Capstone Project

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Machine Learning Engineer Nanodegree

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Dog Breed Classifier

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Definition

Project Overview

A dog breed classifier is a computer vision classifier that uses Convolutional Neural Networks (CNN) to build a pipeline to process real-world, user-supplied images.

Given an image of a dog, The algorithm will identify an estimate of the canine's breed. If supplied an image of a human, the code will identify the resembling dog breed.

Problem Statement

The goal is to create a dog breed classifier based on a dog or human image.

In the real world, there are a lot of different dog breeds. While Humans can detect few dog breeds, The classifier can detect more than 100 different dog breeds.

The output will be the Input Image labeled with the predicted dog class.
The Input will be an RGB image of a dog or a human.

Machine learning will be used to capture the features for the Input image and use those features to predict the dog class.

The project will be developed by completing the following tasks:

1. Download the input data
2. Preprocess the data and see If the classes are imbalanced3. Create
3. Human Face detection using open cv library haar cascades
4. Create a general dog detector using a pre-trained model like VGG which is a sequence of convolution and pooling layers
5. Using transfer learning to create the dog breed classifier after dropping the classifier layer in the pre-trained model and attach the new one after changing the output number.
6. Take a raw image and return the dog breed.

Metrics

CrossEntropyLoss

It is useful when training a classification problem with C classes. This Cross-Entropy Loss is useful when you have an unbalanced training set.

$$\text{loss}(x, class) = -\log\left(\frac{\exp(x[class])}{\sum_j \exp(x[j])}\right) = -x[class] + \log\left(\sum_j \exp(x[j])\right)$$

The losses are averaged across observations for each minibatch.

$$\text{loss} = \frac{\sum_{i=1}^{N} loss(i, class[i])}{\sum_{i=1}^{N} weight[class[i]]}$$

Accuracy

is a common metric for binary and multi-class classifiers; it takes into account both true positives and true
negatives with equal weight.

accuracy =(true positives + true negative) / size of dataset

Because we have multi-class classification precision and recall will not be a good metric as we are focus on the total number of correct prediction

We can use ROC-AUC as a metric and compare the results as the next Improvements.

