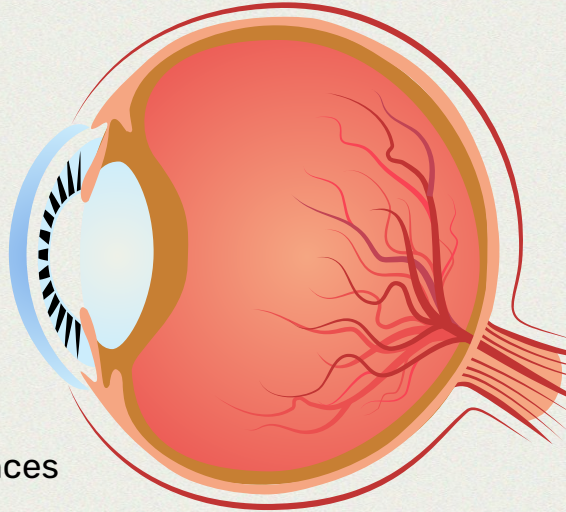
DRIVER DROWSINESS: MODEL PERFORMANCE ANALYSIS



How well models predict driver drowsiness from images of different distances

Jordan Ehlinger, Jui-Jia (Jessica) Lin, Cassie Ren, Anisha Singh, Bolun Zhang

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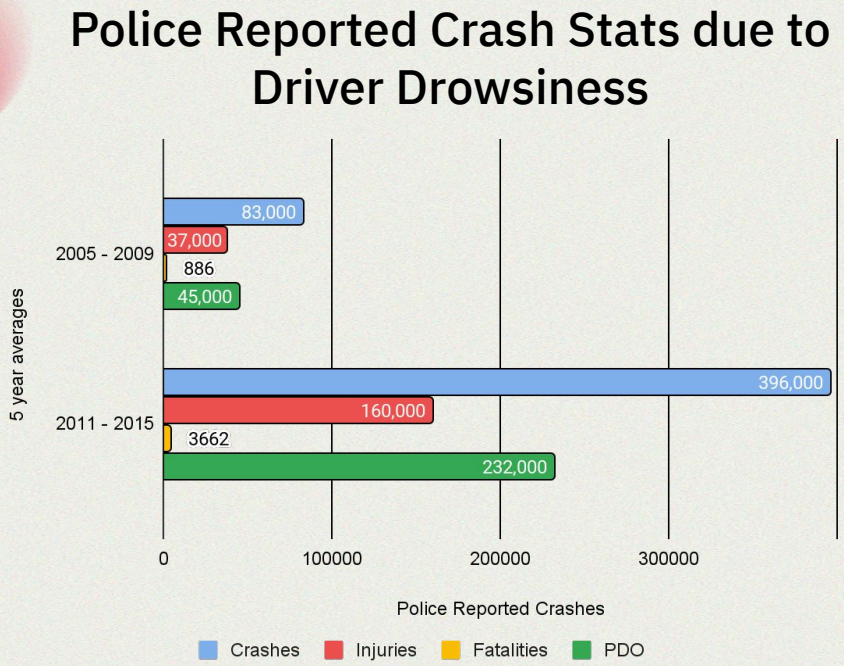
01

THE PROBLEM

Drowsy Driving - What's up with that?

ACCIDENT STATISTICS



1:25

1 in 25 drivers admit to falling asleep at the wheel

20+ hrs

Driving 20+ hours without sleeping = 0.08% BAC

21%

On average, drowsy driving is a factor in 21% of fatal crashes each year

FINANCIAL COSTS

$109 Billion

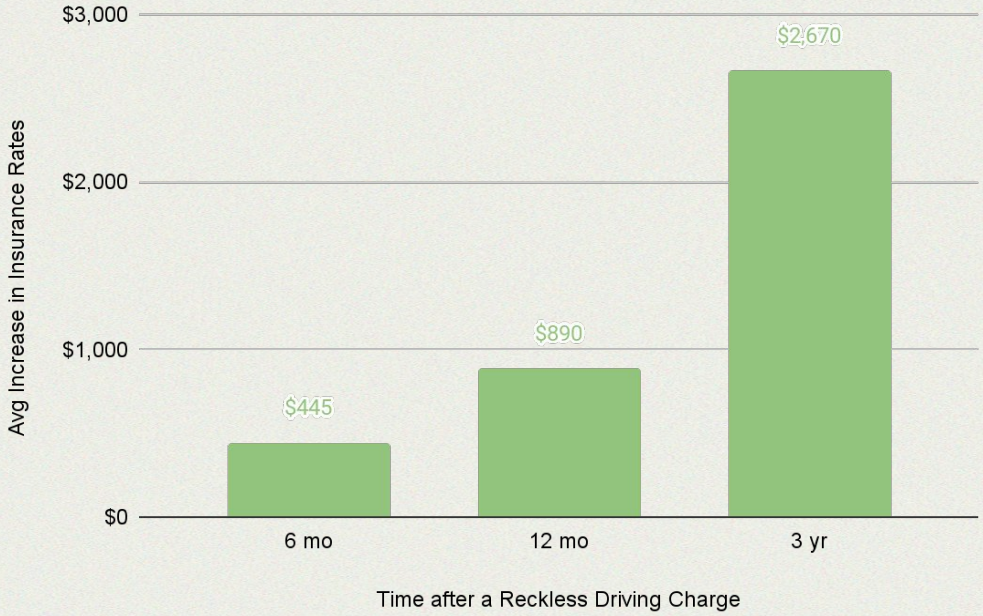
Societal costs, annually - not including property damage (NHTSA)

$12.5 Billion

Monetary losses (NHTSA)

FINANCIAL COSTS

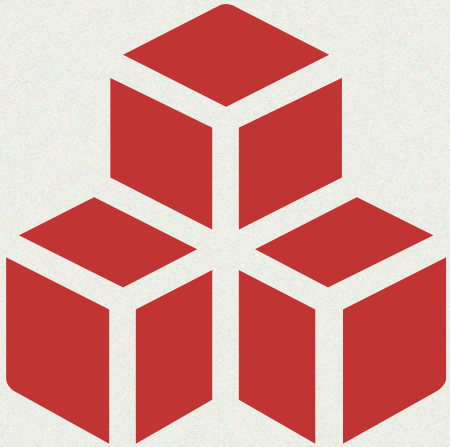
Avg Increase in Car Insurance Rates After Reckless Driving Ticket



Insurance rates increase

- An average of $500/6-mo policy period
- Over $3,000 over the course of a 3 year period.

Avg cost of car insurance	$1,771
Avg. cost of car insurance after accident	$2,521
$ increase	+$750
% increase	+42%



02

DATA OVERVIEW

Where did we find the data?

