Street Views



# Phase 4: Balanced dataset of screenshotted Street Views

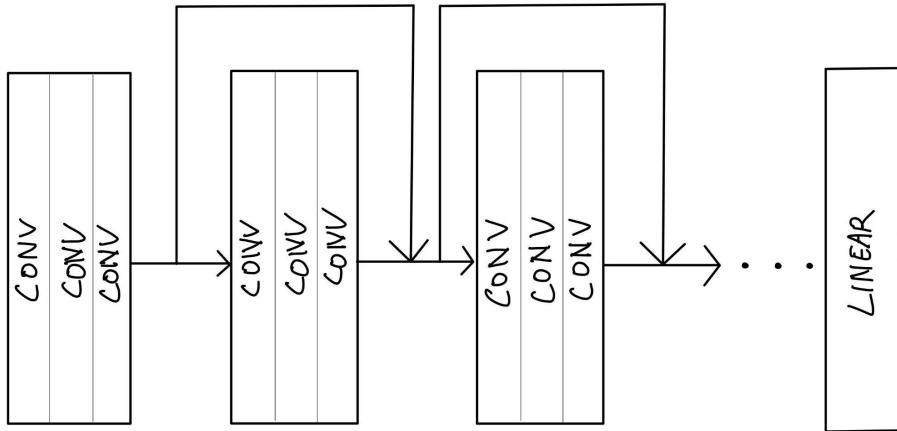
4

**SPEED** (441 images)



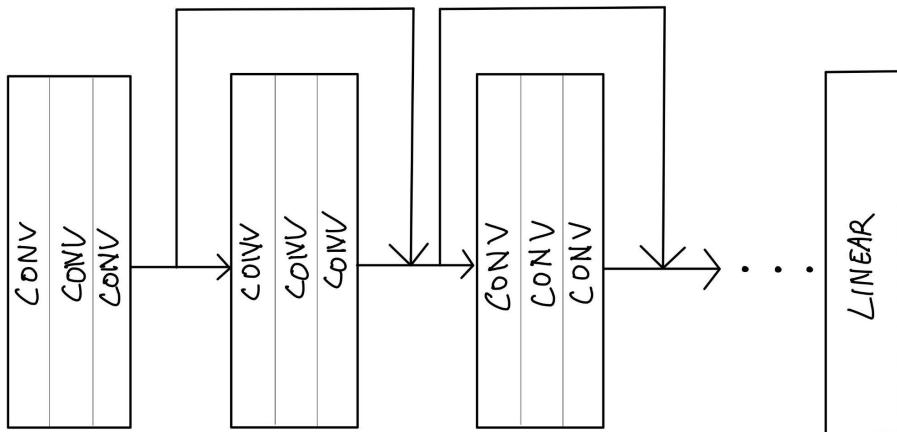
**NONSPEED** (441 images)





Model 4B

Trainable Parameters: 58,147,906

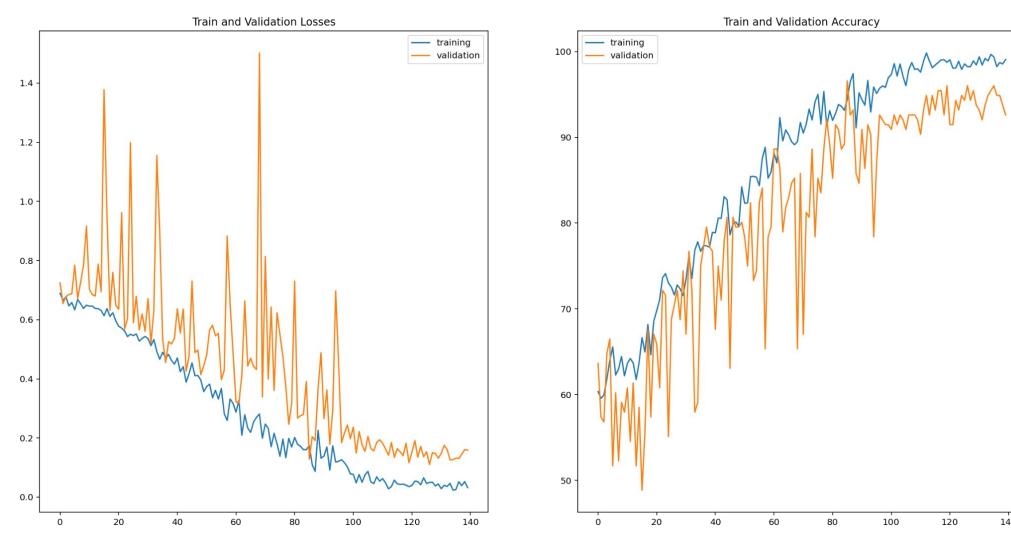
Based on ResNet152  
[3,8,36,3]<https://www.youtube.com/watch?v=DkNIBBBvcPs&t=369s>

Model 4C

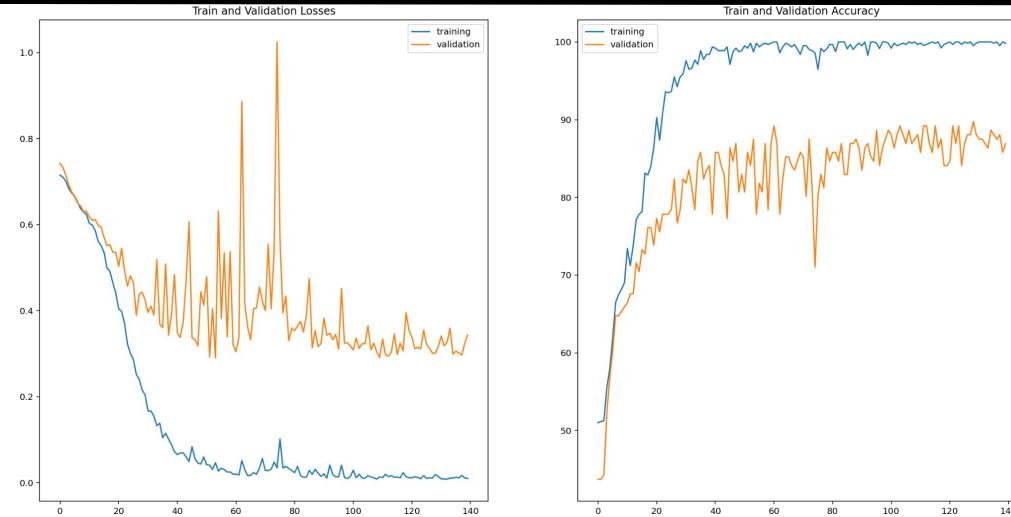
(ANSEL\_KENNETH\_RESNET\_BINARY\_CLASSIFIER)

Trainable Parameters: 1,254,218

inspiration from the paper "Residual Attention Network for Image Classification" by Fei Wang et al. (<https://arxiv.org/abs/1704.06904>).

