

Convolutional Neural Networks

Project: Write an Algorithm for a Dog Identification App

In this notebook, some template code has already been provided for you, and you will need to implement additional functionality to successfully complete this project. You will not need to modify the included code beyond what is requested. Sections that begin with **'(IMPLEMENTATION)'** in the header indicate that the following block of code will require additional functionality which you must provide. Instructions will be provided for each section, and the specifics of the implementation are marked in the code block with a 'TODO' statement. Please be sure to read the instructions carefully!

Note: Once you have completed all of the code implementations, you need to finalize your work by exporting the Jupyter Notebook as an HTML document. Before exporting the notebook to html, all of the code cells need to have been run so that reviewers can see the final implementation and output. You can then export the notebook by using the menu above and navigating to **File -> Download as -> HTML (.html)**. Include the finished document along with this notebook as your submission.

In addition to implementing code, there will be questions that you must answer which relate to the project and your implementation. Each section where you will answer a question is preceded by a **'Question X'** header. Carefully read each question and provide thorough answers in the following text boxes that begin with **'Answer:'**. Your project submission will be evaluated based on your answers to each of the questions and the implementation you provide.

Note: Code and Markdown cells can be executed using the **Shift + Enter** keyboard shortcut. Markdown cells can be edited by double-clicking the cell to enter edit mode.

The rubric contains *optional* "Stand Out Suggestions" for enhancing the project beyond the minimum requirements. If you decide to pursue the "Stand Out Suggestions", you should include the code in this Jupyter notebook.

Why We're Here

In this notebook, you will make the first steps towards developing an algorithm that could be used as part of a mobile or web app. At the end of this project, your code will accept any user-supplied image as input. If a dog is detected in the image, it will provide an estimate of the dog's breed. If a human is detected, it will provide an estimate of the dog breed that is most resembling. The image below displays potential sample output of your finished project (... but we expect that each student's algorithm will behave differently!).



In this real-world setting, you will need to piece together a series of models to perform different tasks; for instance, the algorithm that detects humans in an image will be different from the CNN that infers dog breed. There are many points of possible failure, and no perfect algorithm exists. Your imperfect solution will nonetheless create a fun user experience!

The Road Ahead

We break the notebook into separate steps. Feel free to use the links below to navigate the notebook.

- [Step 0: Import Datasets](#)
- [Step 1: Detect Humans](#)
- [Step 2: Detect Dogs](#)
- [Step 3: Create a CNN to Classify Dog Breeds \(from Scratch\)](#)
- [Step 4: Create a CNN to Classify Dog Breeds \(using Transfer Learning\)](#)
- [Step 5: Write your Algorithm](#)
- [Step 6: Test Your Algorithm](#)

Step 0: Import Datasets

Make sure that you've downloaded the required human and dog datasets:

- Download the [dog dataset](#). Unzip the folder and place it in this project's home directory, at the location `/dog_images`.
- Download the [human dataset](#). Unzip the folder and place it in the home directory, at location `/lfw`.

Note: If you are using a Windows machine, you are encouraged to use [/zip](#) to extract the folder.

In the code cell below, we save the file paths for both the human (LFW) dataset and dog dataset in the numpy arrays `human_files` and `dog_files`.

In [1]:

```
# Importing necessary packages and files

import numpy as np
from glob import glob

# load filenames for human and dog images
human_files = np.array(glob("lfw/*/"))
dog_files = np.array(glob("dogImages/*/"))

# print number of images in each dataset
print('There are %d total human images.' % len(human_files))
print('There are %d total dog images.' % len(dog_files))
```

There are 13233 total human images.
There are 8351 total dog images.

Step 1: Detect Humans

In this section, we use OpenCV's implementation of [Haar feature-based cascade classifiers](#) to detect human faces in images.

OpenCV provides many pre-trained face detectors, stored as XML files on [github](#). We have downloaded one of these detectors and stored it in the `haarcascades` directory. In the next code cell, we demonstrate how to use this detector to find human faces in a sample image.

In [2]:

```
import cv2
import matplotlib.pyplot as plt
%matplotlib inline

# extract pre-trained face detector
face_cascade = cv2.CascadeClassifier('haarcascades/haarcascade_frontalface_alt.xml')

# load color (BGR) image
img = cv2.imread(human_files[0])
# convert BGR image to grayscale
gray = cv2.cvtColor(img, cv2.COLOR_BGR2GRAY)

# find faces in image
faces = face_cascade.detectMultiScale(gray)

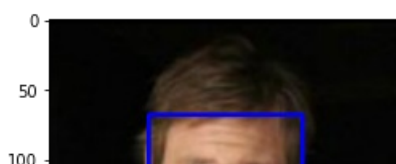
# print number of faces detected in the image
print('Number of faces detected:', len(faces))

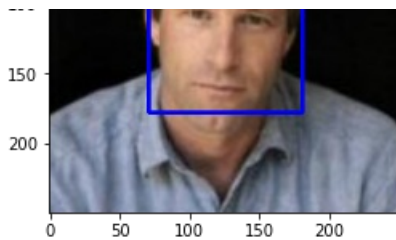
# get bounding box for each detected face
for (x,y,w,h) in faces:
    # add bounding box to color image
    cv2.rectangle(img, (x,y), (x+w,y+h), (255,0,0), 2)

# convert BGR image to RGB for plotting
cv_rgb = cv2.cvtColor(img, cv2.COLOR_BGR2RGB)

# display the image, along with bounding box
plt.imshow(cv_rgb)
plt.show()
```