DATA COLLECTION

MRL Eye Dataset

Training Dataset

Driver Face Dataset

Testing Dataset

Closed Eyes In The Wild

Testing Dataset

METHODS OF ACQUISITION

Histogram of Oriented Gradients (HOG)

- This feature extraction method captures the structure of the eyes by encoding the direction of edges and gradients, which are informative for the appearance of open or closed eyes.

SVM Classifier

- Classifier that uses these features to learn a boundary between the different categories of images (e.g., open vs. closed eyes).

MRL EYE DATASET

Eye Dataset

Close-Up

Only eyes are shown in the image

Gender

Contains the information about gender for each image

Glass

Information if the eye image contains glasses

Reflection

Three reflection states based on the size of reflections

Lightning Condition

Two states (bad, good) based on the amount of light during capturing

CLOSED EYES IN THE WILD

Face Dataset

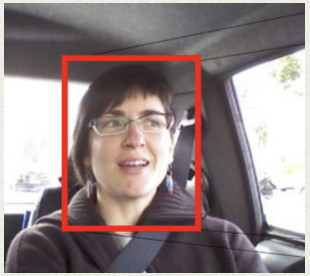
Facial

Focus on the entire face

Facial Key Points

Eyes, nose and mouth, several facial features like glasses and beard.

DRIVER FACE DATASET



Face Dataset

General

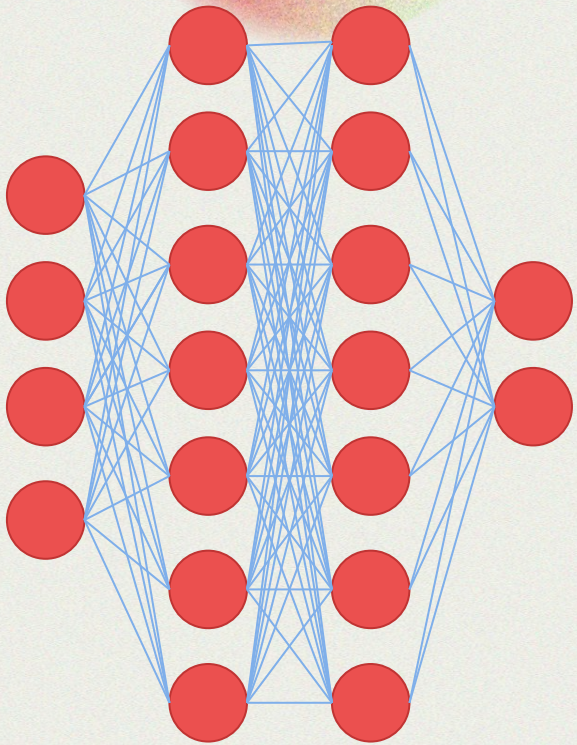
Background with annotation of the face bounding box

Facial Key Points

Eyes, nose and mouth, several facial features like glasses and beard.

Gaze Direction

“Looking-right”, “frontal”, “looking-left”

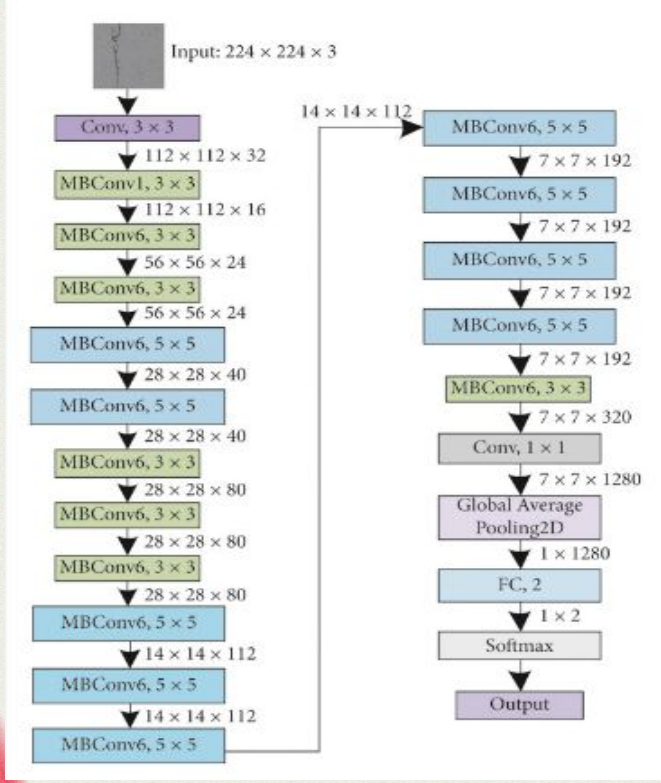


03

THE MODEL

Convolutional Neural Network in TensorFlow
for Binary Image Classification

WHY EFFICIENT NET?



Optimal Balance

Superior balance between accuracy and computational efficiency, which is achieved through a systematic approach to scaling called "compound scaling".

Versatility Across Devices

Can be deployed on a wide range of devices, from mobile and edge devices with EfficientNet-Lite to powerful cloud servers with the larger B7 model.

State of Art Performance

Has achieved state-of-the-art accuracy on image classification tasks, making them a top choice for advanced visual recognition problems.

Pre-Trained and Customizable

Comes with pre-trained models on ImageNet, which can be used as is or further fine-tuned to suit specific tasks and datasets.

MODEL SPECIFICATIONS

Layer (type)	Output Shape	Param #
efficientnetb0 (Functional)	(None, 1280)	4049571
batch_normalization_1 (BatchNormalization)	(None, 1280)	5120
dense_2 (Dense)	(None, 256)	327936
dropout_1 (Dropout)	(None, 256)	0
dense_3 (Dense)	(None, 2)	514

Total params: 4383141 (16.72 MB)
Trainable params: 4338558 (16.55 MB)
Non-trainable params: 44583 (174.16 KB)

Architecture

EfficientNet architecture which uniformly scales all dimensions of depth/width/resolution

