Eyes direction recognition

OpenCV

MediaPipe

Team Work

- Mele Alessandro
- Traini Davide

Master's degree students in Computer Engineering at UNIVPM[1].

Repository link[2]

Dataset link[3]

Workflow

- Dataset creation (60%)
- Classification model (30%)
- Regression model (10%)

Workflow

- Dataset creation
- Classification model
- Regression model

Dataset creation

Bot images → Data augmentation → Face Mesh

Dataset creation

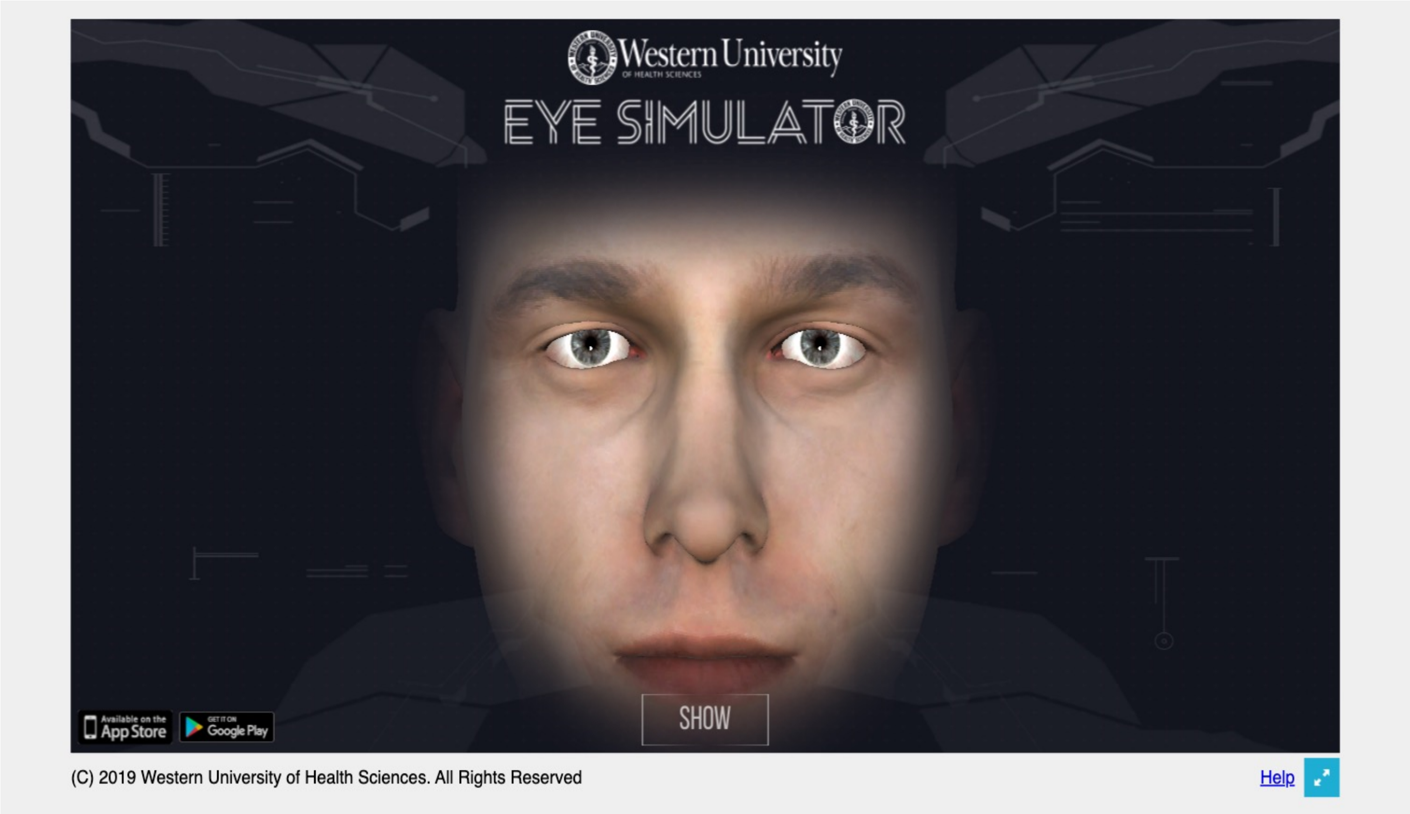
Bot images → Data augmentation → Face Mesh