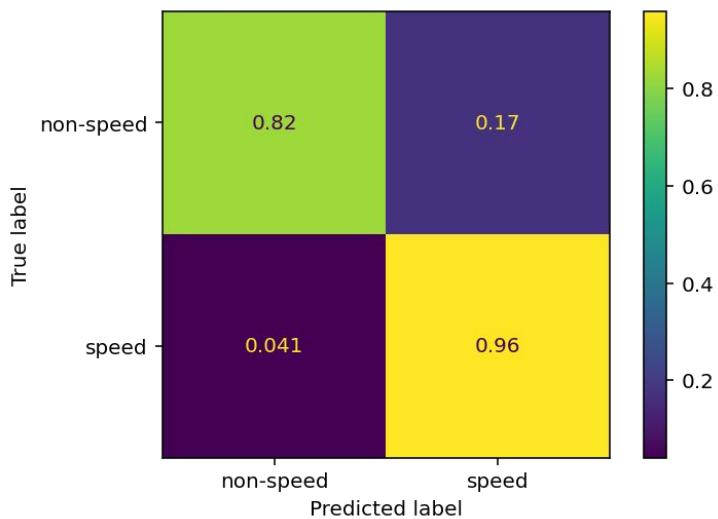


**Model 4B**  
Performance metrics on validation data  
Accuracy 0.9  
F1 score 0.912  
Precision 0.880  
Recall 0.961  
AUC 0.847



**Model 4C**  
Performance metrics on validation data  
Accuracy 0.911  
F1 score 0.858  
Precision 0.911  
Recall 0.911  
AUC 0.866

**Model 4B** “RESNET152”



### Performance metrics on validation data

Accuracy 0.9

F1 score 0.912

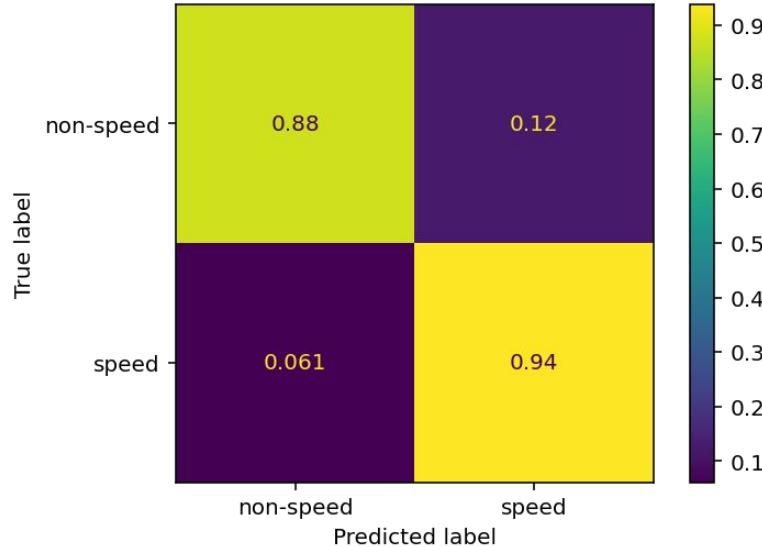
Precision 0.880

Recall 0.961

AUC 0.847

**Number of trainable parameters**  
58,147,906

**Model 4C** ANSEL\_KENNETH\_RESNET \_BINARY\_CLASSIFIER)



### Performance metrics on validation data

Accuracy 0.911

F1 score 0.857

Precision 0.911

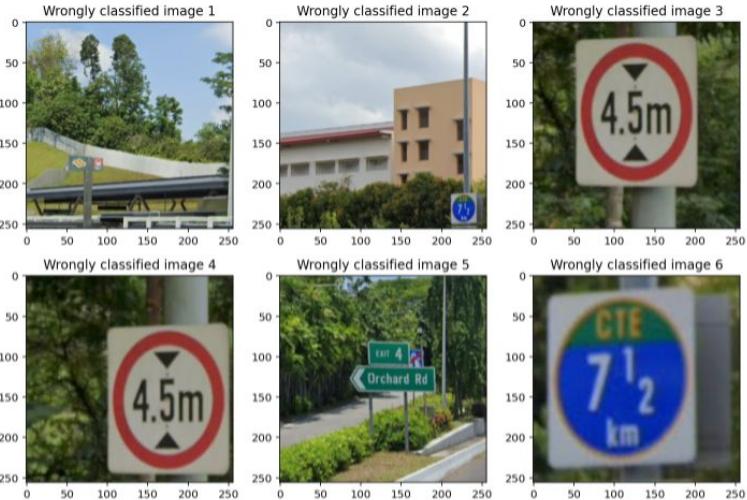
Recall 0.911

AUC 0.866

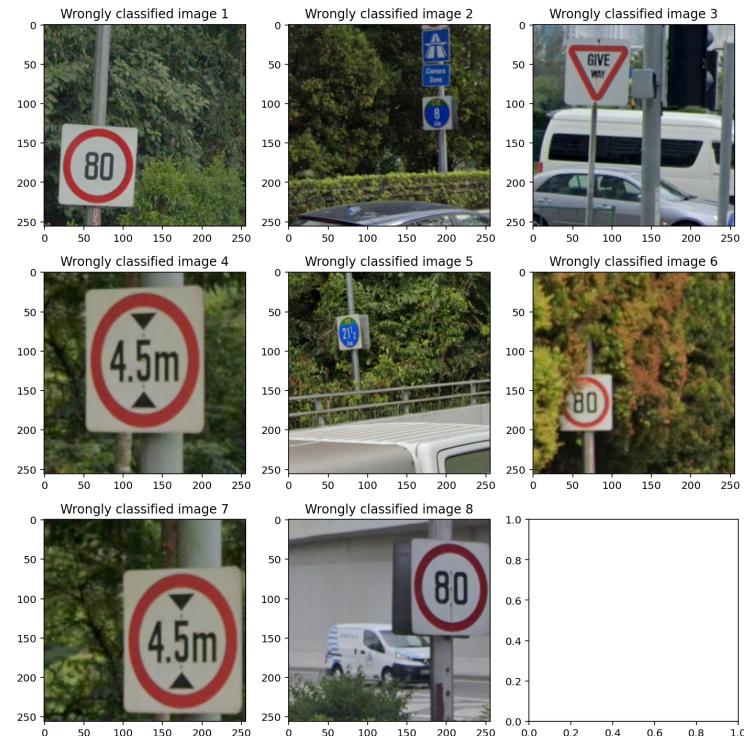
**Number of trainable parameters**  
1,254,218