Normalization

Batch normalization that utilizes momentum to reduce training duration

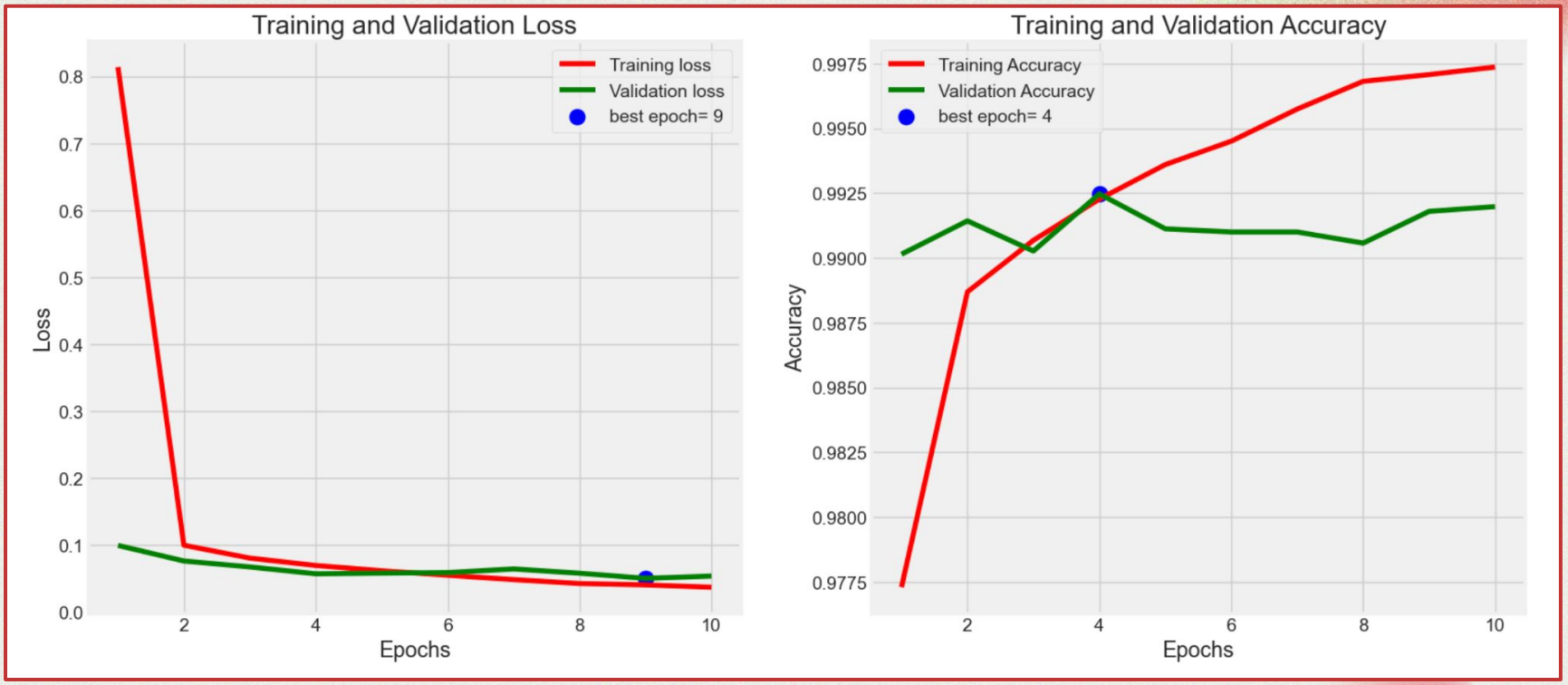
Dropout

Drops nodes during training at rate of 0.45 to reduce overfitting

Optimizer

Legacy Adamax with learning rate of 0.001

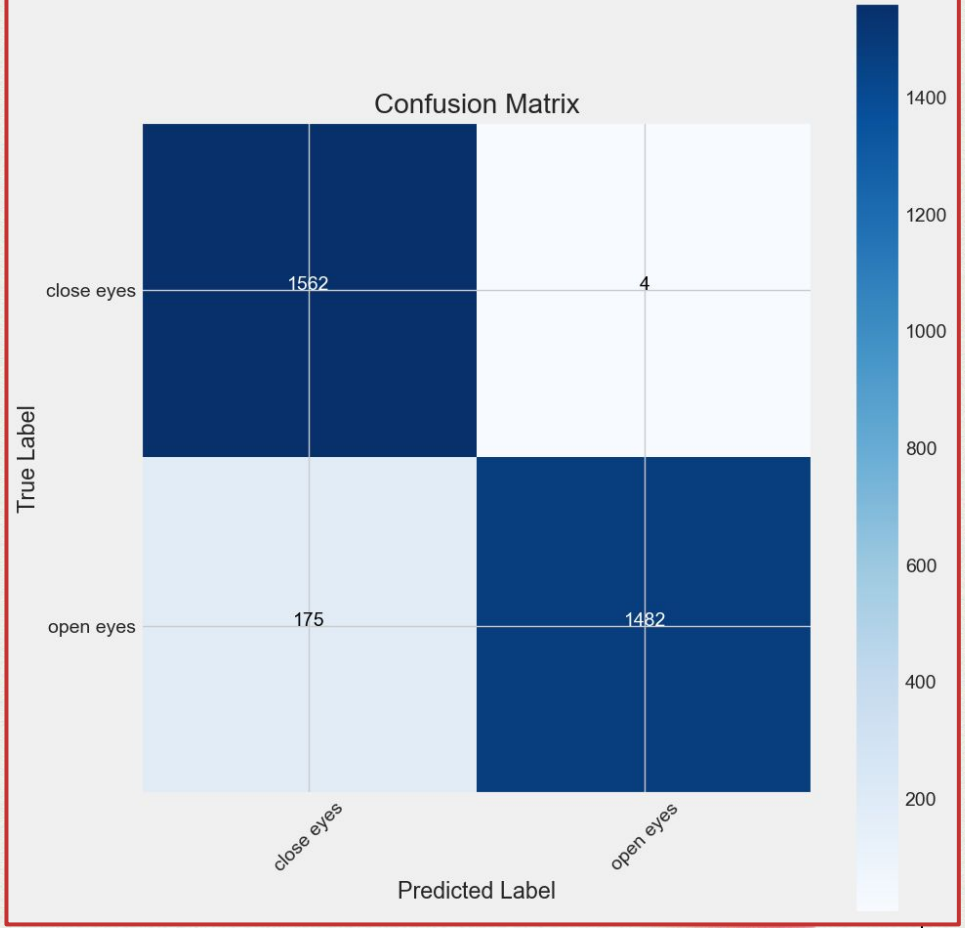
TRAINING PERFORMANCE



Test Performance

	precision	recall	f1-score	support
close eyes	0.90	1.00	0.95	1566
open eyes	1.00	0.89	0.94	1657
accuracy			0.94	3223
macro avg	0.95	0.95	0.94	3223
weighted avg	0.95	0.94	0.94	3223

```
Train Loss:  0.026102516800165176
Train Accuracy:  0.9985068440437317
--------------------
Validation Loss:  0.04426911473274231
Validation Accuracy:  0.9933874011039734
--------------------
Test Loss:  0.24402648210525513
Test Accuracy:  0.9444617033004761
```



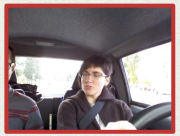
EXTERNAL DATASET TESTING

CLOSED EYES IN THE WILD EYE PATCHES[1]

Eye patches are collected based on the coarse face region and eye position automatically and respectively estimated by the face detector and eye localization. We first resize the cropped coarse faces to the size 100×100 (pixels) and then extract eye patches of 24×24 centered at the localized eye position.

CLOSED EYES IN THE WILD[1]

This dataset contains 2423 subjects, among which 1192 subjects with both eyes closed are collected directly from Internet, and 1231 subjects with eyes open are selected from the Labeled Face in the Wild database.