Dataset creation

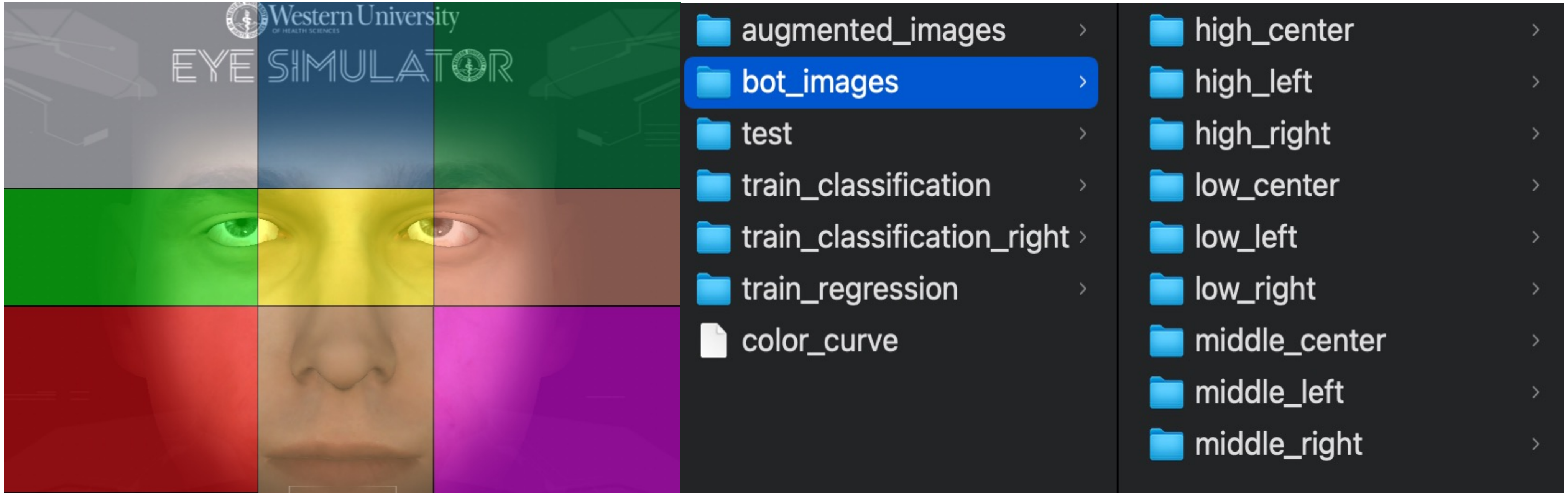
The dataset consists of images derived by an eye simulator of Wester University[4].

We developed a bot in Node.JS[5] that automatically takes screenshots about images moving mouse’s pointer.

Dataset creation



Dataset creation



Dataset creation

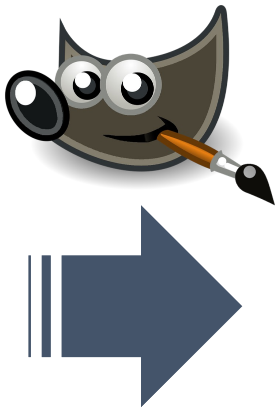
Bot images → Data augmentation → Face Mesh