Model 4B

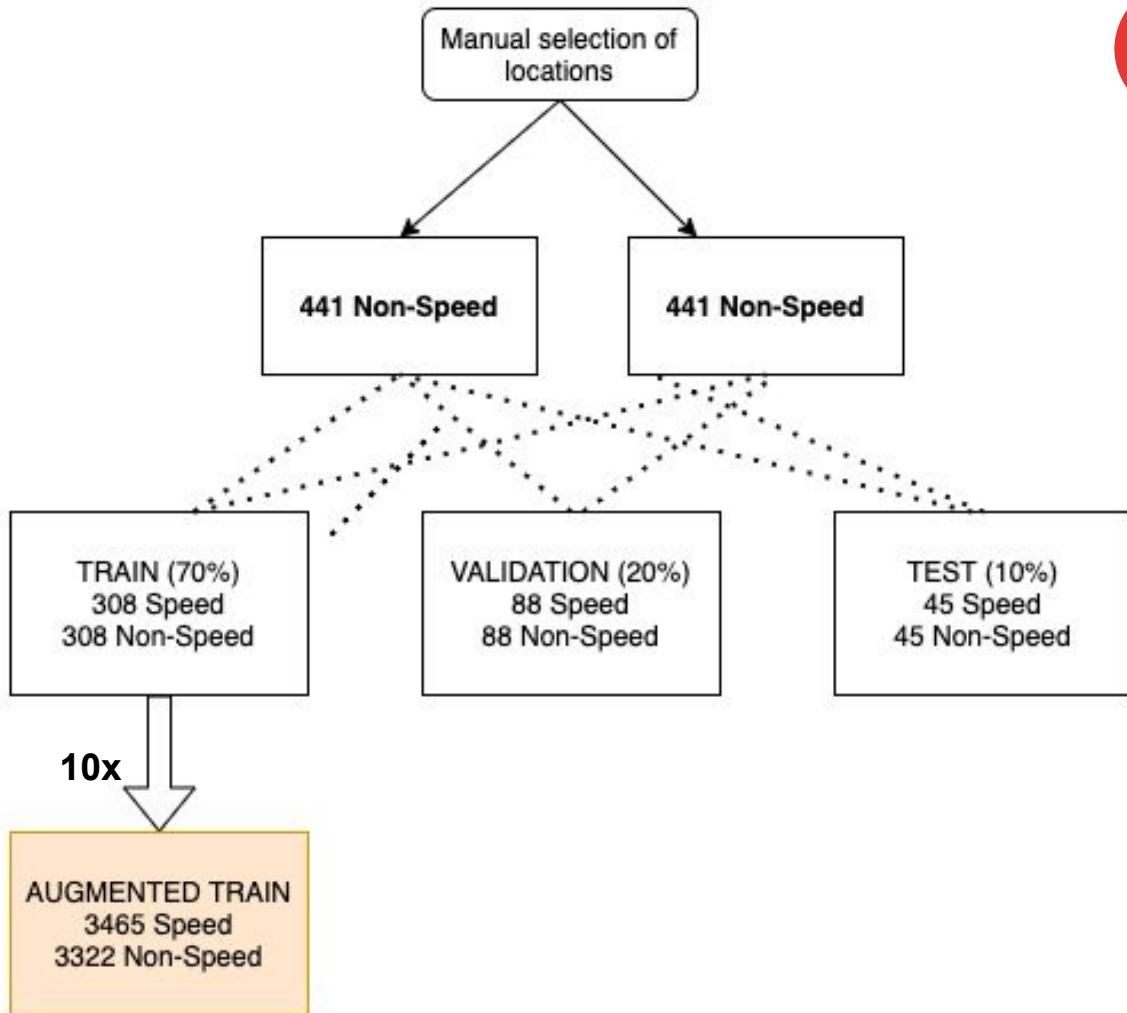
“RESNET152”

**WRONGLY CLASSIFIED IMAGES**

Model 4C

ANSEL\_KENNETH\_RESNET  
\_BINARY\_CLASSIFIER)

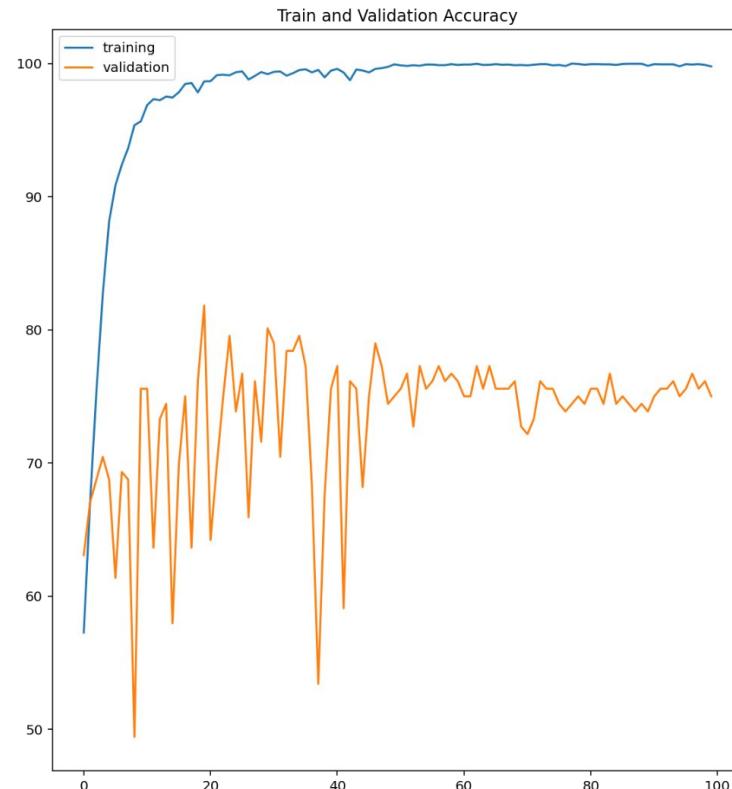
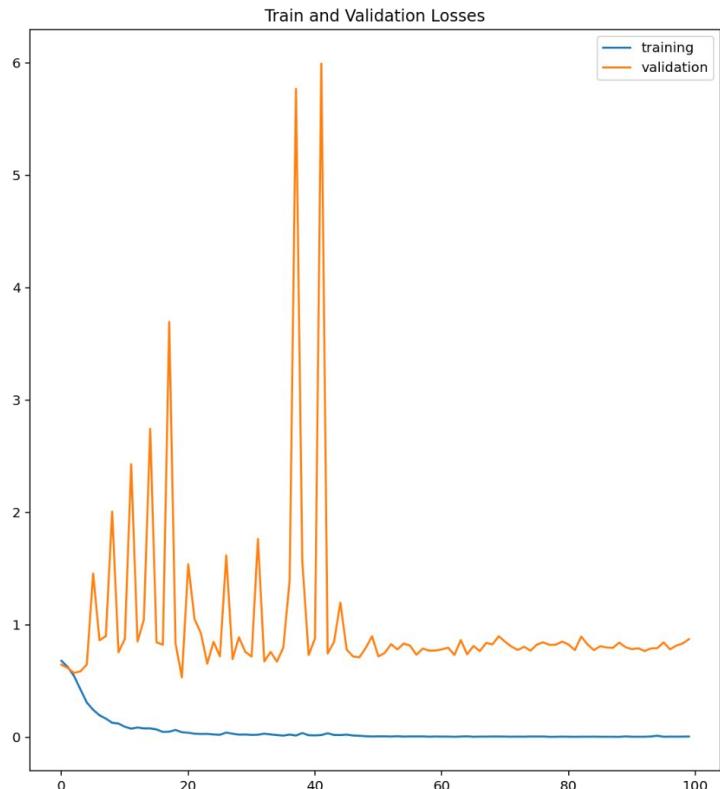
## Phase 4 Part 2