Analysis

Data Exploration and Visualization

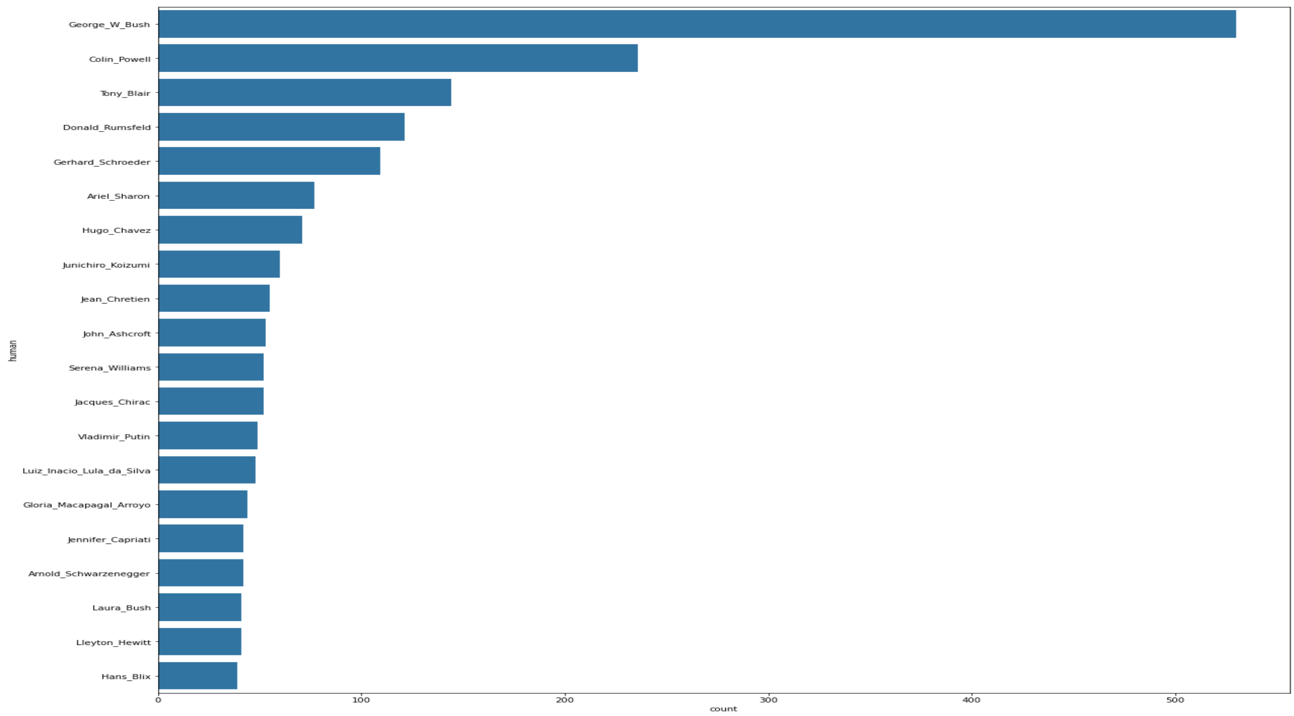
Human dataset

The human dataset has 13233 images with 5749 unique Humans. George_W_Bush has the most counts with 530 image

The top 20 Humans were:

Name	# of images
George_W_Bush	530
Colin_Powell	236
Tony_Blair	144
Donald_Rumsfeld	121
Gerhard_Schroeder	109
Ariel_Sharon	77
Hugo_Chavez	71
Junichiro_Koizumi	60
Jean_Chretien	55
John_Ashcroft	53
Serena_Williams	52
Jacques_Chirac	52
Vladimir_Putin	49
Luiz_Inacio_Lula_da_Silva	48
Gloria_Macapagal_Arroyo	44
Jennifer_Capriati	42
Arnold_Schwarzenegger	42
Laura_Bush	41
Lleyton_Hewitt	41
Hans_Blix	39