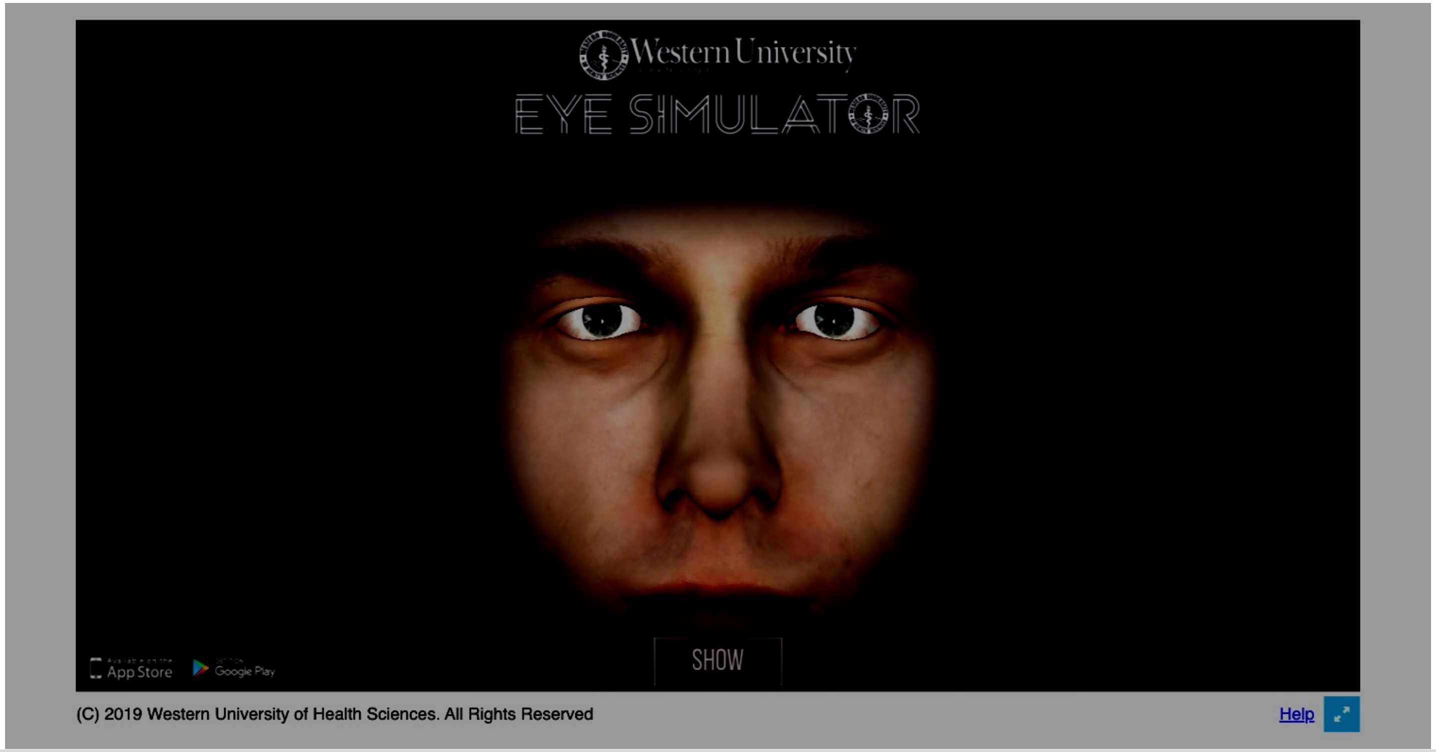
Data augmentation

Starting here

Data augmentation

Modified colour curves, through BIMP[6], a GIMP[7] plugin





Data augmentation

Rotation changes +-5°, through OpenCV[8]

Data augmentation

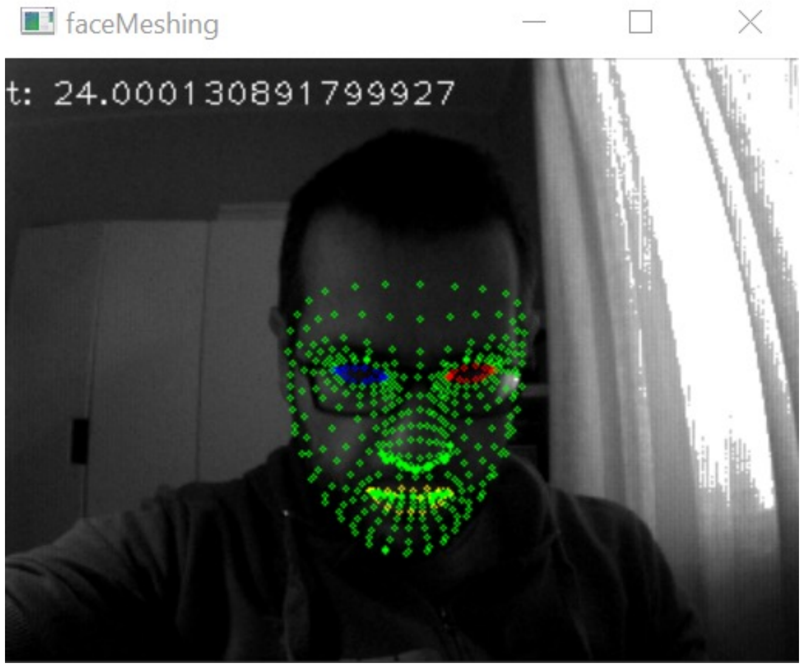
Perspective changes, through OpenCV

Dataset creation

Bot images → Data augmentation → Face Mesh

Eyes extraction with Facemesh

MediaPipe Face Mesh[9] is a Machine Learning solution that estimates 468 3D face landmarks: it uses lightweight model architectures and delivers real-time performance critical for live experiences.