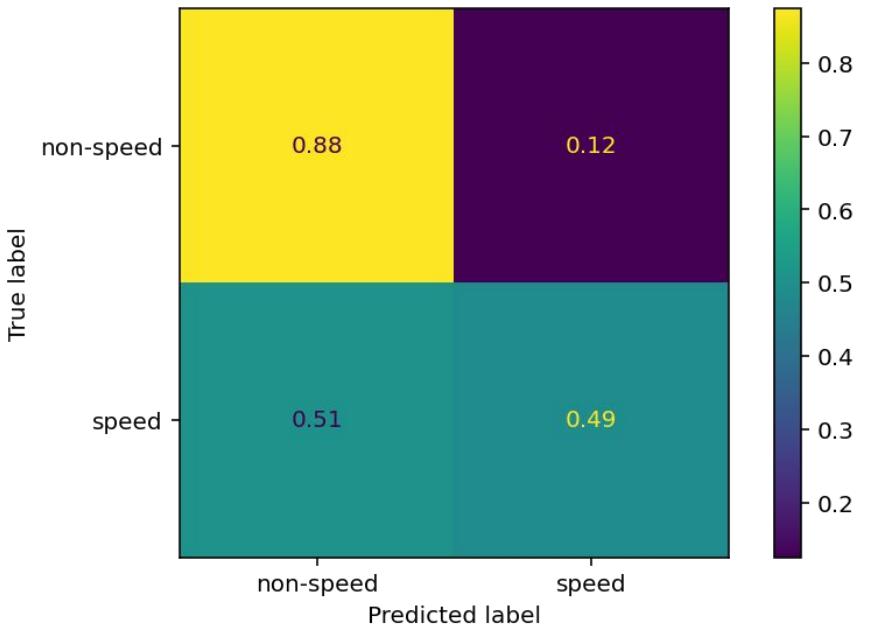
# Phase 4 Part 2: Phase 4 + Augmented Train Set



# Phase 4 Part 2

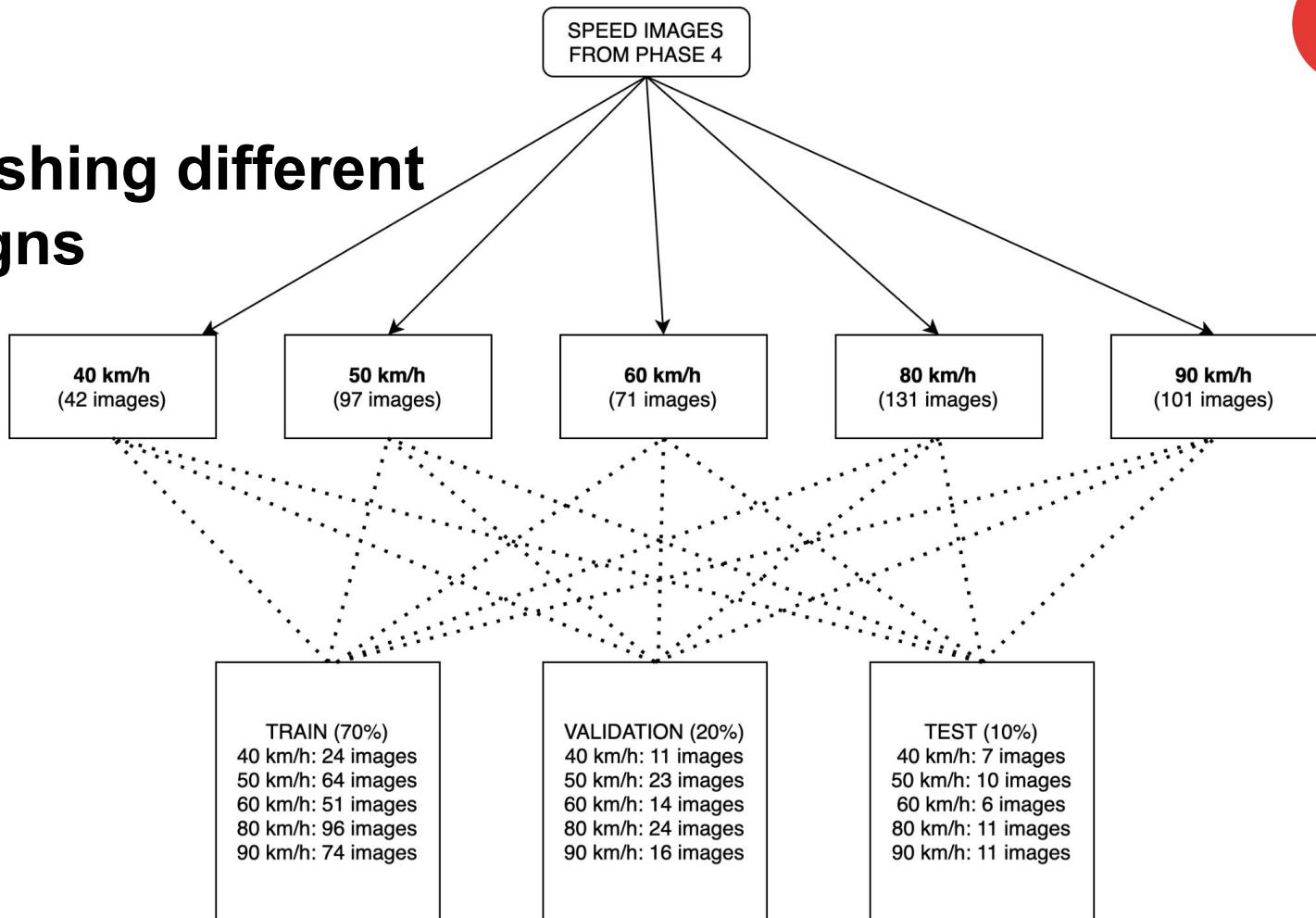


# Phase 4 Part 2

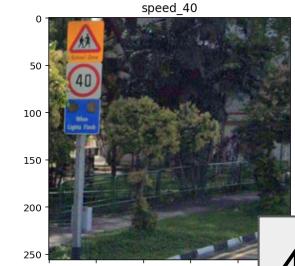


# Phase 5

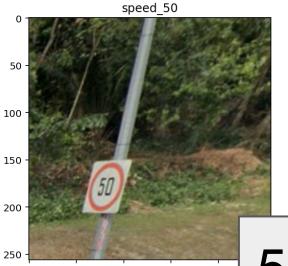
## Distinguishing different speed signs



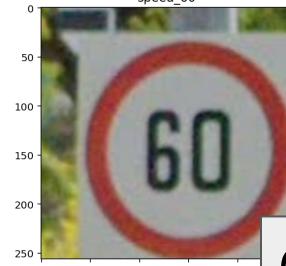
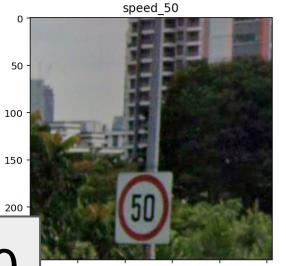
5