Number of faces detected: 1





Before using any of the face detectors, it is standard procedure to convert the images to grayscale. The `detectMultiScale` function executes the classifier stored in `face_cascade` and takes the grayscale image as a parameter.

In the above code, `faces` is a numpy array of detected faces, where each row corresponds to a detected face. Each detected face is a 1D array with four entries that specifies the bounding box of the detected face. The first two entries in the array (extracted in the above code as `x` and `y`) specify the horizontal and vertical positions of the top left corner of the bounding box. The last two entries in the array (extracted here as `w` and `h`) specify the width and height of the box.

Write a Human Face Detector

We can use this procedure to write a function that returns `True` if a human face is detected in an image and `False` otherwise. This function, aptly named `face_detector`, takes a string-valued file path to an image as input and appears in the code block below.

In [3]:

```
# returns "True" if face is detected in image stored at img_path
def face_detector(img_path):
    """
    This function detects face in the given image and returns True if so.
    """
    img = cv2.imread(img_path)
    gray = cv2.cvtColor(img, cv2.COLOR_BGR2GRAY)
    faces = face_cascade.detectMultiScale(gray)
    return len(faces) > 0
```

(IMPLEMENTATION) Assess the Human Face Detector

Question 1: Use the code cell below to test the performance of the `face_detector` function.

- What percentage of the first 100 images in `human_files` have a detected human face?
- What percentage of the first 100 images in `dog_files` have a detected human face?

Ideally, we would like 100% of human images with a detected face and 0% of dog images with a detected face. You will see that our algorithm falls short of this goal, but still gives acceptable performance. We extract the file paths for the first 100 images from each of the datasets and store them in the numpy arrays `human_files_short` and `dog_files_short`.

Answer:

- 96 % of the first 100 images in `human_files` have a detected human face.
- 18 % of the first 100 images in `dog_files` have a detected human face.

In [4]:

```
from tqdm import tqdm

human_files_short = human_files[:100]
dog_files_short = dog_files[:100]

def human_faces_(files):
    """
    This function gives the total no. of images where our model found the face and total images
    """
    _faces = 0
    total_img = len(files)
    for i in files:
        _faces += face_detector(i)
```

```

    return _faces, total_img

_faces, total_img = human_faces_(human_files_short)
print((_faces/total_img)*100," % of images have human face in Human files")

_faces, total_img = human_faces_(dog_files_short)
print((_faces/total_img)*100," % of images have human face in Dog files")

```

```

96.0  % of images have human face in Human files
18.0  % of images have human face in Dog files

```

Step 2: Detect Dogs

In this section, we use a [pre-trained model](#) to detect dogs in images.

Obtain Pre-trained VGG-16 Model

The code cell below downloads the VGG-16 model, along with weights that have been trained on [ImageNet](#), a very large, very popular dataset used for image classification and other vision tasks. ImageNet contains over 10 million URLs, each linking to an image containing an object from one of [1000 categories](#).

In [5]:

```

import torch
import torchvision.models as models

# define VGG16 model
VGG16 = models.vgg16(pretrained=True)

# check if CUDA is available
use_cuda = torch.cuda.is_available()

# move model to GPU if CUDA is available
if use_cuda:
    VGG16 = VGG16.cuda()

```

Given an image, this pre-trained VGG-16 model returns a prediction (derived from the 1000 possible categories in ImageNet) for the object that is contained in the image.

(IMPLEMENTATION) Making Predictions with a Pre-trained Model

In the next code cell, you will write a function that accepts a path to an image (such as

'dogImages/train/001.Affenpinscher/Affenpinscher_00001.jpg') as input and returns the index corresponding to the ImageNet class that is predicted by the pre-trained VGG-16 model. The output should always be an integer between 0 and 999, inclusive.

Before writing the function, make sure that you take the time to learn how to appropriately pre-process tensors for pre-trained models in the [PyTorch documentation](#).

In [6]:

```

from PIL import Image
import torchvision.transforms as transforms
from PIL import ImageFile
ImageFile.LOAD_TRUNCATED_IMAGES = True

def VGG16_predict(img_path):
    image_ = Image.open(img_path)
    transformation = transforms.Compose([transforms.RandomResizedCrop(224),
                                         transforms.ToTensor()])

    image_ = transformation(image_)
    image_.unsqueeze_(0)

    if use_cuda:
        image_ = image_.cuda()

    output = VGG16(image_)

```

```
return torch.max(output, 1)[1].item()
```

(IMPLEMENTATION) Write a Dog Detector

While looking at the [dictionary](#), you will notice that the categories corresponding to dogs appear in an uninterrupted sequence and correspond to dictionary keys 151-268, inclusive, to include all categories from 'Chihuahua' to 'Mexican hairless'. Thus, in order to check to see if an image is predicted to contain a dog by the pre-trained VGG-16 model, we need only check if the pre-trained model predicts an index between 151 and 268 (inclusive).