George.W.Bush



Sample images with labels


Nabil_Shaath


Brendan_Stai


Jennifer_Garner


Lisa_Murkowski


Jamie_Cooke


Hernan_Crespo


Cemil_Cicek


Allison_Janney

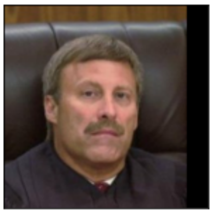

Travis_Rudolph


Demetrius_Ferraciu


Sanjay_Gupta


Brian_Cook


Hussam_Mohammed_Amin


LeRoy_Millette_Jr


Eddie_Lucio


Ward_Cuff


Nia_Vardalos


Don_King


Bill_Bradley


Steve_Zahn

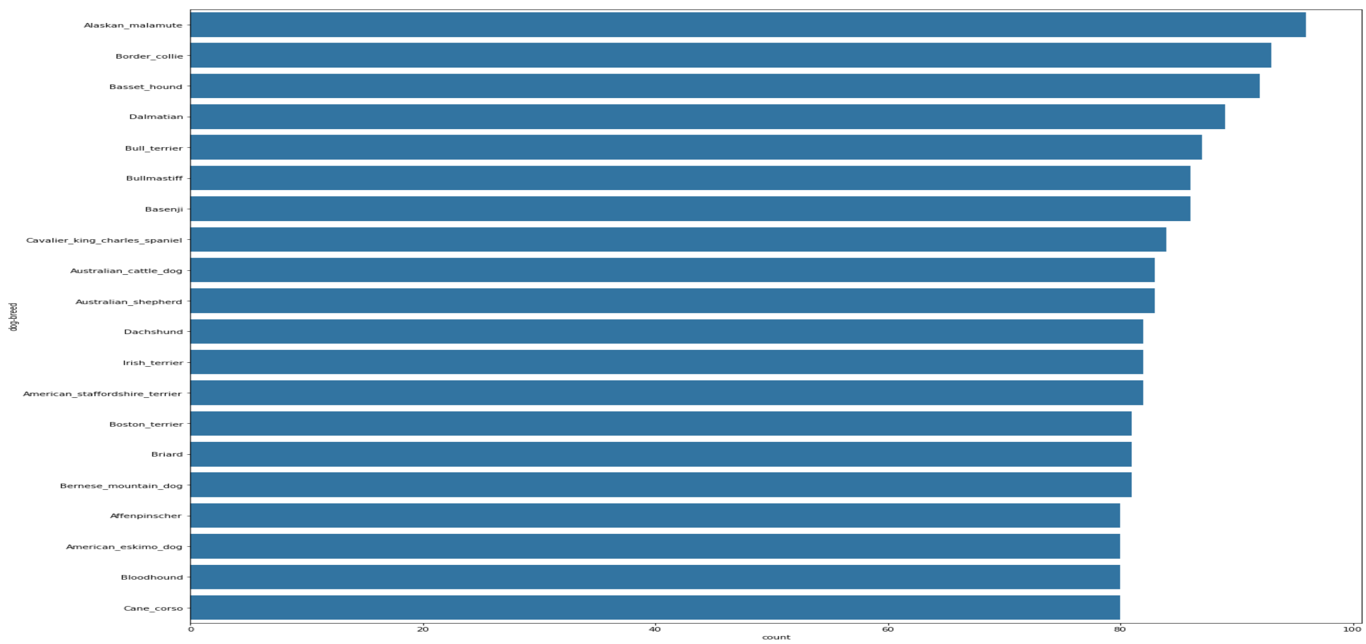
Dog dataset

The Dog dataset has 8351 images with 133 unique dog breeds. the Alaskan malamute has the most counts with 95 image

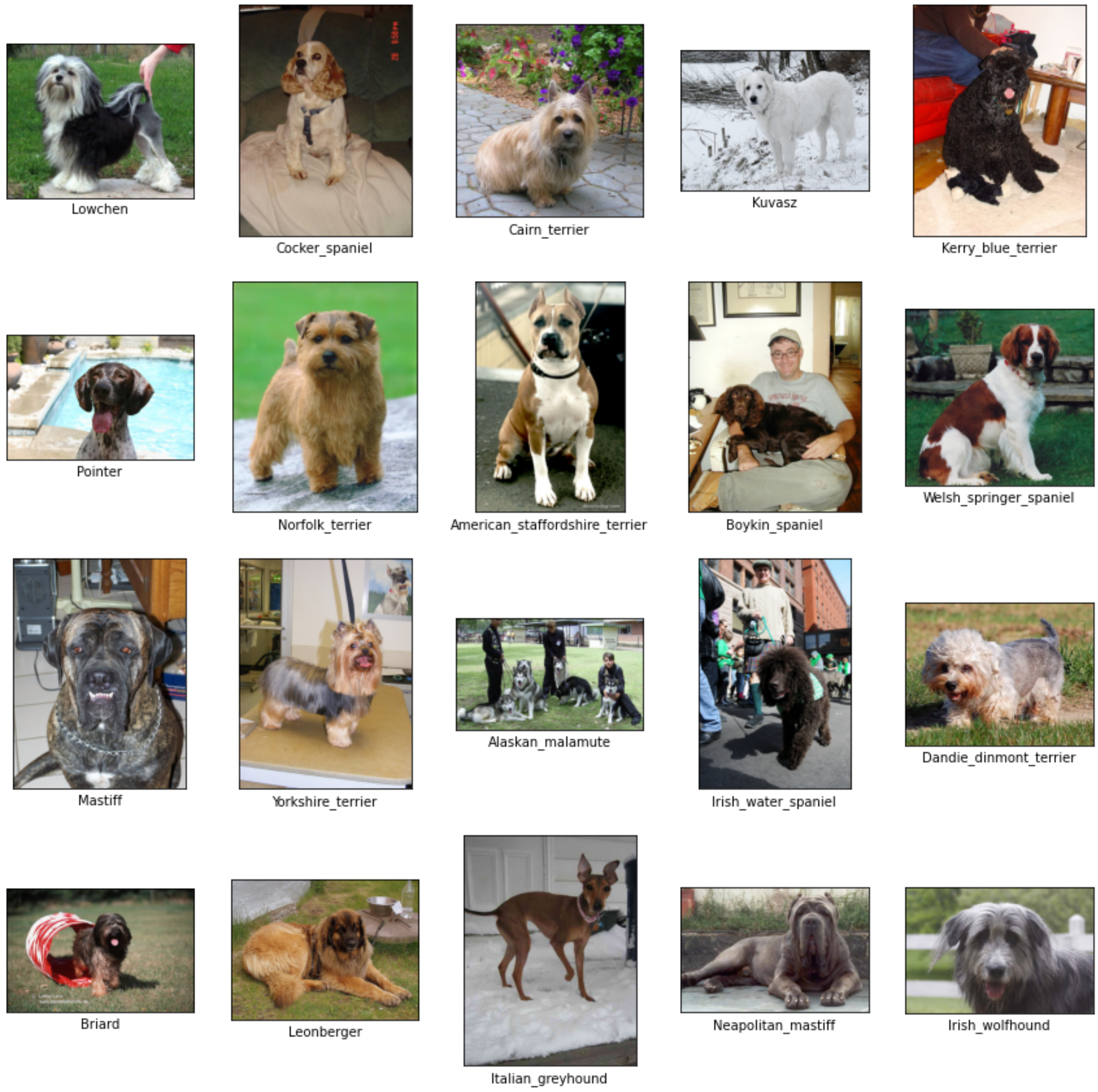
The top 20 Dogs were:

Dog breed	# counts
Alaskan_malamute	96
Border_collie	93
Basset_hound	92
Dalmatian	89
Bull_terrier	87
Bullmastiff	86
Basenji	86
Cavalier_king_charles_spaniel	84
Australian_cattle_dog	83
Australian_shepherd	83
Dachshund	82
Irish_terrier	82
American_staffordshire_terrier	82
Boston_terrier	81
Briard	81
Bernese_mountain_dog	81
Affenpinscher	80
American_eskimo_dog	80
Bloodhound	80
Cane_corso	80

Alaskan malamute



Sample images with labels



Algorithms and Techniques

The classifier is a Convolutional Neural Network, which is the state-of-the-art algorithm for most image processing tasks, including classification. It needs a large amount of training data compared to other approaches.

The following parameters can be tuned to optimize the classifier:

1. Training parameters:
    - Training length (number of epochs)
    - Batch size (how many images to look at once during a single training step)
    - Learning rate (how fast to learn; this can be dynamic)
2. Neural network architecture:
    - Number of layers

- Layer types (convolutional, fully-connected, or pooling)

3. Preprocessing parameters

During training, both the training and the validation sets are loaded into the RAM. After that, random batches are selected to be loaded into the GPU memory for processing.

We could use Two Techniques:

1- Train the model from scratch :

We can build our model from scratch specifically to the problem. This Technique is when we want to build a detector for simple use cases

The problem with that Technique that we need to train the model from the beginning and need to design every layer in the model (Convolution, fully connected and pooling ...etc)

2- Use pre-trained Network by transfer learning

We can use the CNN model that has been trained and use the layers that detect the features from the input whatever the Input type or shape and replace the pre-trained Network classifier for a custom classifier.

This Technique save a lot of training time as we freeze the feature layers and train only the classifier

I have used transfer learning in the final solution using the VGG16 model as It was trained on a huge dataset.

Benchmark

I have used Two benchmarks.

the first one was training a model from scratch and test the model and record the highest score that we can get with a given dataset and try to beat this result using other techniques.

The second one was to set an accuracy threshold from the model that we can accept for the application. I targeted 75% accuracy on the test set

I have set a timing constraint for real-time classification, so the model target to classify the input image in time doesn’t exceed 50 ms

Methodology

Data Pre-processing

The preprocessing has the following steps:

1. Make augmentation for images (RandomRotation,RandomResizedCrop and RandomHorizontalFlip)
2. Normalize the input images
3. The images are divided into training, validation, and test sets
4. Create the data loaders by configuring the batch size and shuffle the training data

Implementation

The implementation process can be split into two main stages:

1. The classifier training stage
2. Using the trained model to classify dogs

The classifier training stage

During the first stage, the classifier was trained on the preprocessed training data using transfer learning.