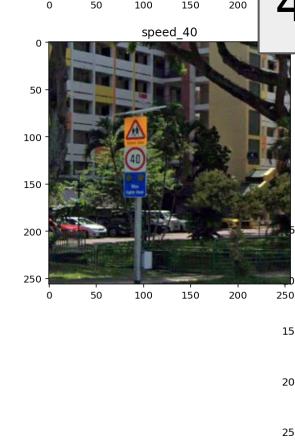
40



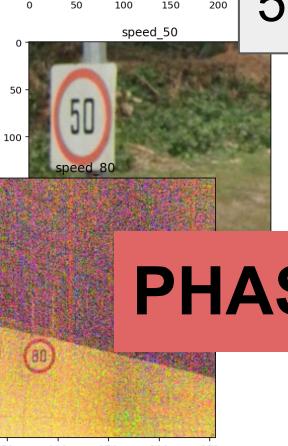
50



60



40



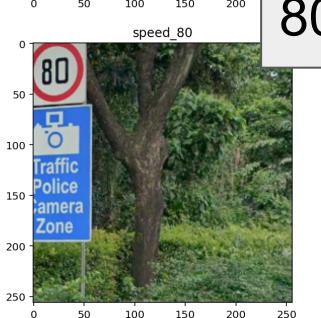
80

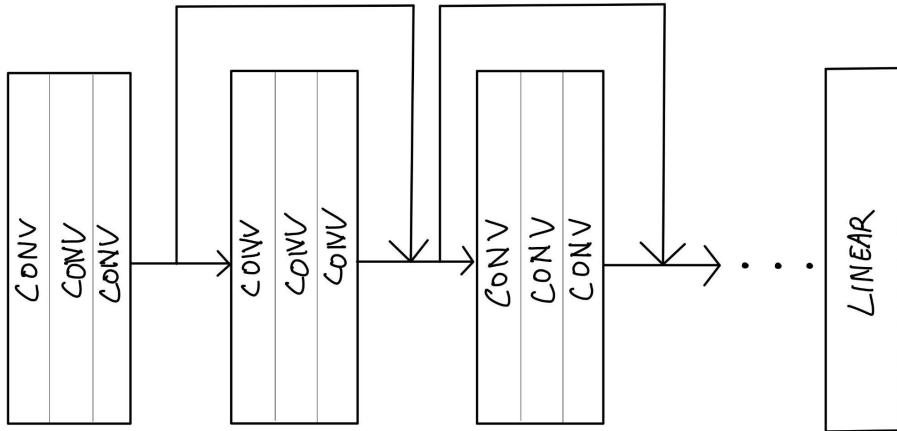


PHASE 5



90





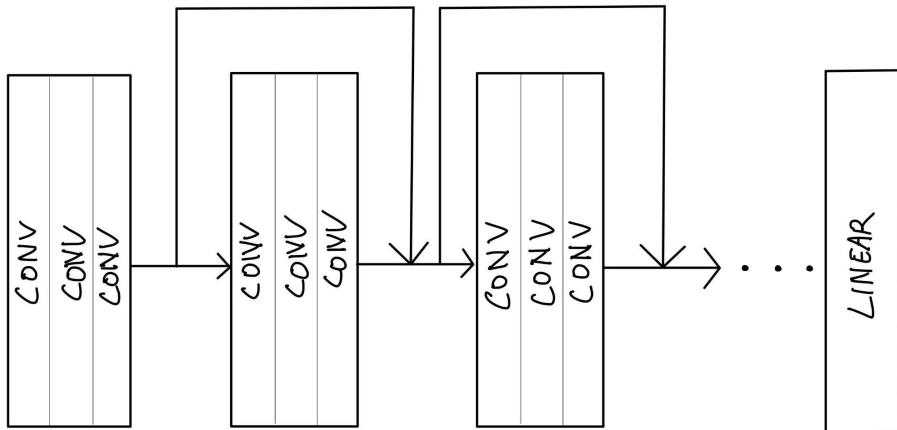
Model 5A

Trainable Parameters: 58,147,906

Based on ResNet152

[3,8,36,3]

expansion = 4 x number of input channels

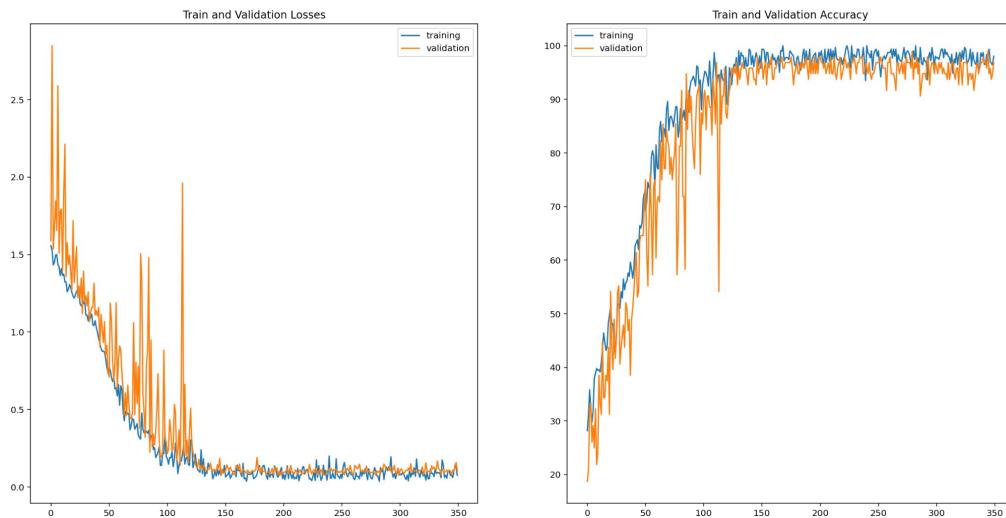
<https://www.youtube.com/watch?v=DkNIBBBvcPs&t=369s>

Model 5B

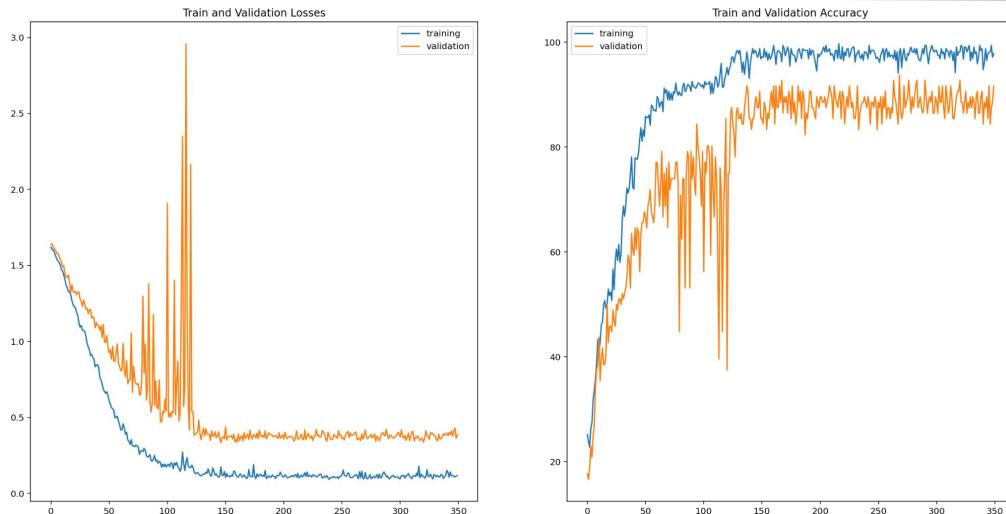
(ANSEL\_KENNETH\_RESNET\_BINARY\_CLASSIFIER)

Trainable Parameters: 1,254,218

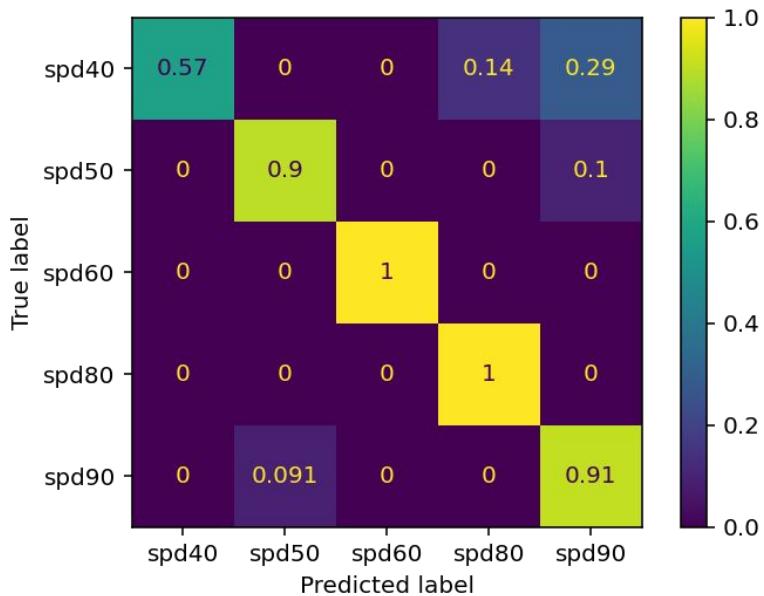
inspiration from the paper "Residual Attention Network for Image Classification" by Fei Wang et al. (<https://arxiv.org/abs/1704.06904>).