Use these ideas to complete the `dog_detector` function below, which returns `True` if a dog is detected in an image (and `False` if not).

In [7]:

```
### returns "True" if a dog is detected in the image stored at img_path
def dog_detector(img_path):
    """
    This function predicts if a dog is present in the image and returns True if so.
    """

    idx_ = VGG16_predict(img_path)
    return idx_ >= 151 and idx_ <= 268
```

(IMPLEMENTATION) Assess the Dog Detector

Question 2: Use the code cell below to test the performance of your `dog_detector` function.

- What percentage of the images in `human_files_short` have a detected dog?
- What percentage of the images in `dog_files_short` have a detected dog?

Answer:

- 0 % of the images in `human_files_short` have detected dog
- 82 % of the images in `dog_files_short` have a detected dog

In [8]:

```
def detect_dogs_(files):
    """
    This function gives the total no. of images where our model found dog and the total images.
    """
    _dogs = 0
    total_img = len(files)
    for i in files:
        _dogs += dog_detector(i)

    return _dogs, total_img

_dogs, total_img = detect_dogs_(human_files_short)
print((_dogs/total_img)*100, "% of images have detected with dog in Human files")

_dogs, total_img = detect_dogs_(dog_files_short)
print((_dogs/total_img)*100, "% of images have detected with dog in Dog files")
```

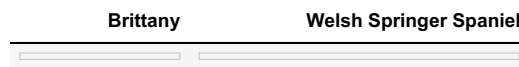
```
0.0 % of images have detected with dog in Human files
85.0 % of images have detected with dog in Dog files
```

We suggest VGG-16 as a potential network to detect dog images in your algorithm, but you are free to explore other pre-trained networks (such as [Inception-v3](#), [ResNet-50](#), etc). Please use the code cell below to test other pre-trained PyTorch models. If you decide to pursue this *optional* task, report performance on `human_files_short` and `dog_files_short`.

Step 3: Create a CNN to Classify Dog Breeds (from Scratch)

Now that we have functions for detecting humans and dogs in images, we need a way to predict breed from images. In this step, you will create a CNN that classifies dog breeds. You must create your CNN *from scratch* (so, you can't use transfer learning yet!), and you must attain a test accuracy of at least 10%. In Step 4 of this notebook, you will have the opportunity to use transfer learning to create a CNN that attains greatly improved accuracy.

We mention that the task of assigning breed to dogs from images is considered exceptionally challenging. To see why, consider that *even a human* would have trouble distinguishing between a Brittany and a Welsh Springer Spaniel.



It is not difficult to find other dog breed pairs with minimal inter-class variation (for instance, Curly-Coated Retrievers and American Water Spaniels).



Likewise, recall that labradors come in yellow, chocolate, and black. Your vision-based algorithm will have to conquer this high intra-class variation to determine how to classify all of these different shades as the same breed.



We also mention that random chance presents an exceptionally low bar: setting aside the fact that the classes are slightly imbalanced, a random guess will provide a correct answer roughly 1 in 133 times, which corresponds to an accuracy of less than 1%.

Remember that the practice is far ahead of the theory in deep learning. Experiment with many different architectures, and trust your intuition. And, of course, have fun!

(IMPLEMENTATION) Specify Data Loaders for the Dog Dataset

Use the code cell below to write three separate [data loaders](#) for the training, validation, and test datasets of dog images (located at `dog_images/train`, `dog_images/valid`, and `dog_images/test`, respectively). You may find [this documentation on custom datasets](#) to be a useful resource. If you are interested in augmenting your training and/or validation data, check out the wide variety of [transforms](#)!