DRIVER FACE[2]

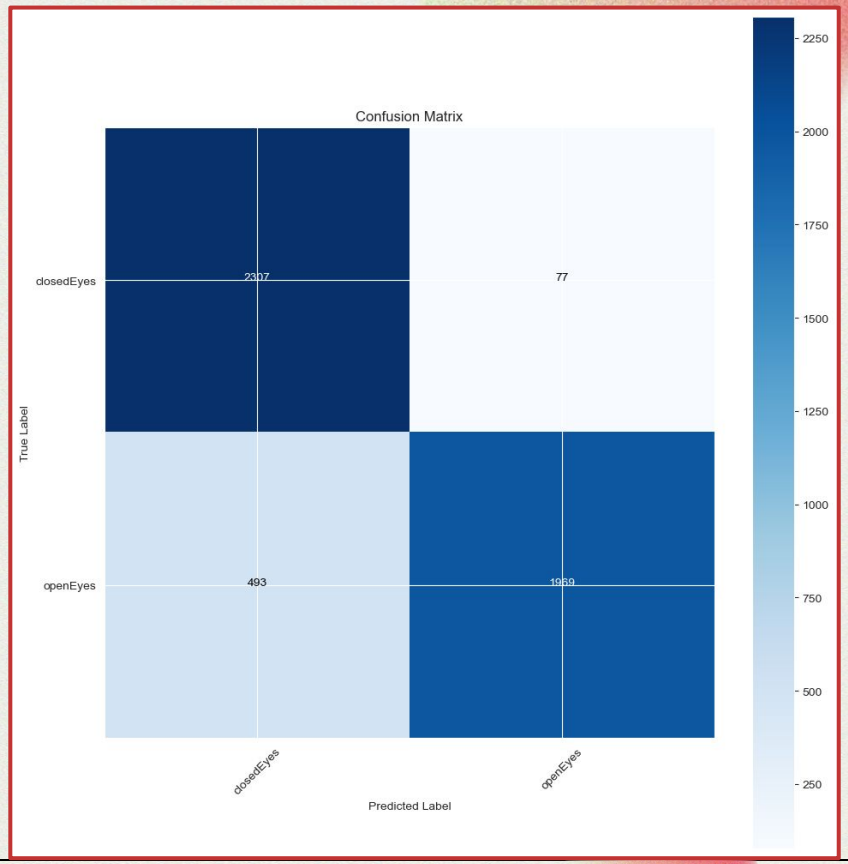
The DrivFace database contains images sequences of subjects while driving in real scenarios. It is composed of 606 samples of 640×480 pixels each, acquired over different days from 4 drivers (2 women and 2 men) with several facial features like glasses and beard.

1. https://parnec.nuaa.edu.cn/_upload/tpl/02/db/731/template731/pages/xtan/ClosedEyeDatabases.html
2. http://adas.cvc.uab.es/elektra/enigma-portfolio/cvc11-drivface-dataset/

Closed Eyes In the Wild Eye Patches Test Performance

```
Test Loss:  0.3227684795856476
Test Accuracy:  0.8823772072792053
```

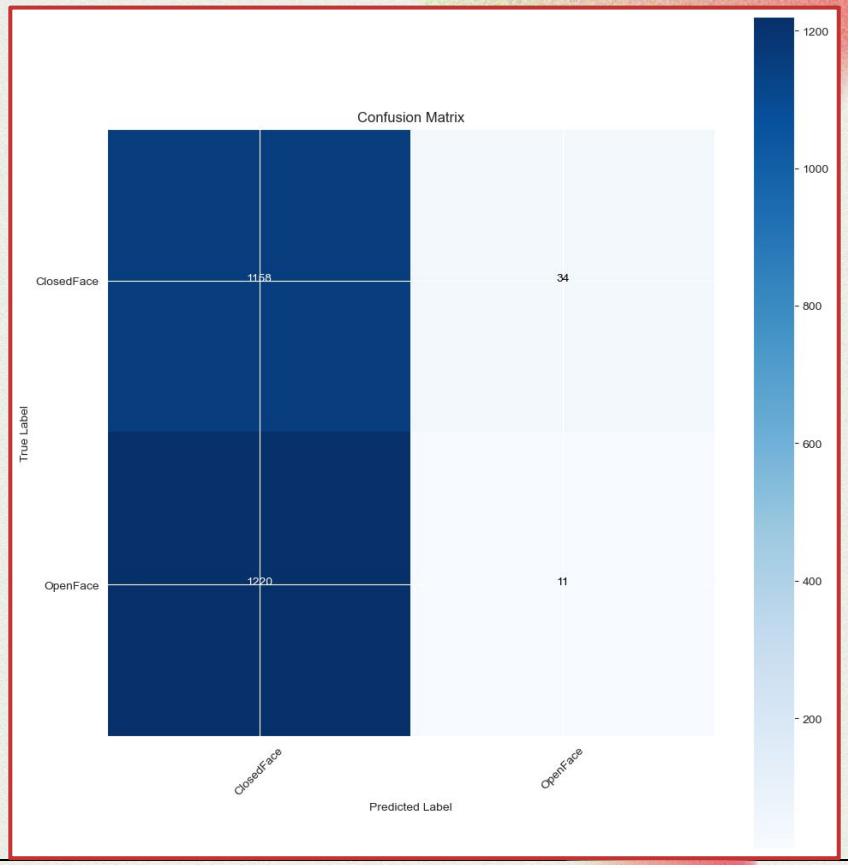
	precision	recall	f1-score	support
closedEyes	0.82	0.97	0.89	2384
openEyes	0.96	0.80	0.87	2462
accuracy			0.88	4846
macro avg	0.89	0.88	0.88	4846
weighted avg	0.89	0.88	0.88	4846



Closed Eyes In The Wild Test Performance

```
Test Loss:  41.48398971557617
Test Accuracy:  0.48245975375175476
```