**Model 5A**  
(RESNET152)  
Performance metrics on validation data  
Accuracy 0.889  
F1 score 0.889  
Precision 0.889  
Recall 0.889



**Model 5B**  
(ANSEL\_KENNETH\_RESNET)  
Performance metrics on validation data  
Accuracy 0.844  
F1 score 0.844  
Precision 0.844  
Recall 0.844

**Model 5A****Performance metrics on validation data**

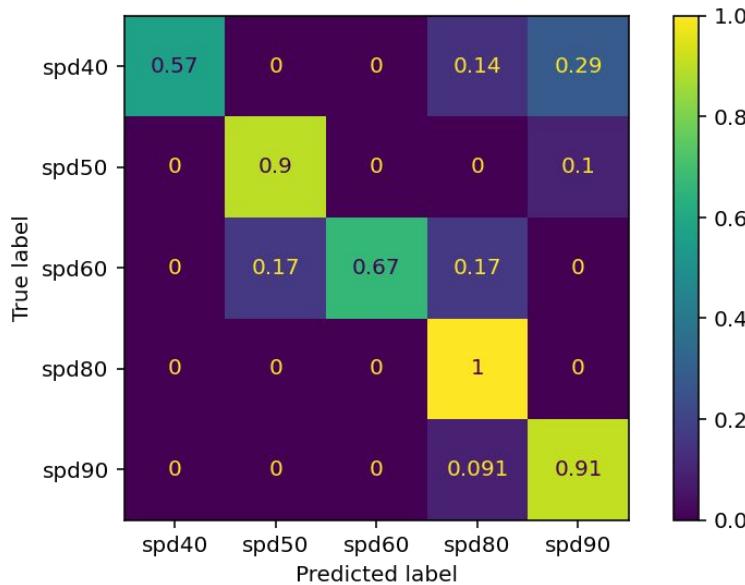
Accuracy 0.889

F1 score 0.889

Precision 0.889

Recall 0.889

**Number of trainable parameters**  
58,147,906

**Model 5B****Performance metrics on validation data**

Accuracy 0.844

F1 score 0.844

Precision 0.844

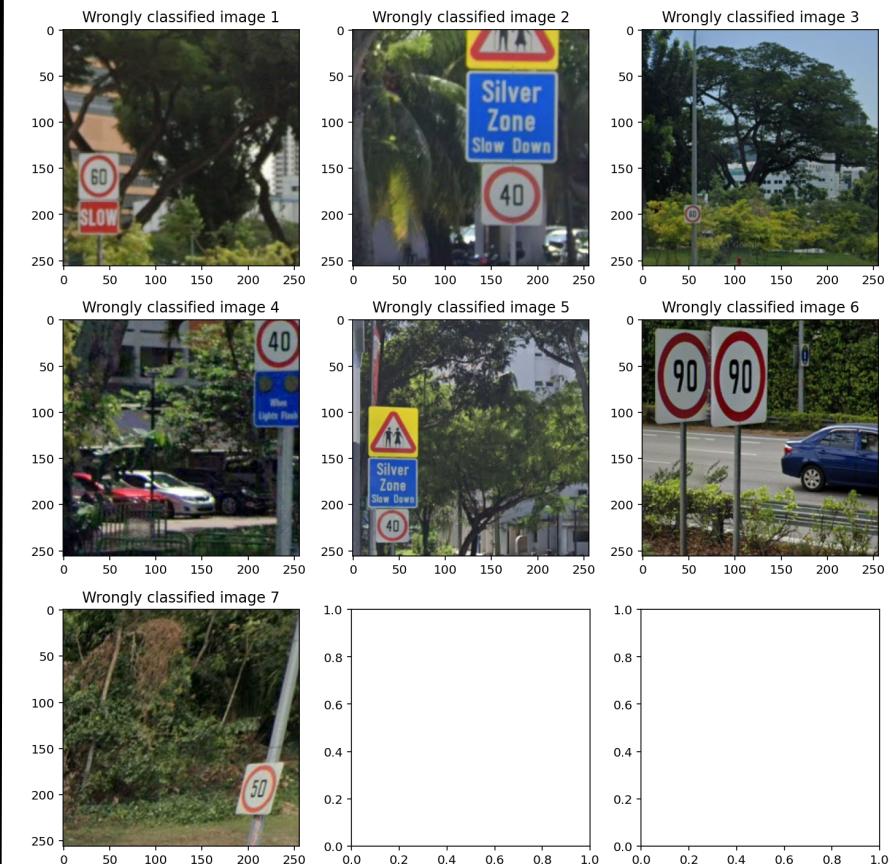
Recall 0.844

**Number of trainable parameters**  
1,254,218

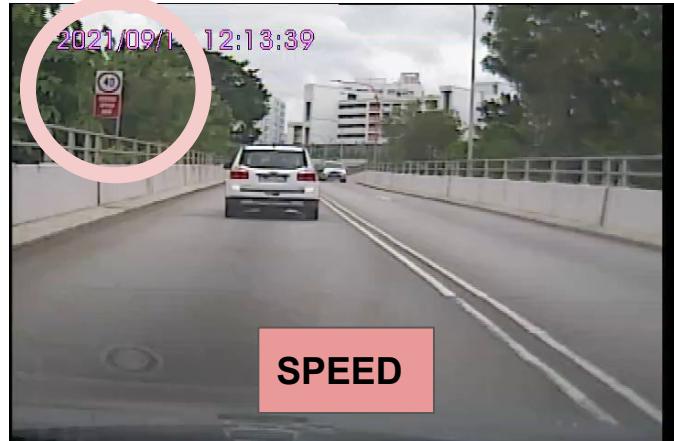
# WRONGLY CLASSIFIED IMAGES

Model 5B