In [9]:

```
import os
from torchvision import datasets

num_workers = 0
batch_size = 20
data_dir = 'dogImages'

data_transformations = {
    'train' : transforms.Compose([
        transforms.Resize(256),
        transforms.RandomResizedCrop(224),
        transforms.RandomHorizontalFlip(),
        transforms.ToTensor(),
        transforms.Normalize(mean=[0.485, 0.456, 0.406], std=[0.229, 0.224, 0.225])
    ]),

    'valid' : transforms.Compose([
        transforms.Resize(256),
        transforms.CenterCrop(224),
        transforms.ToTensor(),
        transforms.Normalize(mean=[0.485, 0.456, 0.406], std=[0.229, 0.224, 0.225])
    ]),

    'test' : transforms.Compose([
        transforms.Resize(256),
        transforms.CenterCrop(224),
        transforms.ToTensor(),
        transforms.Normalize(mean=[0.485, 0.456, 0.406], std=[0.229, 0.224, 0.225])
    ]),
}

train_dir = data_dir + '/train'
```

```

train_dir_ = data_dir + '/train'
valid_dir_ = data_dir + '/valid'
test_dir_ = data_dir + '/test'

train_data_ = datasets.ImageFolder(train_dir_, transform = data_transformations['train'])
valid_data_ = datasets.ImageFolder(valid_dir_, transform = data_transformations['valid'])
test_data_ = datasets.ImageFolder(test_dir_, transform = data_transformations['test'])

train_loader_ = torch.utils.data.DataLoader(train_data_, batch_size= batch_size, num_workers = num_
workers, shuffle = True)
valid_loader_ = torch.utils.data.DataLoader(valid_data_, batch_size=batch_size, num_workers = num_w
orkers, shuffle = False)
test_loader_ = torch.utils.data.DataLoader(test_data_, batch_size= batch_size, num_workers = num_wo
rkers, shuffle = False)

```

Question 3: Describe your chosen procedure for preprocessing the data.

- How does your code resize the images (by cropping, stretching, etc)? What size did you pick for the input tensor, and why?
- Did you decide to augment the dataset? If so, how (through translations, flips, rotations, etc)? If not, why not?

Answer:

- I have followed different procedure for the Train and validation data.
- For the Train data I have used RandomResizeCrop to crop and resize the image with the same size specified in the model and then transfer that into tensors.
- I augmented the train data which will prevent overfitting by providing randomness in the data.
- I have augmented the train data using RandomHorizontalFlip.
- For the validation and test data I did not augmented the data and just simply resized it and then converted it to tensors.

(IMPLEMENTATION) Model Architecture

Create a CNN to classify dog breed. Use the template in the code cell below.

In [10]:

```

import torch.nn as nn
import torch.nn.functional as F

# define the CNN architecture
class Net(nn.Module):
    def __init__(self):
        super(Net, self).__init__()
        # Defining 3 convolutional layers
        self.conv1 = nn.Conv2d(3, 32, 3, stride = 2, padding = 1)
        self.conv2 = nn.Conv2d(32, 64, 3, stride = 2, padding = 1)
        self.conv3 = nn.Conv2d(64, 128, 3, padding = 1)

        # Pooling Layer
        self.pool = nn.MaxPool2d(2, 2)

        # Fully-connected layer
        self.fc1 = nn.Linear(7 * 7 * 128, 500)
        self.fc2 = nn.Linear(500, 133)

        # Introducing Dropout
        self.dropout = nn.Dropout(0.31)

    def forward(self, x):
        x = F.relu(self.conv1(x))
        x = self.pool(x)

        x = F.relu(self.conv2(x))
        x = self.pool(x)

        x = F.relu(self.conv3(x))
        x = self.pool(x)

        x = x.view(-1, 7 * 7 * 128)
        x = self.dropout(x)
        x = F.relu(self.fc1(x))
        x = self.dropout(x)
        x = self.fc2(x)

```

```

        return x

##-## You so NOT have to modify the code below this line. ##-##

# instantiate the CNN
model_scratch = Net()
print(model_scratch)
# move tensors to GPU if CUDA is available
if use_cuda:
    model_scratch.cuda()

Net(
  (conv1): Conv2d(3, 32, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1))
  (conv2): Conv2d(32, 64, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1))
  (conv3): Conv2d(64, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
  (pool): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1, ceil_mode=False)
  (fc1): Linear(in_features=6272, out_features=500, bias=True)
  (fc2): Linear(in_features=500, out_features=133, bias=True)
  (dropout): Dropout(p=0.31, inplace=False)
)

```

Question 4: Outline the steps you took to get to your final CNN architecture and your reasoning at each step.

Answer:

- I wanted to use very simple architecture and while I was going through throuid some of the articles I got to know that I can achieve the mentioned accuracy using 3 only 3 layers.
- At the end I got accuracy of 12%.
- In this architecture I have 3 convolutional layers, 1 maxpooling level, 2 fully connected layes and at the end I have introduced dropout with the probability of 0.31.
- For the first 2 convolutional layers I have used padding size of 1 with strides = 2.
- For the third convolutional layes I have only used padding.
- Then the MaxPolling layes will reduce the size by 2.
- At last I have introduced the dropout to avoid overfitting.

(IMPLEMENTATION) Specify Loss Function and Optimizer

Use the next code cell to specify a [loss function](#) and [optimizer](#). Save the chosen loss function as `criterion_scratch`, and the optimizer as `optimizer_scratch` below.

In [11]:

```

import torch.optim as optim

### TODO: select loss function
criterion_scratch = nn.CrossEntropyLoss()

### TODO: select optimizer
optimizer_scratch = optim.SGD(model_scratch.parameters(), lr=0.06)

```

(IMPLEMENTATION) Train and Validate the Model

Train and validate your model in the code cell below. [Save the final model parameters](#) at filepath `'model_scratch.pt'`.