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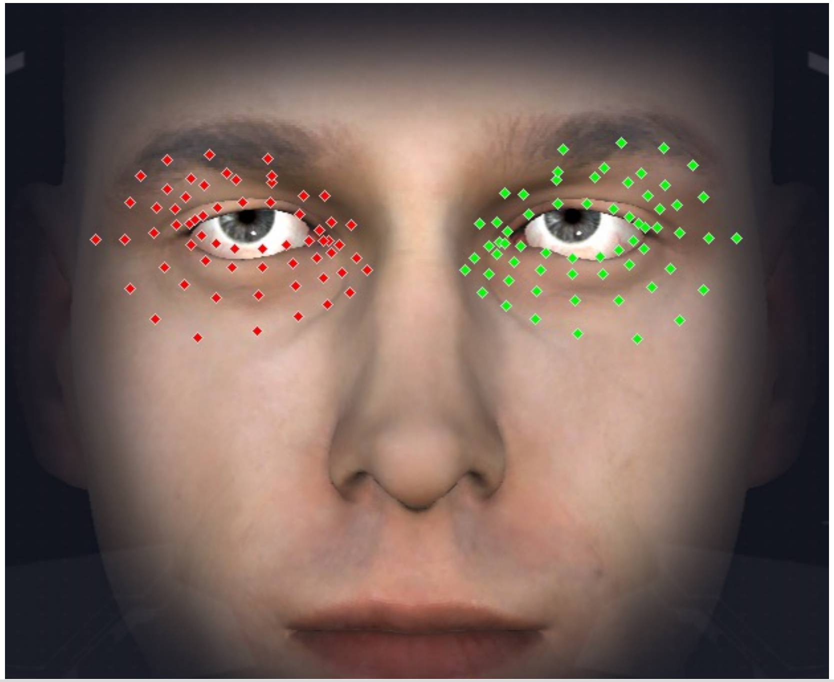
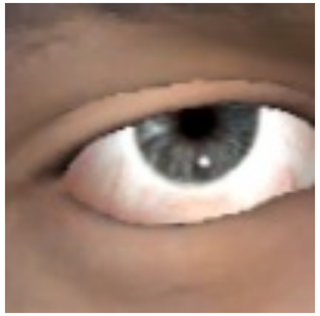
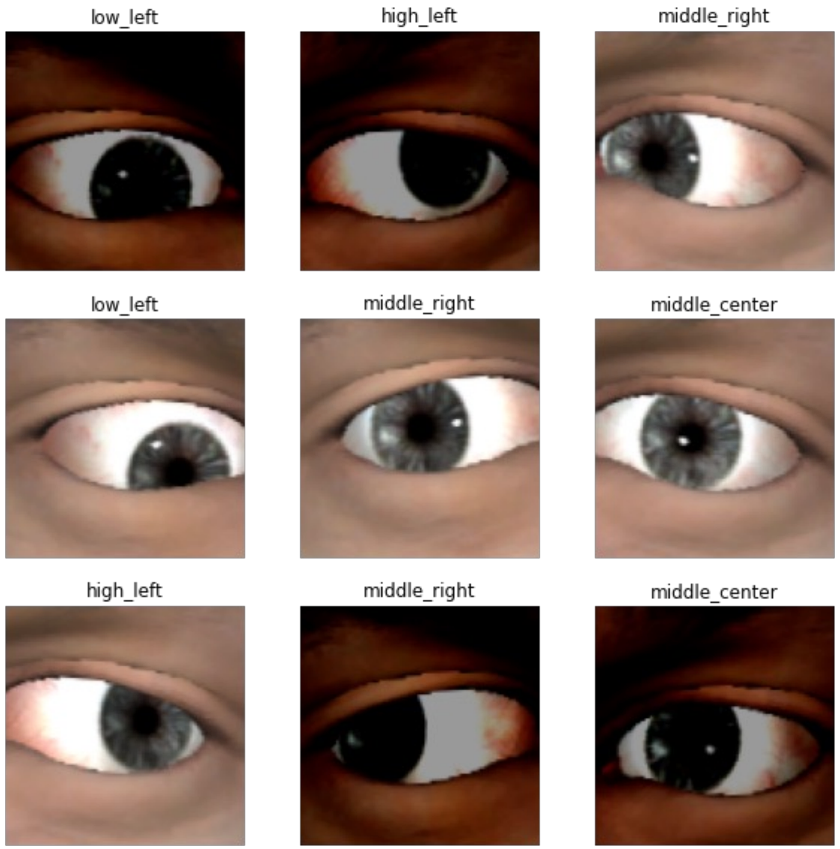
Eyes extraction with Facemesh

Then images have been cropped in two ones which contained right and left eye, and resized at 100x100px.