Model 5A

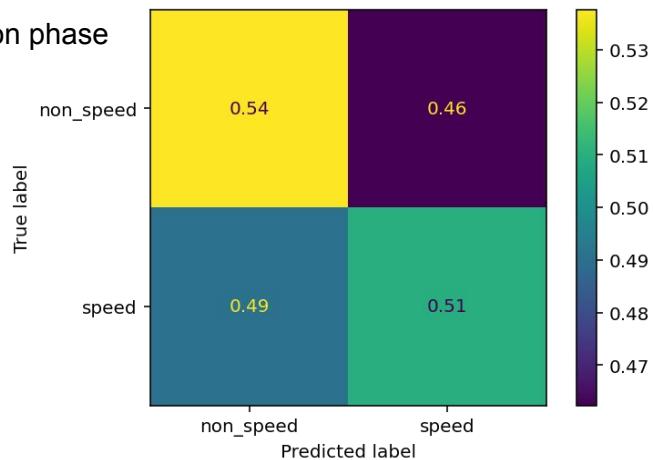


# Phase 6 Dataset

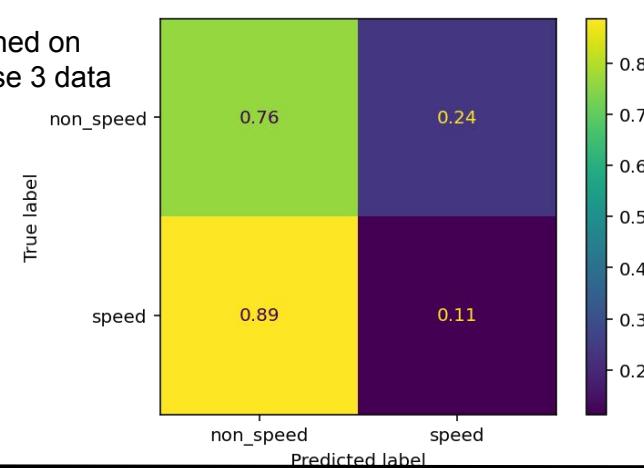


**Model 2E** (2 conv + 2 linear layers)

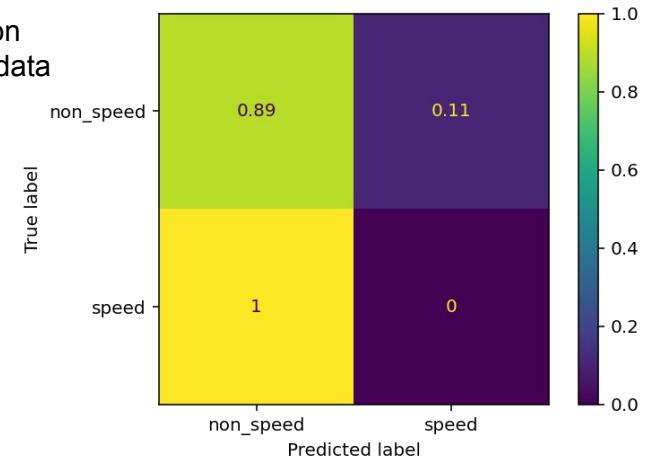
Trained on phase  
2 data

**Model 3B** (ResNet50)

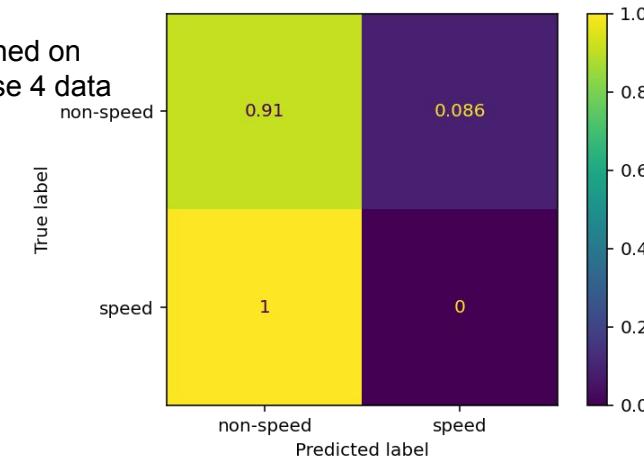
Trained on  
phase 3 data

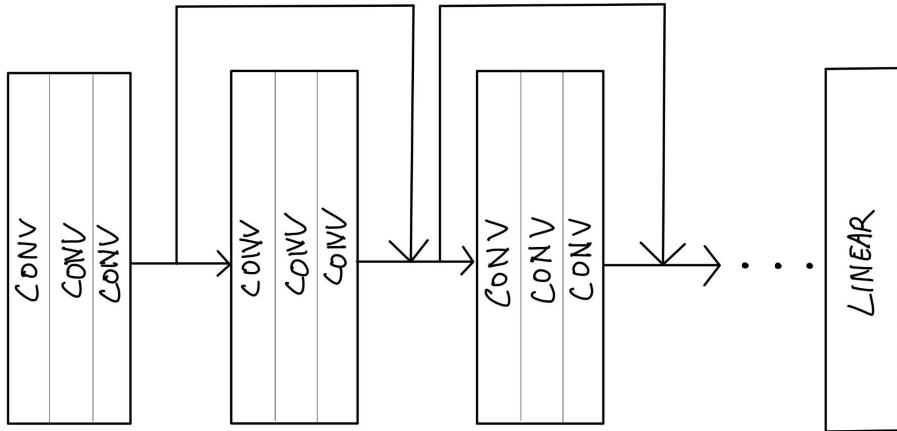
**Model 4A** (ResNet 152)

Trained on  
phase 4 data

**Model 4B** (ANSEL\_KENNETH\_RESNET)

Trained on  
phase 4 data



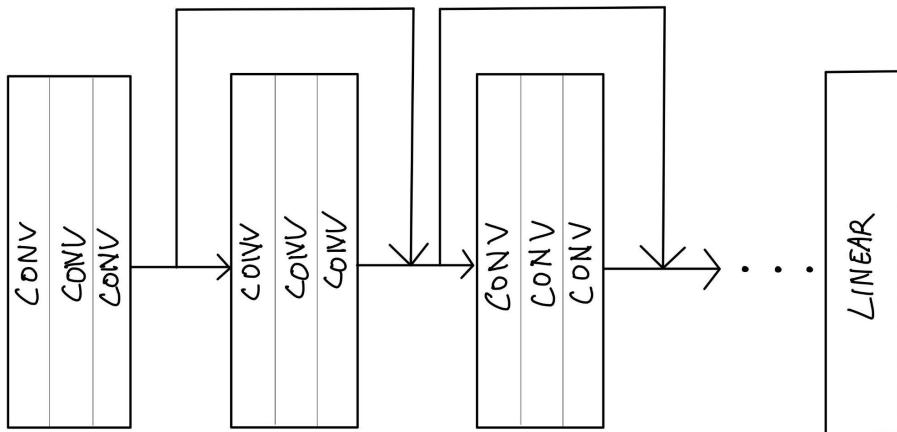


Model 6A

[Finetuned/Retrained Model 4A \(ResNet152\)](#)

Trainable Parameters: 58,147,906

<https://www.youtube.com/watch?v=DkNIBBBvcPs&t=369s>

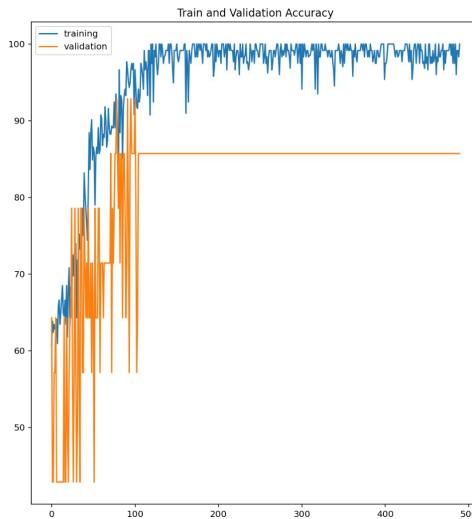
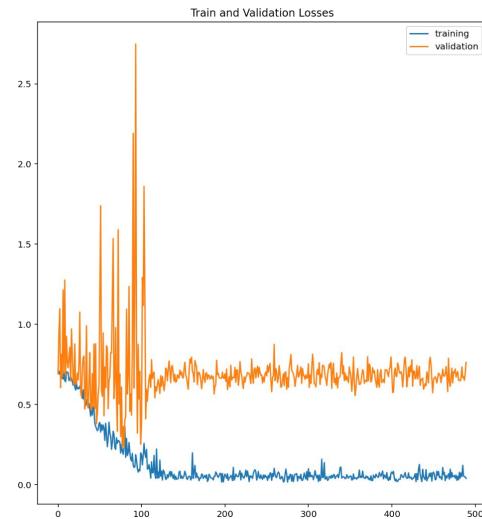