In [12]:

```

ImageFile.LOAD_TRUNCATED_IMAGES = True
def train(n_epochs, loaders, model, optimizer, criterion, use_cuda, save_path):
    """returns trained model"""
    # initialize tracker for minimum validation loss
    valid_loss_min = np.Inf

    for epoch in tqdm(range(1, n_epochs+1)):
        # initialize variables to monitor training and validation loss
        train_loss = 0.0
        valid_loss = 0.0

```



```

#####
# train the model #
#####
model.train()
for batch_idx, (data, target) in tqdm(enumerate(loaders)):
    # move to GPU
    if use_cuda:
        data, target = data.cuda(), target.cuda()

    # Clearing the gradients of all optimized variables
    optimizer.zero_grad()

    # Forward pass
    output = model(data)

    # calculating the loss
    loss = criterion(output, target)

    # Backward pass
    loss.backward()

    optimizer.step()

    # updating the Training loss
    train_loss += loss.item() * data.size(0) #train_loss + ((1 / (batch_idx + 1)) * (loss.data - train_loss))

#####
# validate the model #
#####
model.eval()

for batch_idx, (data, target) in enumerate(valid_loader_):
    # move to GPU
    if use_cuda:
        data, target = data.cuda(), target.cuda()
    ## update the average validation loss
    # Forward pass
    output = model(data)

    # calculating Batch loss
    loss = criterion(output, target)

    # update average validation loss
    valid_loss += loss.item() * data.size(0) #valid_loss + ((1 / (batch_idx + 1)) * (loss.data - valid_loss))

    # calculating average train and Validation loss
    train_loss = train_loss/len(loaders.dataset)
    valid_loss = valid_loss/len(loaders.dataset)

    # print training/validation statistics
    print('Epoch: {} \tTraining Loss: {:.6f} \tValidation Loss: {:.6f}'.format(
        epoch,
        train_loss,
        valid_loss
    ))

    ## TODO: save the model if validation loss has decreased
    ## save the model if validation loss has decreased
    if valid_loss <= valid_loss_min:
        print('Validation loss decreased from {:.6f} to {:.6f}). Saving model .....'.format(
            valid_loss_min,
            valid_loss))
        torch.save(model.state_dict(), save_path)
        valid_loss_min = valid_loss

# return trained model
return model

# train the model
model_scratch = train(15, train_loader_, model_scratch, optimizer_scratch, criterion_scratch, use_cuda, 'model_scratch.pt')

# load the model that got the best validation accuracy
model_scratch.load_state_dict(torch.load('model_scratch.pt'))

```

```
0%|
[00:00<?, ?it/s]
0it [00:00, ?it/s]
1it [00:00, 1.23it/s]
2it [00:01, 1.20it/s]
3it [00:02, 1.29it/s]
4it [00:03, 1.24it/s]
5it [00:03, 1.31it/s]
6it [00:04, 1.28it/s]
7it [00:05, 1.07it/s]
8it [00:06, 1.18it/s]
9it [00:07, 1.17it/s]
10it [00:08, 1.25it/s]
11it [00:08, 1.33it/s]
12it [00:09, 1.45it/s]
13it [00:10, 1.47it/s]
14it [00:10, 1.64it/s]
15it [00:10, 1.72it/s]
16it [00:11, 1.57it/s]
17it [00:12, 1.37it/s]
18it [00:13, 1.42it/s]
19it [00:14, 1.37it/s]
20it [00:14, 1.40it/s]
21it [00:15, 1.47it/s]
22it [00:15, 1.54it/s]
23it [00:16, 1.54it/s]
24it [00:17, 1.58it/s]
25it [00:18, 1.36it/s]
26it [00:19, 1.30it/s]
27it [00:19, 1.27it/s]
28it [00:20, 1.36it/s]
29it [00:21, 1.39it/s]
30it [00:21, 1.35it/s]
31it [00:22, 1.36it/s]
32it [00:23, 1.46it/s]
33it [00:24, 1.38it/s]
34it [00:24, 1.42it/s]
35it [00:25, 1.35it/s]
36it [00:26, 1.14it/s]
37it [00:27, 1.18it/s]
38it [00:28, 1.10it/s]
39it [00:29, 1.19it/s]
40it [00:29, 1.24it/s]
41it [00:30, 1.23it/s]
42it [00:31, 1.32it/s]
43it [00:32, 1.31it/s]
44it [00:32, 1.35it/s]
45it [00:33, 1.41it/s]
46it [00:34, 1.48it/s]
47it [00:34, 1.49it/s]
48it [00:35, 1.51it/s]
49it [00:36, 1.23it/s]
50it [00:37, 1.30it/s]
51it [00:38, 1.29it/s]
52it [00:38, 1.39it/s]
53it [00:39, 1.40it/s]
54it [00:40, 1.30it/s]
55it [00:41, 1.08it/s]
56it [00:42, 1.21it/s]
57it [00:43, 1.19it/s]
58it [00:43, 1.27it/s]
59it [00:44, 1.32it/s]
60it [00:44, 1.40it/s]
61it [00:45, 1.51it/s]
62it [00:46, 1.27it/s]
63it [00:47, 1.21it/s]
64it [00:48, 1.11it/s]
65it [00:49, 1.09it/s]
66it [00:50, 1.14it/s]
67it [00:51, 1.19it/s]
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7% [██████████]
7:36, 289.77s/it]
0it [00:00, ?it/s]
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| 1/15 [04:49<

Epoch: 1 Training Loss: 4.872892 Validation Loss: 0.598561
Validation loss decreased from (inf to 0.598561). Saving model

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233it [02:05, 1.31it/s]
234it [02:05, 1.61it/s]
235it [02:05, 1.66it/s]
236it [02:06, 1.86it/s]
237it [02:06, 1.99it/s]
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239it [02:08, 1.26it/s]
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266it [02:20, 4.57it/s]
267it [02:20, 4.83it/s]
268it [02:20, 4.75it/s]
269it [02:20, 4.76it/s]

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282it [02:24, 4.25it/s]
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328it [02:35, 3.86it/s]
329it [02:35, 3.96it/s]
330it [02:35, 4.44it/s]
331it [02:35, 4.22it/s]
332it [02:36, 2.72it/s]
333it [02:37, 2.62it/s]
334it [02:37, 2.12it/s]
13%|██████████|
[07:35<54:42, 252.48s/it]
0it [00:00, ?it/s]
1it [00:00, 7.01it/s]
```