Dataset creation



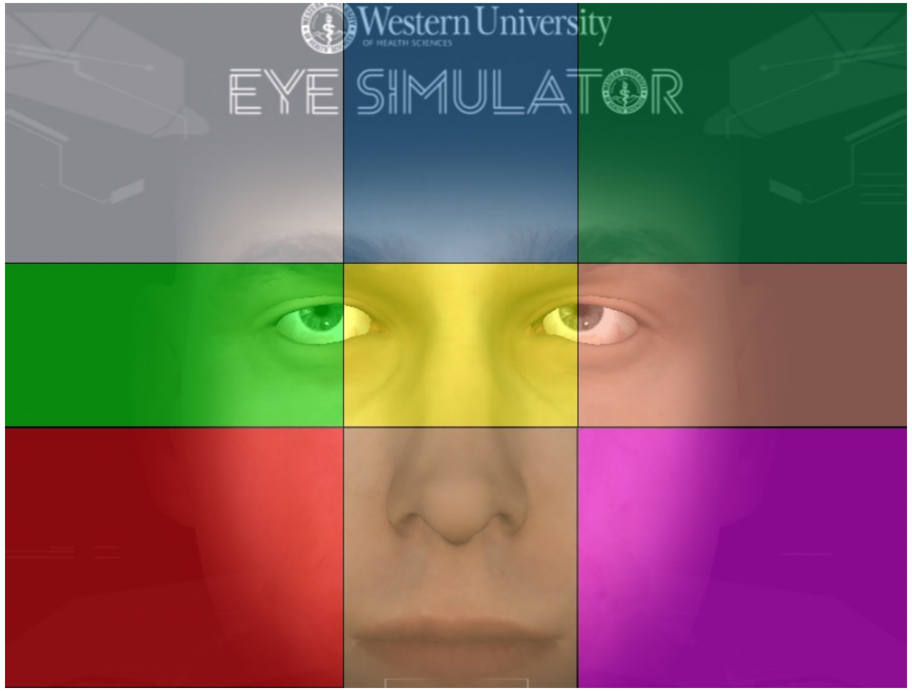
Workflow

- Dataset creation
- Classification model
- Regression model

Classification model

The classifier was trained to recognize nine classes, identified by the quadrants visible in the image.

The chosen network is MobileNet v2.



Classification model

Dataset: 5.376 images divided in:

- 80% Training set;
- 15% Validation set;
- 5% Test set;

Weights: Imagenet[10].

Every image has been rescaled, so pixels values are between 0 and 1.

Classification model: Structure

```
 Layer (type)                Output Shape              Param #
=================================================================
 input_2 (InputLayer)        [(None, 100, 100, 3)]     0

 tf.math.truediv (TFOpLambda  (None, 100, 100, 3)      0
 )

 tf.math.subtract (TFOpLambd  (None, 100, 100, 3)      0
 a)

 mobilenetv2_1.00_224 (Funct  (None, 4, 4, 1280)       2257984
 ional)

 global_average_pooling2d (G  (None, 1280)             0
 lobalAveragePooling2D)

 dropout (Dropout)           (None, 1280)              0

 dense (Dense)               (None, 9)                 11529

=================================================================
Total params: 2,269,513
Trainable params: 2,050,313
Non-trainable params: 219,200
```

Classification model: Train

```
Dropout = 0.3
Optimizer = tf.keras.optimizers.Adam(learning_rate=0.001)
Loss = tf.keras.losses.SparseCategoricalCrossentropy(
       from_logits = False)
Metrics = ['accuracy']
```

```
BATCH_SIZE = 64
IMG_SIZE = (100, 100)
```

```
initial_epochs = 20
```

Classification model: Fine Tuning

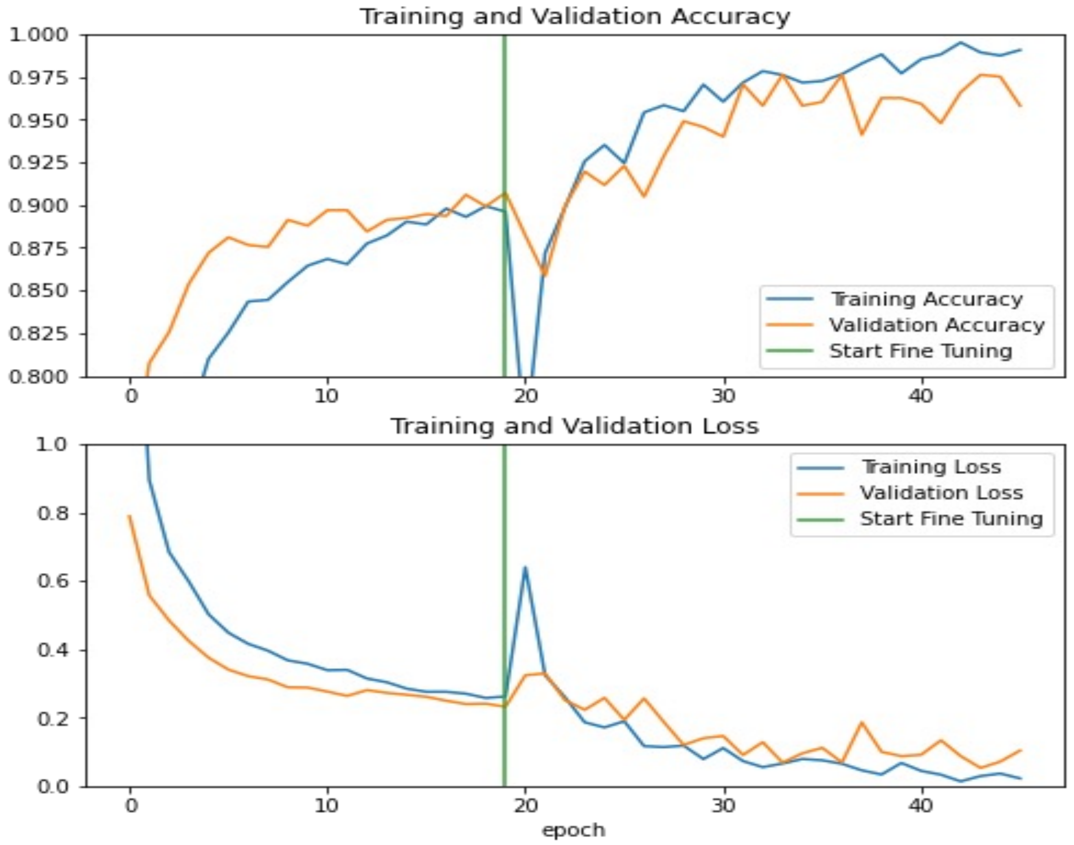
```
Dropout = 0.3
Optimizer = tf.keras.optimizers.Adam(learning_rate=0.0001)
Loss = tf.keras.losses.SparseCategoricalCrossentropy(
       from_logits = False)
Metrics = ['accuracy’]
```

```
BATCH_SIZE = 64
IMG_SIZE = (100, 100)
```