Model 6B

[Finetuned/Retrained Model 4B  
\(ANSEL\\_KENNETH\\_RESNET\)](#)

Trainable Parameters: 1,254,218

inspiration from the paper "Residual Attention Network for Image Classification" by Fei Wang et al. (<https://arxiv.org/abs/1704.06904>).



## Model 6A

Finetuned/Retrained Model 4A  
(ResNet152)

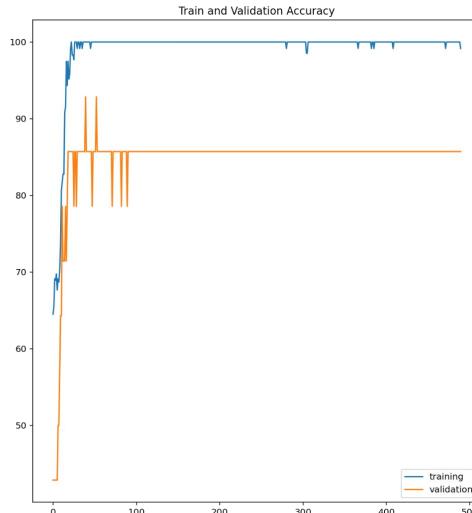
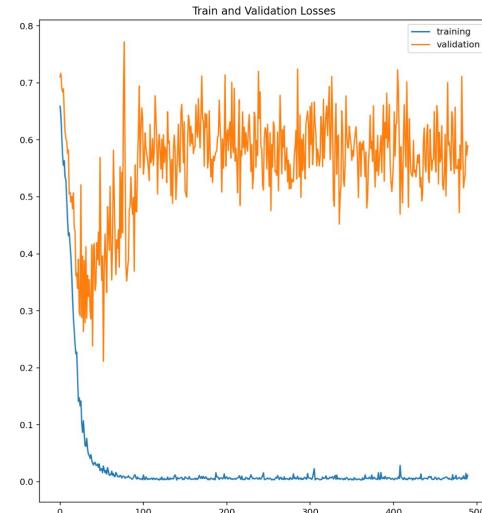
Performance metrics on validation data

Accuracy 0.9

F1 score 0.9

Precision 0.9

Recall 0.9



## Model 6B

Finetuned/Retrained Model 4B  
(ANSEL\_KENNETH\_RESNET)

Performance metrics on validation data

Accuracy 0.85

F1 score 0.85

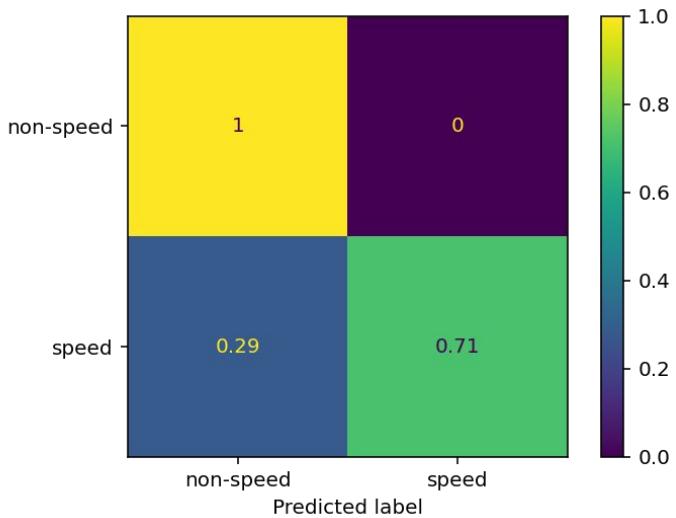
Precision 0.85

Recall 0.85

Model 6A

Finetuned/Retrained Model 4A  
(ResNet152)

True label

**Performance metrics on validation data**

Accuracy 0.9

F1 score 0.9

Precision 0.9

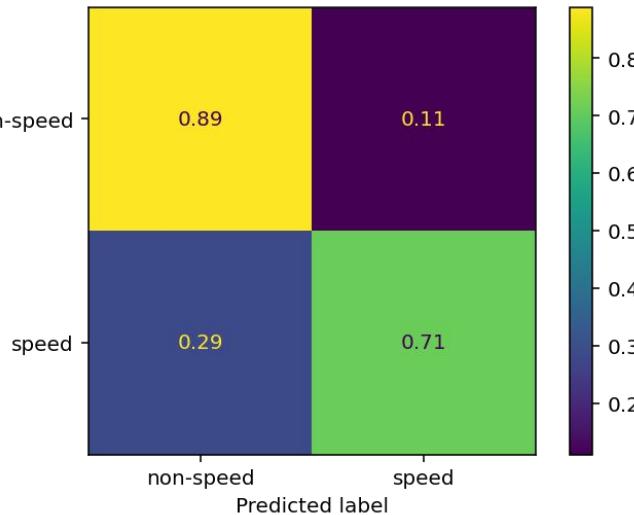
Recall 0.9

**Number of trainable parameters**  
58,147,906

Model 6B

Finetuned/Retrained Model 4B  
(ANSEL\_KENNETH\_RESNET)

True label

**Performance metrics on validation data**

Accuracy 0.85

F1 score 0.85

Precision 0.85

Recall 0.85

**Number of trainable parameters**  
1,254,218

## WRONGLY CLASSIFIED IMAGES

Model 6A



Model 6B



# “Phase 7”: Finetuned Pretrained Models on Phase 4 Data

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#	Model	Name	accuracy	f1	precision	recall	auc
0	<b>Model 4c from Phase 4 AK_RESNET_BINARY_CLASSIFIER()</b>		<b>0.91</b>	<b>0.86</b>	<b>0.91</b>	<b>0.91</b>	<b>0.87</b>
1	model7a	ResNet18	0.96	0.9	0.89	0.93	0.79
2	model7b	AlexNet	0.83	0.8	0.81	0.81	0.77
3	model7c	SqueezeNet	0.8	0.78	0.82	0.81	0.76
4	model7d	VGG16	0.85	0.81	0.87	0.79	0.71
5	<b>model7e</b>	<b>DenseNet</b>	<b>0.95</b>	<b>0.97</b>	<b>0.97</b>	<b>0.97</b>	<b>0.91</b>
6	model7f	GoogleNet	0.9	0.91	0.92	0.92	0.78
7	model7g	ShuffleNet	0.92	0.88	0.88	0.9	0.84
8	<b>model7h</b>	<b>InceptionNet</b>	<b>0.94</b>	<b>0.95</b>	<b>0.94</b>	<b>0.94</b>	<b>0.95</b>