The training steps were:

1. load both the training and validation images into memory using the data loaders that we have created
2. Define the network architecture and training parameters
3. Define the loss function, accuracy
4. Train the network, logging the validation/training loss and the validation accuracy
5. If the accuracy is not high enough, return to step 2
6. Save and freeze the trained network

The network architecture

I have used transfer learning using the vgg16 model

```
 (features): Sequential(
   (0): Conv2d(3, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
   (1): ReLU(inplace=True)
   (2): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
   (3): ReLU(inplace=True)
   (4): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1, ceil_mode=False)
```

```
    (5): Conv2d(64, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (6): ReLU(inplace=True)
    (7): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (8): ReLU(inplace=True)
    (9): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1, ceil_mode=False)
    (10): Conv2d(128, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (11): ReLU(inplace=True)
    (12): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (13): ReLU(inplace=True)
    (14): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (15): ReLU(inplace=True)
    (16): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1, ceil_mode=False)
    (17): Conv2d(256, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (18): ReLU(inplace=True)
    (19): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (20): ReLU(inplace=True)
    (21): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (22): ReLU(inplace=True)
    (23): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1, ceil_mode=False)
    (24): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (25): ReLU(inplace=True)
    (26): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (27): ReLU(inplace=True)
    (28): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (29): ReLU(inplace=True)
    (30): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1, ceil_mode=False)
  )
  (avgpool): AdaptiveAvgPool2d(output_size=(7, 7))
  (classifier): Sequential(
    (fc1): Linear(in_features=25088, out_features=4096, bias=True)
    (relu): ReLU()
    (Dropout1): Dropout(p=0.5, inplace=False)
    (fc2): Linear(in_features=4096, out_features=1024, bias=True)
    (Dropout2): Dropout(p=0.5, inplace=False)
    (fc3): Linear(in_features=1024, out_features=133, bias=True)
    (output): LogSoftmax()
  )
)
```

I have kept the features layers as It has already trained to detect shapes and patterns and replaced the classifiers layers with one that I need to classify the new 133 dog breed.

The new classifier becomes:

```
(classifier): Sequential(
    (fc1): Linear(in_features=25088, out_features=4096, bias=True)
    (relu): ReLU()
    (Dropout1): Dropout(p=0.5, inplace=False)
```

```
  (fc2): Linear(in_features=4096, out_features=1024, bias=True)
  (Dropout2): Dropout(p=0.5, inplace=False)
  (fc3): Linear(in_features=1024, out_features=133, bias=True)
  (output): LogSoftmax()
)
```

Using the trained model to classify dogs

1. Create the model using the given layers
2. Load the pre-trained weights
3. Process the input Images
4. Using open cv to detect faces in Images
5. Using a pre-trained VGG model to detect dogs
6. Predict the input Image using the model

Results

Model Evaluation and Validation

During development, a validation set was used to evaluate the model.
The final architecture and hyperparameters were chosen because they performed the best among the tried combinations.
For a complete description of the final model and the training process, refer to
The network architecture section

I have trained the model after replacing the Classifier layers for 10 `Epochs with the following train and Validation losses:`

```
Epoch: 1    Training Loss: 1.343471      Validation Loss: 0.829716
Epoch: 2    Training Loss: 1.270921      Validation Loss: 0.739991
Epoch: 3    Training Loss: 1.208083      Validation Loss: 0.681313
Epoch: 4    Training Loss: 1.185337      Validation Loss: 0.700088
```

```
Epoch: 5   Training Loss: 1.175069     Validation Loss: 0.613085
Epoch: 6   Training Loss: 1.112700     Validation Loss: 0.649210
Epoch: 7   Training Loss: 1.109303     Validation Loss: 0.549573
Epoch: 8   Training Loss: 1.084382     Validation Loss: 0.585246
Epoch: 9   Training Loss: 1.055470     Validation Loss: 0.690492
Epoch: 10  Training Loss: 1.021630     Validation Loss: 0.687842
```

So as we can see the Validation was still decreasing so we can have better accuracy If we Increased the number of epochs but It will take a longer time.