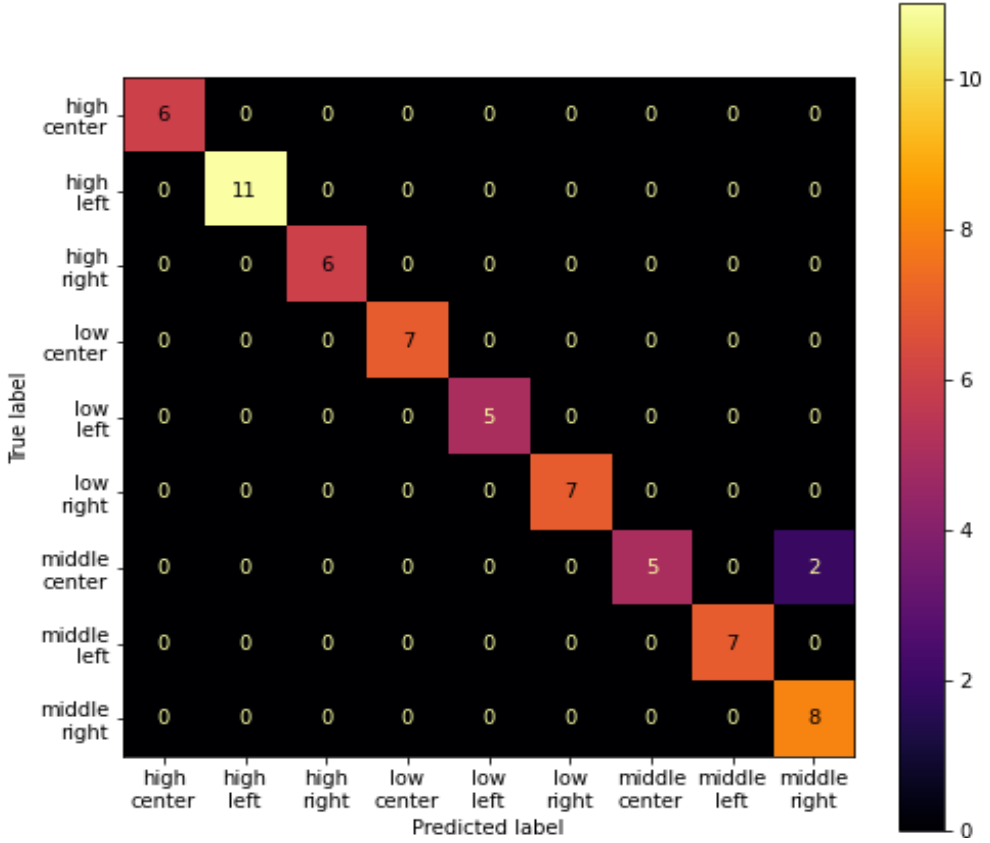
```
fit_epochs = 25
```

```
Fine_tune_at = 80
```

Classification model: Performance



Classification model: Confusion Matrix



Classification model: Real images

Using real images the model was not able to generalize,
so we tried to resolve with three methods:

- Train one model for left and another for right eye;
- Train the model with only middle_left and middle_right classes;
- Apply a cost matrix, to avoid unbalanced class problems.

The above listed methods were not sufficiently able to mitigate the generalization issue. A more complete data-set with synthetic and real images is a good candidate for that.