| 2/15

Epoch: 2 Training Loss: 4.792951 Validation Loss: 0.583973
Validation loss decreased from (0.598561 to 0.583973). Saving model

```
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3it [00:00, 3.94it/s]
4it [00:01, 4.16it/s]
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5it [00:01, 4.66it/s]
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8it [00:01, 4.04it/s]
9it [00:02, 3.72it/s]
10it [00:02, 4.06it/s]
11it [00:02, 3.68it/s]
12it [00:03, 3.26it/s]
13it [00:03, 3.58it/s]
14it [00:03, 3.28it/s]
15it [00:03, 3.72it/s]
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18it [00:04, 3.14it/s]
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21it [00:06, 2.67it/s]
22it [00:06, 2.76it/s]
23it [00:06, 2.92it/s]
24it [00:07, 3.04it/s]
25it [00:07, 3.57it/s]
26it [00:07, 3.97it/s]
27it [00:07, 4.30it/s]
28it [00:07, 3.99it/s]
29it [00:08, 4.07it/s]
30it [00:08, 4.48it/s]
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37it [00:09, 4.27it/s]
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53it [00:13, 4.96it/s]
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225it [00:59, 3.09it/s]
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227it [00:59, 3.57it/s]
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232it [01:00, 4.20it/s]
233it [01:00, 4.12it/s]
234it [01:01, 4.34it/s]
235it [01:01, 4.51it/s]

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237it	[01:01,	4.57it/s]
238it	[01:01,	4.55it/s]
239it	[01:02,	4.93it/s]
240it	[01:02,	4.89it/s]
241it	[01:02,	5.01it/s]
242it	[01:02,	5.34it/s]
243it	[01:03,	4.31it/s]
244it	[01:03,	4.58it/s]
245it	[01:03,	4.65it/s]
246it	[01:03,	4.42it/s]
247it	[01:03,	4.08it/s]
248it	[01:04,	4.15it/s]
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250it	[01:04,	4.46it/s]
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253it	[01:05,	3.37it/s]
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255it	[01:06,	3.09it/s]
256it	[01:06,	3.12it/s]
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259it	[01:07,	3.64it/s]
260it	[01:07,	3.78it/s]
261it	[01:07,	4.01it/s]
262it	[01:08,	3.33it/s]
263it	[01:08,	2.61it/s]
264it	[01:09,	2.74it/s]
265it	[01:09,	3.24it/s]
266it	[01:09,	3.41it/s]
267it	[01:09,	3.69it/s]
268it	[01:10,	3.86it/s]
269it	[01:10,	3.16it/s]
270it	[01:10,	3.30it/s]
271it	[01:11,	3.20it/s]
272it	[01:11,	3.62it/s]
273it	[01:11,	3.80it/s]
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275it	[01:11,	4.27it/s]
276it	[01:12,	4.24it/s]
277it	[01:12,	4.47it/s]
278it	[01:12,	4.27it/s]
279it	[01:12,	4.32it/s]
280it	[01:13,	4.52it/s]
281it	[01:13,	4.32it/s]
282it	[01:13,	3.82it/s]
283it	[01:14,	3.52it/s]
284it	[01:14,	3.55it/s]
285it	[01:14,	3.76it/s]
286it	[01:14,	4.13it/s]
287it	[01:14,	4.08it/s]
288it	[01:15,	4.15it/s]
289it	[01:15,	4.14it/s]
290it	[01:15,	4.51it/s]
291it	[01:15,	4.75it/s]
292it	[01:16,	3.21it/s]
293it	[01:16,	3.55it/s]
294it	[01:16,	4.03it/s]
295it	[01:16,	4.06it/s]
296it	[01:17,	3.69it/s]
297it	[01:17,	4.04it/s]
298it	[01:17,	3.88it/s]
299it	[01:18,	3.86it/s]
300it	[01:18,	3.11it/s]
301it	[01:18,	3.35it/s]
302it	[01:19,	3.52it/s]
303it	[01:19,	4.11it/s]
304it	[01:19,	3.78it/s]
305it	[01:19,	4.03it/s]
306it	[01:19,	3.78it/s]
307it	[01:20,	3.67it/s]
308it	[01:20,	3.83it/s]
309it	[01:20,	3.64it/s]
310it	[01:20,	4.15it/s]
311it	[01:21,	3.47it/s]