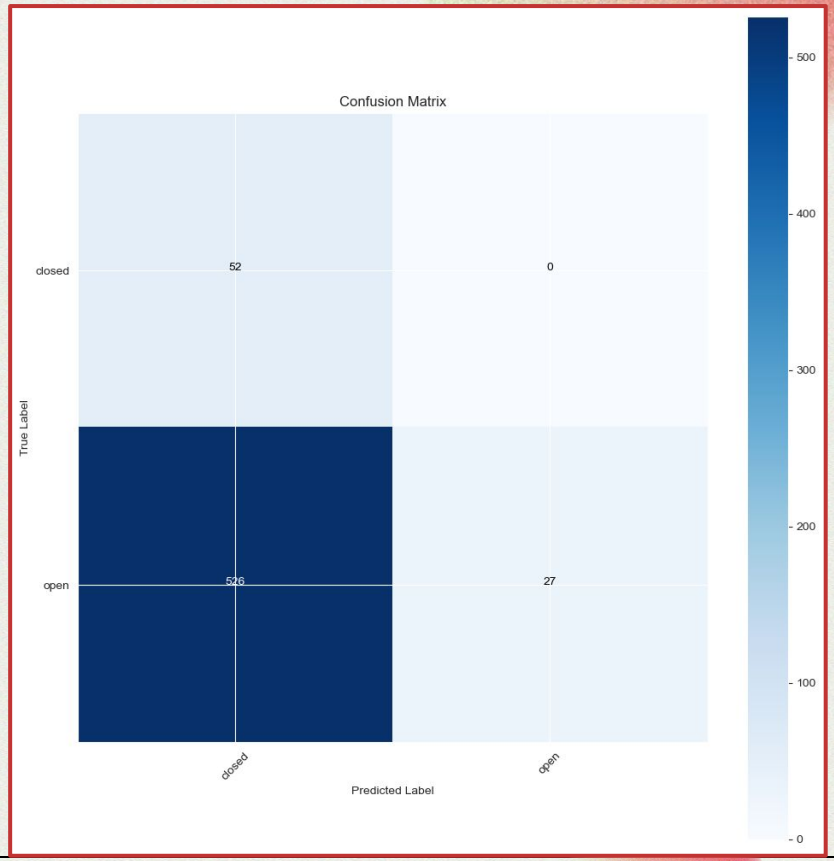
	precision	recall	f1-score	support
ClosedFace	0.49	0.97	0.65	1192
OpenFace	0.24	0.01	0.02	1231
accuracy			0.48	2423
macro avg	0.37	0.49	0.33	2423
weighted avg	0.36	0.48	0.33	2423



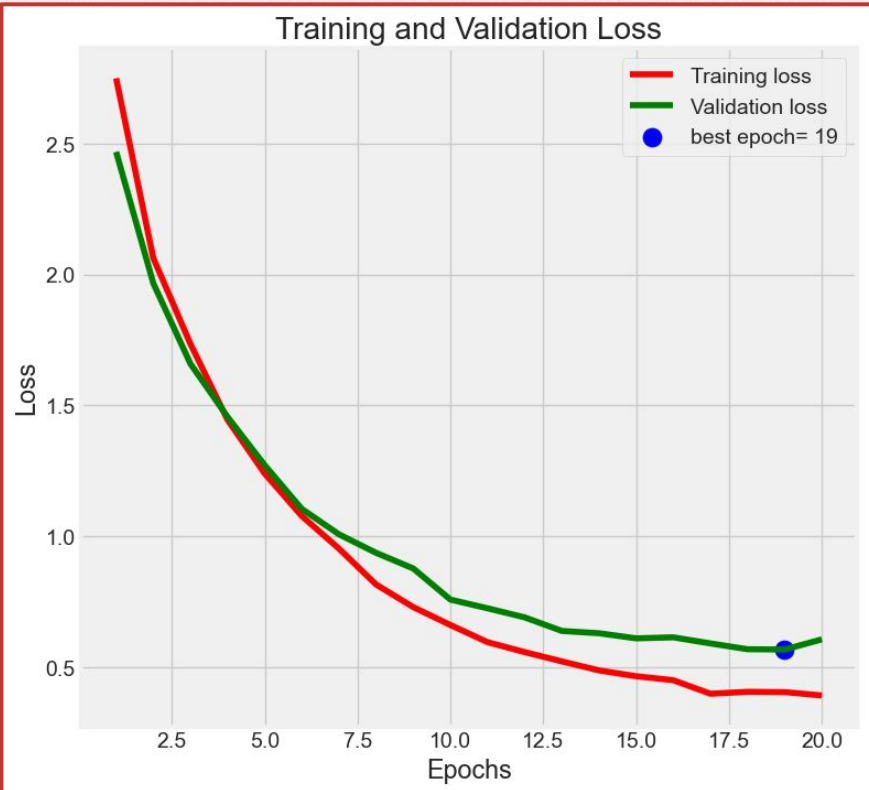
Drive Face
Test Performance

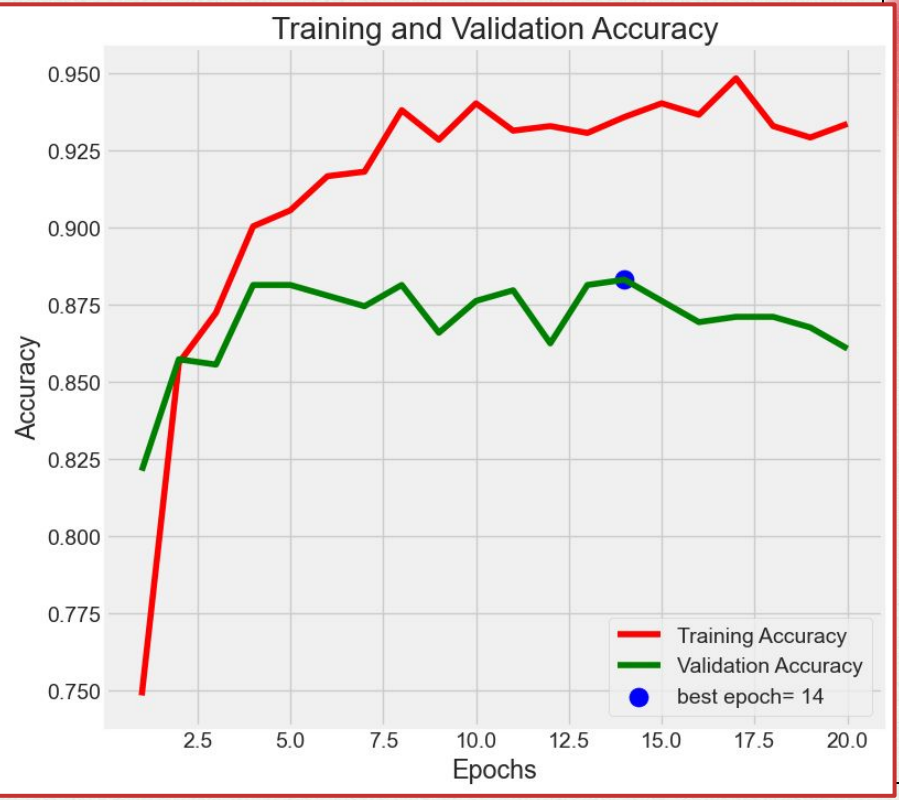
```
Test Loss:  2.8023948669433594
Test Accuracy:  0.13057851791381836
```

	precision	recall	f1-score	support
closed	0.09	1.00	0.17	52
open	1.00	0.05	0.09	553
accuracy			0.13	605
macro avg	0.54	0.52	0.13	605
weighted avg	0.92	0.13	0.10	605