Workflow

- Dataset creation
- Classification model
- Regression model

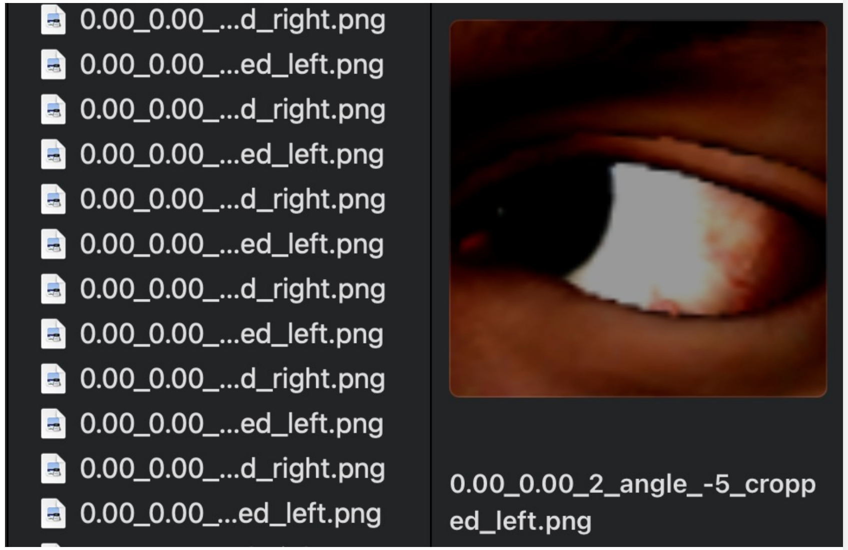
Regression model: Dataset

Same as classification, but without folders (classes).

Images has been saved as ***horPerc_verPerc***

where ***Perc(s)*** are normalized than maximum

and minimum (x,y) cursor movement.



Regression model: Structure

```
 Layer (type)                Output Shape              Param #
=================================================================
 input_2 (InputLayer)        [(None, 100, 100, 3)]     0

 tf.math.truediv (TFOpLambda  (None, 100, 100, 3)      0
 )

 tf.math.subtract (TFOpLambd  (None, 100, 100, 3)      0
 a)

 mobilenetv2_1.00_224 (Funct  (None, 4, 4, 1280)       2257984
 ional)

 global_average_pooling2d (G  (None, 1280)             0
 lobalAveragePooling2D)

 dropout (Dropout)           (None, 1280)              0

 dense (Dense)               (None, 2)                 2562

=================================================================
Total params: 2,260,546
Trainable params: 2,041,346
Non-trainable params: 219,200
```

Regression model: Train

```
Dropout = 0.3
Optimizer = tf.keras.optimizers.Adam(learning_rate=0.01)
loss = 'mse'
Metrics = ['mse','mae','mape']
```

```
BATCH_SIZE = 64
IMG_SIZE = (100, 100)
```

```
initial_epochs = 20
```