```
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313it [01:21, 3.82it/s]
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315it [01:22, 4.22it/s]
316it [01:22, 4.19it/s]
317it [01:22, 4.52it/s]
318it [01:23, 4.03it/s]
319it [01:23, 3.89it/s]
320it [01:23, 3.92it/s]
321it [01:23, 4.30it/s]
322it [01:24, 3.46it/s]
323it [01:24, 3.63it/s]
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326it [01:25, 4.43it/s]
327it [01:25, 3.39it/s]
328it [01:25, 3.86it/s]
329it [01:25, 4.18it/s]
330it [01:26, 4.08it/s]
331it [01:26, 4.52it/s]
332it [01:26, 4.14it/s]
333it [01:26, 4.05it/s]
334it [01:27, 3.83it/s]
20%|██████████|
[09:10<41:05, 205.44s/it]
0it [00:00, ?it/s]
```

| 3/15

Epoch: 3 Training Loss: 4.691200 Validation Loss: 0.565958
Validation loss decreased from (0.583973 to 0.565958). Saving model

```
1it [00:00, 4.94it/s]
2it [00:00, 4.82it/s]
3it [00:00, 4.41it/s]
4it [00:00, 4.13it/s]
5it [00:01, 4.55it/s]
6it [00:01, 4.65it/s]
7it [00:01, 4.16it/s]
8it [00:01, 4.41it/s]
9it [00:02, 4.52it/s]
10it [00:02, 5.01it/s]
11it [00:02, 4.19it/s]
12it [00:02, 3.99it/s]
13it [00:02, 4.37it/s]
14it [00:03, 4.57it/s]
15it [00:03, 4.39it/s]
16it [00:03, 4.61it/s]
17it [00:03, 4.84it/s]
18it [00:03, 4.99it/s]
19it [00:04, 4.37it/s]
20it [00:04, 4.51it/s]
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24it [00:05, 4.52it/s]
25it [00:05, 4.57it/s]
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35it [00:08, 4.05it/s]
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38it [00:08, 4.59it/s]
39it [00:09, 4.81it/s]
40it [00:09, 4.91it/s]
41it [00:09, 5.25it/s]
42it [00:09, 5.30it/s]
43it [00:09, 5.52it/s]
44it [00:09, 5.22it/s]
45it [00:10, 5.19it/s]
46it [00:10, 5.12it/s]
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Validation loss decreased from (0.549679 to 0.542762). Saving model

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Validation loss decreased from (0.517900 to 0.508789). Saving model

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334it [01:26, 3.85it/s]

73%

| 11/15

[22:12<06:51, 102.85s/it]

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Epoch: 11 Training Loss: 4.177698 Validation Loss: 0.490792
Validation loss decreased from (0.508789 to 0.490792). Saving model

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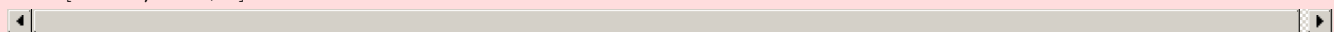
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331it [01:27, 3.46it/s]
332it [01:27, 3.58it/s]
333it [01:27, 3.91it/s]
334it [01:28, 3.79it/s]
```

87%

| 13/15 [25:2

8<03:20, 100.29s/it]

0it [00:00, ?it/s]

Epoch: 13 Training Loss: 4.097081 Validation Loss: 0.487604

Validation loss decreased from (0.490792 to 0.487604). Saving model