NEW APPROACH
New Model Trained on Closed Eyes in the Wild

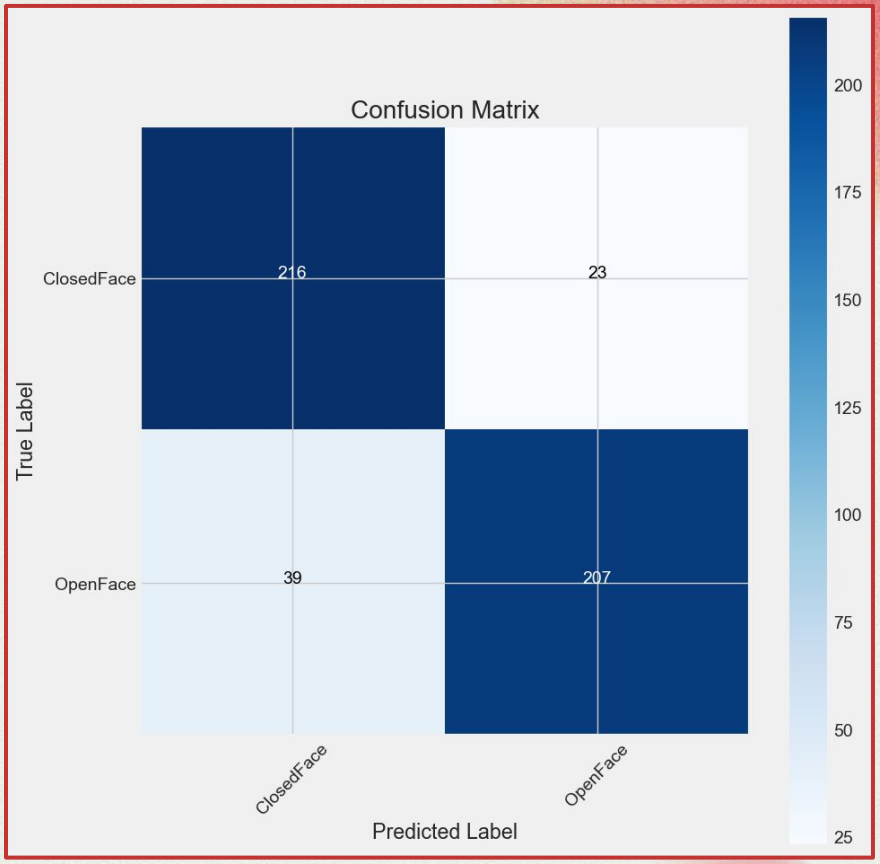




Test Performance

	precision	recall	f1-score	support
ClosedFace	0.85	0.90	0.87	239
OpenFace	0.90	0.84	0.87	246
accuracy			0.87	485
macro avg	0.87	0.87	0.87	485
weighted avg	0.87	0.87	0.87	485

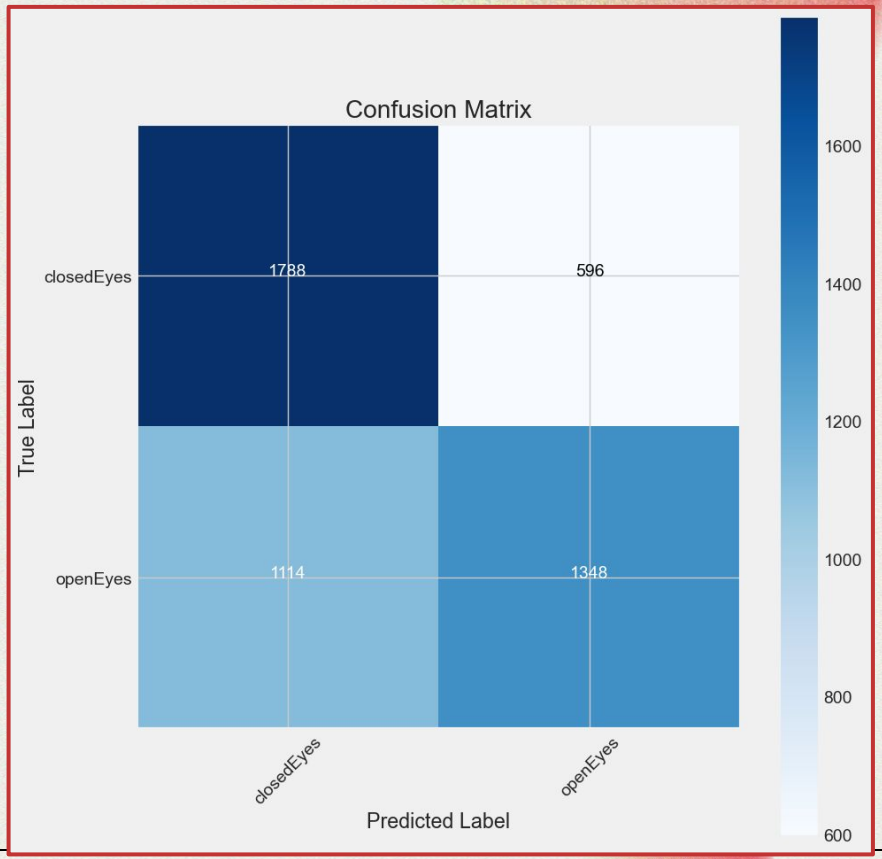
```
Train Loss:  0.2952400743961334
Train Accuracy:  0.982300877571106
--------------------
Validation Loss:  0.6066295504570007
Validation Accuracy:  0.8608247637748718
--------------------
Test Loss:  0.5450876355171204
Test Accuracy:  0.8721649646759033
```



Closed Eyes In the Wild Eye Patches Test Performance

```
Test Loss:  0.866802990436554
Test Accuracy:  0.6471316814422607
```