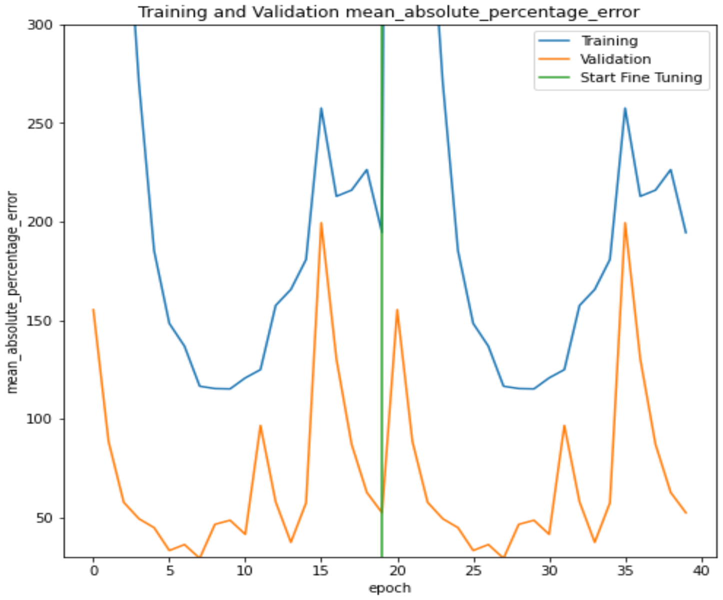
Regression model: Fine Tuning

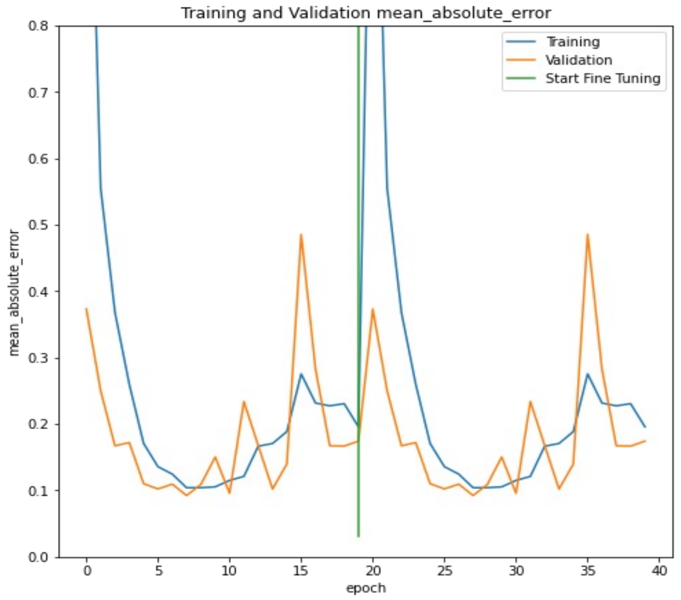
```
Dropout = 0.3
Optimizer = tf.keras.optimizers.Adam(learning_rate=0.0001)
loss = 'mse'
Metrics = ['mse','mae','mape']
```

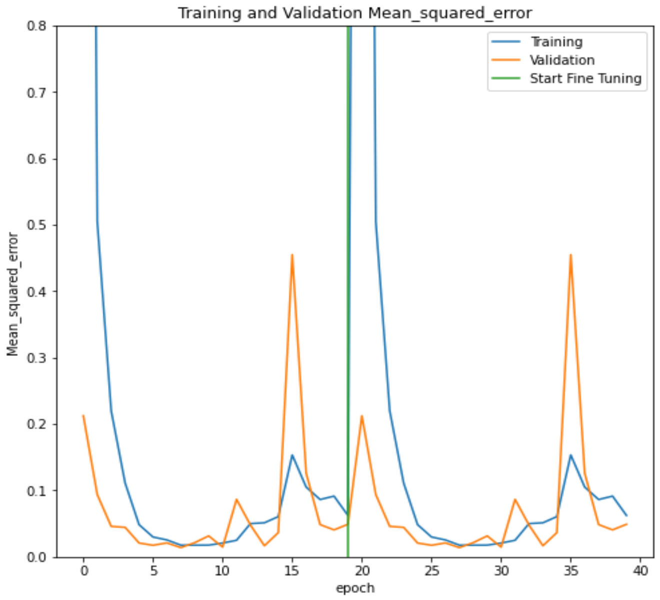
```
BATCH_SIZE = 64
IMG_SIZE = (100, 100)
```

```
fit_epochs = 25
Fine_tune_at = 80
```

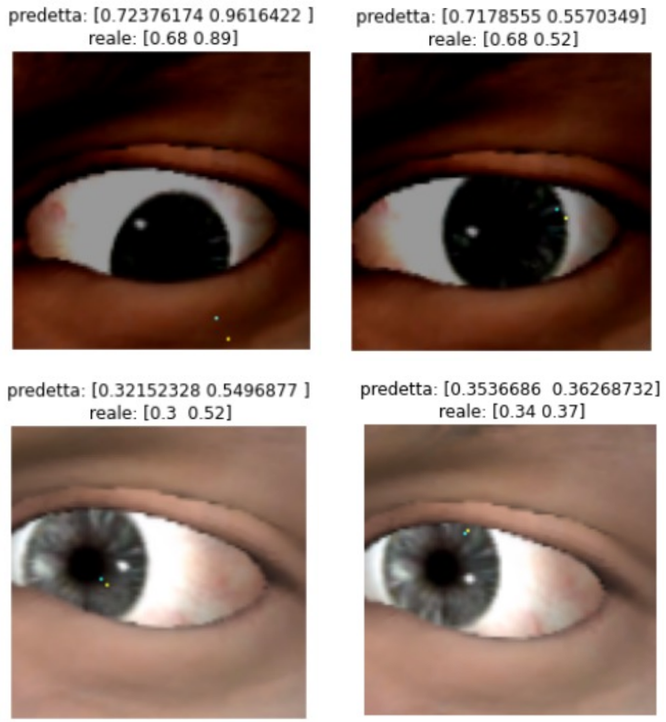
Regression model: Performance







Regression model: Apply model



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Conclusions

Both classification and regression models are really accurate on synthetic dataset, but have poor performances on real world data.

A further approach would be to train the network on both synthetic and real data.

References

UNIVPM: https://www.univpm.it/Entra/

GitHub Repository: https://github.com/AlessandroMele/eyes_direction_recognition

Drive folder for dataset: https://drive.google.com/drive/folders/1CYh07UE_v58td-wKqa1jO1x-bAOt65gS?usp=sharing

Western University eye simulator: https://edtech.westernu.edu/3D-eye-movement-simulator/

Node.JS: https://nodejs.org/it/

BIMP: https://alessandrofrancesconi.it/projects/bimp/

GIMP: https://www.gimp.org

OpenCV: https://opencv.org

Face Mesh: https://google.github.io/mediapipe/solutions/face_mesh.html

ImageNet: https://www.image-net.org/