Using the test set, the Test Accuracy was 80% (677/836)

Justification

The Test accuracy using **transfer learning** is **80**%

- For the first benchmark, The Test accuracy using the trained model from **scratch** was **18**% using the same input data set and environment which is a significant improvement.

- For the second benchmark, the target was to exceed the 75% test accuracy and that was done using **transfer learning.**

- For the timing constraints for real-time, we were target to classify images at average 40ms/image
  It took 5.42 Second to classify 200 Image so the average was 27 ms/image

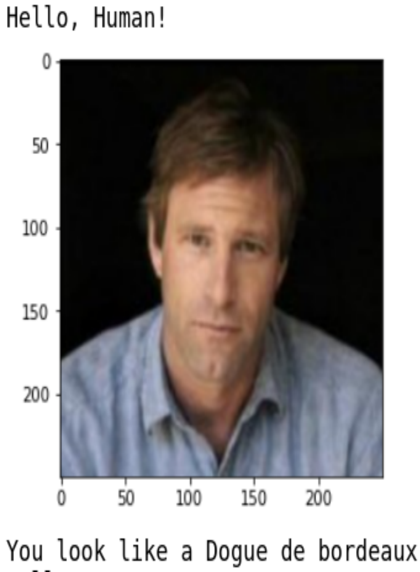
I used my local machine (6 GByte GPU”
NVIDIA Corporation TU116M [GeForce GTX 1660 Ti Mobile]”, 12 logical CPU “Intel® CoreTM
i7-9750H CPU @ 2.60GHz × 12”) in the training and testing

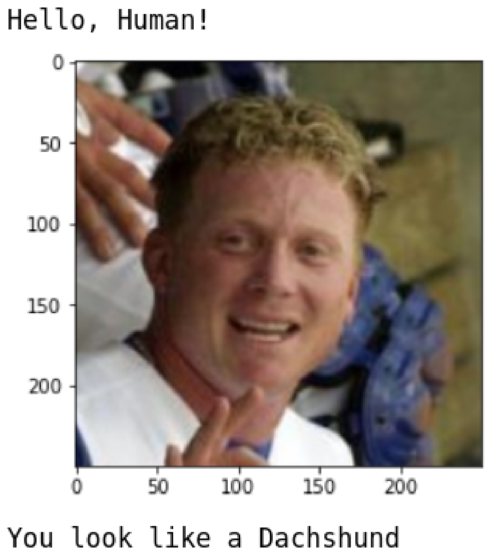
The result is stronger than I expected as the model was trained for just 10 Epochs and we got 80 % accuracy.

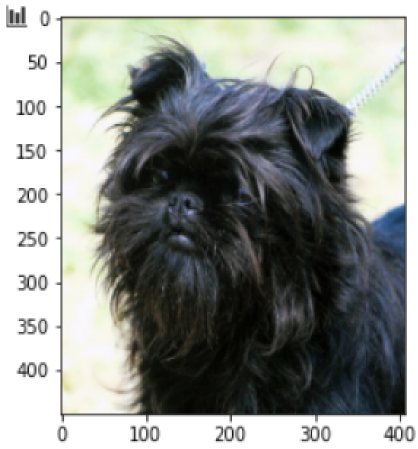
```
We didn’t train the feature layers and use them as it with trained
weights so we achieved our target with min. Training time.

The model is good enough to detect 8 images from the given 10 input
images. this ratio could be increased by train the model for more
Epochs
```

Conclusion

Using Convolution neural networks we can classify the dog breeds with an accuracy of more than 80 % and we can even make this classification for humans.







You look like a Affenpinscher

You look like a Brussels griffon

Reflection

The process used for this project can be summarized using the following steps:

1. An initial problem and relevant, public datasets were found
2. The data was downloaded and preprocessed (segmented)
3. A benchmark was created for the classifier
4. The classifier was trained using the data and transfer learning (multiple times, until a good set of parameters, were found)
5. The model was used to detect the dog breed on unseen images.

Improvement

To achieve better accuracy for the model

1- we can use different model features layers for our model

2- we can CNN to detect humans better than a face classifier

3- we can train for more epochs