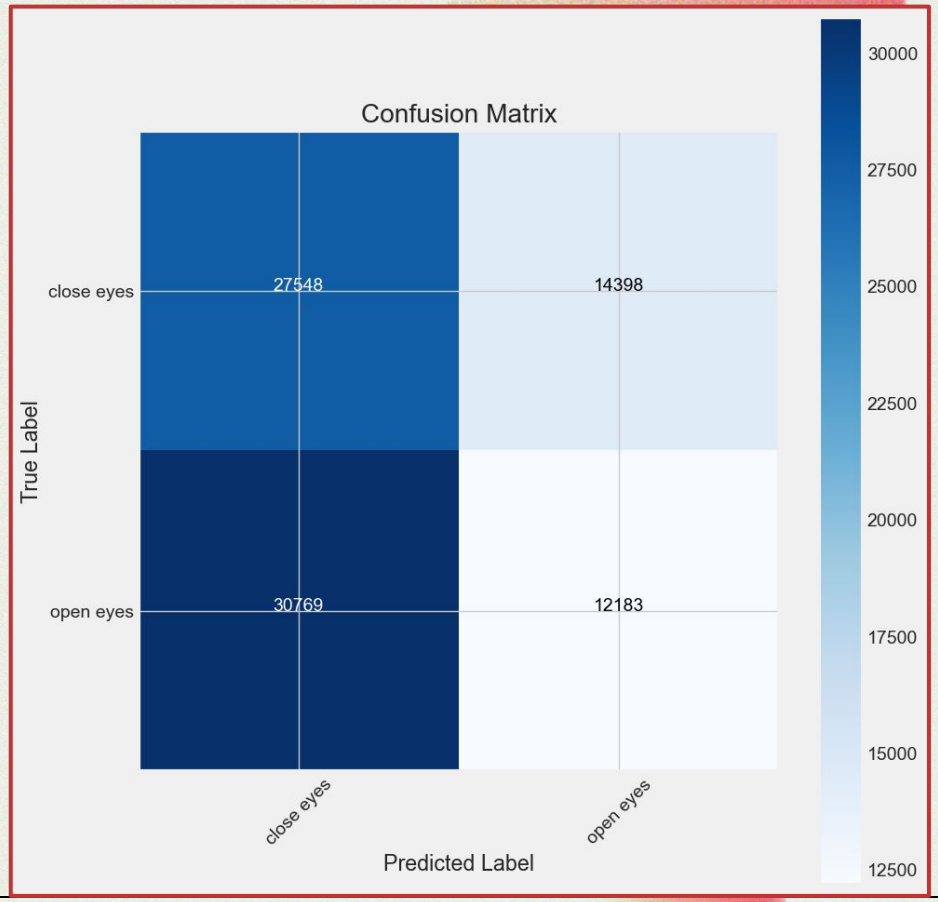
	precision	recall	f1-score	support
closedEyes	0.62	0.75	0.68	2384
openEyes	0.69	0.55	0.61	2462
accuracy			0.65	4846
macro avg	0.65	0.65	0.64	4846
weighted avg	0.66	0.65	0.64	4846



MRL
Test Performance

```
Test Loss:  1.6714320182800293
Test Accuracy:  0.4679851233959198
```

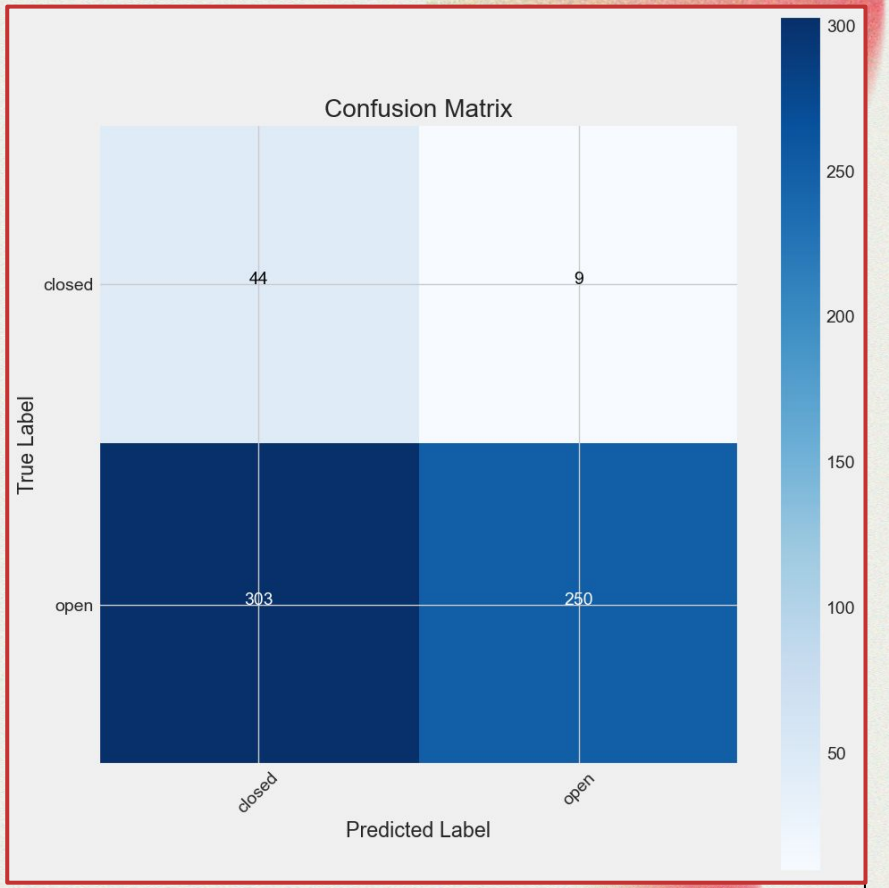
	precision	recall	f1-score	support
close eyes	0.47	0.66	0.55	41946
open eyes	0.46	0.28	0.35	42952
accuracy			0.47	84898
macro avg	0.47	0.47	0.45	84898
weighted avg	0.47	0.47	0.45	84898



Drive Face Test Performance

```
Test Loss:  2.4694907665252686
Test Accuracy:  0.48514851927757263
```

	precision	recall	f1-score	support
closed	0.13	0.83	0.22	53
open	0.97	0.45	0.62	553
accuracy			0.49	606
macro avg	0.55	0.64	0.42	606
weighted avg	0.89	0.49	0.58	606



04

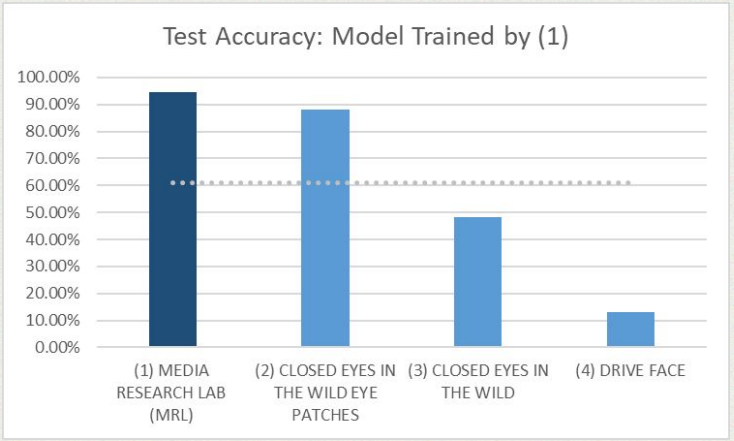
CONCLUSIONS & BUSINESS IMPACT

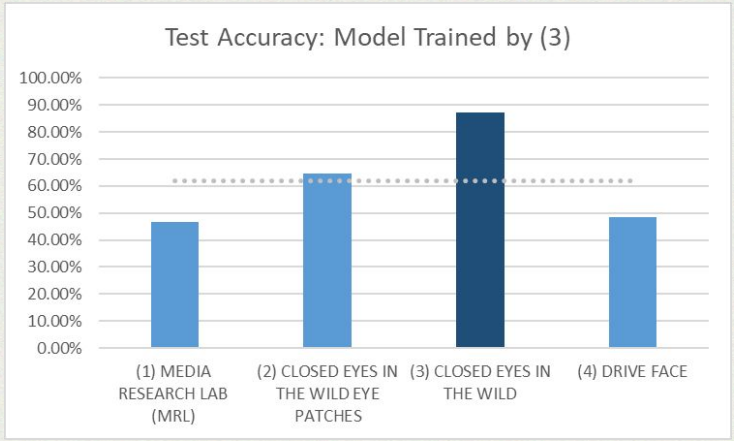
Learnings and Business Applications

Dataset Selection on Model Performance

- Test Accuracy

	(1) MEDIA RESEARCH LAB (MRL)	(2) CLOSED EYES IN THE WILD EYE PATCHES	(3) CLOSED EYES IN THE WILD (CEW)	(4) DRIVER FACE
Model Trained by (1)	**94.45%**	88.24%	48.25%	13.06%
Model Trained by (3)	46.80%	64.71%	**87.22%**	48.51%

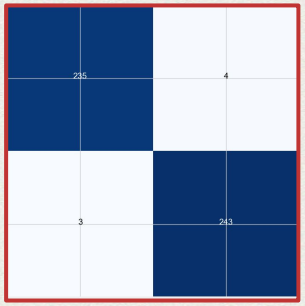


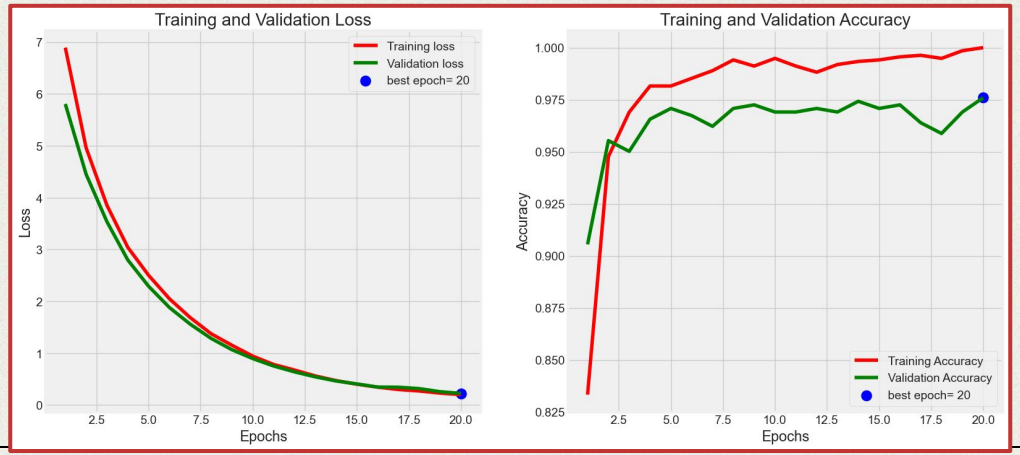


Impact of Overfitting on Out-of-Sample Model Performance

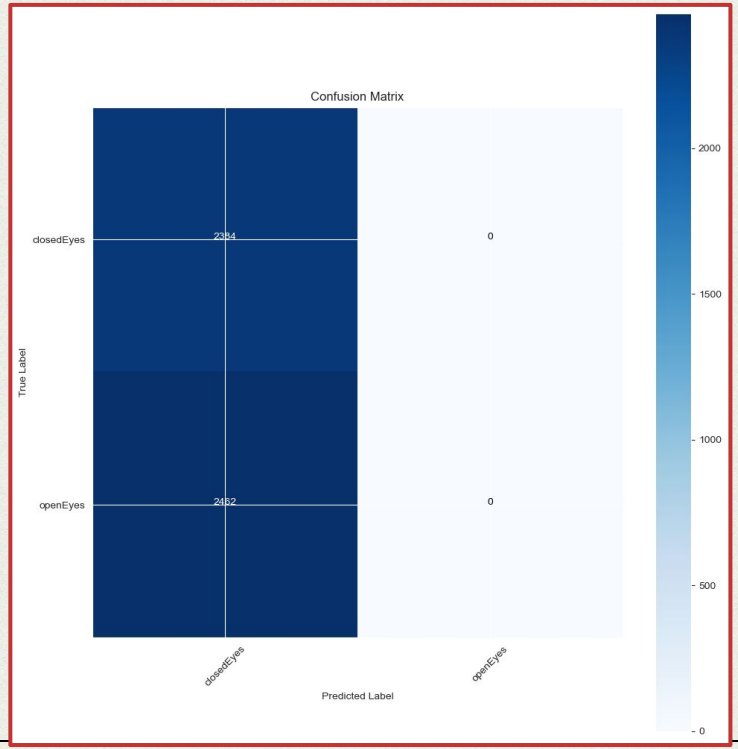
Original Model Architecture trained on CEW

```
Train Loss:  0.17708471417427063
Train Accuracy:  1.0
--------------------
Validation Loss:  0.2203344851732254
Validation Accuracy:  0.9774305820465088
--------------------
Test Loss:  0.20876258611679077
Test Accuracy:  0.985567033290863
```



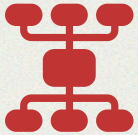


Closed Eyes in the Wild Eye Patches Confusion Matrix



Real-Time Application: Accident Prevention

Install video camera in car that faces the driver



Feed the live footage through a trained CNN

Identify when the driver closes their eyes for an extended period of time

Trigger an alarm to alert/awake the driver.

Business Impact: Insurance Companies

Reduced Claims Costs
- Automated Monitoring
- Prevention of Accidents

Enhanced Policy Pricing
- Risk Profiling
- Dynamic Policy Customization

Premium ↑

Classification of UBI (Usage-Based Insurance)

Arumugam, S., Bhargavi, R. A survey on driving behavior analysis in usage based insurance using big data. J Big Data 6, 86 (2019).

05

KEY LIMITATIONS & NEXT STEPS

How we move forward

NEXT STEPS

Model Improvement

- Limited labeled datasets with images of people with their eyes open and closed for model out-of-sample performance testing
- Test other model architectures and classification methods
- Create higher threshold for closed eyes classification for real-time application so program does not overpenalize insured drivers or exceedingly annoy drivers using live prevention systems
- Choose/tune model based on what camera setup/images that will be classified

Image Background and Timing Selection

- Identify whether driver is on a rural road or highway
- Factor in time of day when photo was taken - between midnight and 6am or late afternoon

Music Selection

- Design an experiment and model to determine whether audio selection has an impact on eye open-close status
- Play different genres of music (beats/min, etc), take photos, and evaluate a classifier on whether eyes are open or closed

Thank you!

Questions?