```
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2it [00:00, 2.01it/s]
3it [00:01, 2.37it/s]
4it [00:01, 2.56it/s]
5it [00:01, 2.69it/s]
6it [00:02, 3.10it/s]
7it [00:02, 3.55it/s]
8it [00:02, 3.85it/s]
9it [00:02, 4.24it/s]
10it [00:03, 3.39it/s]
11it [00:03, 3.66it/s]
12it [00:03, 3.54it/s]
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23it [00:06, 3.49it/s]
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25it [00:07, 2.64it/s]
26it [00:08, 2.49it/s]
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333it [01:29, 4.66it/s]
334it [01:29, 3.71it/s]
93%|███████████
[27:07<01:39, 99.89s/it]
0it [00:00, ?it/s]
```

Epoch: 14 Training Loss: 4.038365 Validation Loss: 0.479213
Validation loss decreased from (0.487604 to 0.479213). Saving model

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2it	[00:00,	2.29it/s]
3it	[00:01,	2.56it/s]
4it	[00:01,	2.80it/s]
5it	[00:01,	2.38it/s]
6it	[00:02,	2.83it/s]
7it	[00:02,	3.20it/s]
8it	[00:02,	3.48it/s]
9it	[00:02,	3.87it/s]
10it	[00:03,	3.93it/s]
11it	[00:03,	4.25it/s]
12it	[00:03,	4.10it/s]
13it	[00:03,	4.07it/s]
14it	[00:03,	3.88it/s]
15it	[00:04,	4.23it/s]
16it	[00:04,	4.00it/s]
17it	[00:04,	4.20it/s]
18it	[00:04,	3.82it/s]
19it	[00:05,	3.68it/s]
20it	[00:05,	3.33it/s]
21it	[00:05,	3.61it/s]
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23it	[00:06,	3.94it/s]
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45it	[00:12,	3.87it/s]
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51it	[00:14,	3.80it/s]
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53it	[00:14,	4.18it/s]
54it	[00:14,	4.10it/s]

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Epoch: 15 Training Loss: 3.986934 Validation Loss: 0.480099

Out[12]:

```
<All keys matched successfully>
```

(IMPLEMENTATION) Test the Model

Try out your model on the test dataset of dog images. Use the code cell below to calculate and print the test loss and accuracy. Ensure that your test accuracy is greater than 10%.

In [13]:

```
def test(loader, model, criterion, use_cuda):
    # monitor test loss and accuracy
    test_loss = 0.
    correct = 0.
    total = 0.

    model.eval()
```

```

model.eval()
for batch_idx, (data, target) in enumerate(loader):
    # move to GPU
    if use_cuda:
        data, target = data.cuda(), target.cuda()
    # forward pass: compute predicted outputs by passing inputs to the model
    output = model(data)
    # calculate the loss
    loss = criterion(output, target)
    # update average test loss
    test_loss = test_loss + ((1 / (batch_idx + 1)) * (loss.data - test_loss))
    # convert output probabilities to predicted class
    pred = output.data.max(1, keepdim=True)[1]
    # compare predictions to true label
    correct += np.sum(np.squeeze(pred.eq(target.data.view_as(pred))).cpu().numpy())
    total += data.size(0)

print('Test Loss: {:.6f}\n'.format(test_loss))

print('\nTest Accuracy: %2d%% (%2d/%2d)' % (
    100. * correct / total, correct, total))

# call test function
test(test_loader_, model_scratch, criterion_scratch, use_cuda)

```

Test Loss: 3.805828

Test Accuracy: 13% (115/836)

Step 4: Create a CNN to Classify Dog Breeds (using Transfer Learning)

You will now use transfer learning to create a CNN that can identify dog breed from images. Your CNN must attain at least 60% accuracy on the test set.

(IMPLEMENTATION) Specify Data Loaders for the Dog Dataset

Use the code cell below to write three separate [data loaders](#) for the training, validation, and test datasets of dog images (located at `dogImages/train`, `dogImages/valid`, and `dogImages/test`, respectively).

If you like, **you are welcome to use the same data loaders from the previous step**, when you created a CNN from scratch.

(IMPLEMENTATION) Model Architecture

Use transfer learning to create a CNN to classify dog breed. Use the code cell below, and save your initialized model as the variable `model_transfer`.

In [14]:

```

import torchvision.models as models
import torch.nn as nn

model_transfer = models.vgg16(pretrained=True)

for param in model_transfer.parameters():
    param.requires_grad = False

input_size = model_transfer.classifier[6].in_features

model_transfer.classifier[6] = nn.Linear(input_size, 133)

if use_cuda:
    model_transfer = model_transfer.cuda()

```

Question 5: Outline the steps you took to get to your final CNN architecture and your reasoning at each step. Describe why you think the architecture is suitable for the current problem.

Answer:

- Since we already have models which are pretrained on the dataset like imagenet then It is preferable to use the those pretrained models instead of defining the whole architecture ourself and tuning the hyperparameters.
- We can use pretrained models like Resnet50, Densenet, VGG16, VGG19,etc. I have tried resnet and VGG, VGG16 gave me better results so I am using VGG16 in this project.
- These models are available to us for the direct usage so I have directly used VGG16 but I have removed the top layers because these fully connected layers are often depends upon the Dataset and If we want to use the VGG16 on our dataset then it is better to define the top layers on our own.

(IMPLEMENTATION) Specify Loss Function and Optimizer

Use the next code cell to specify a [loss function](#) and [optimizer](#). Save the chosen loss function as `criterion_transfer`, and the optimizer as `optimizer_transfer` below.

In [15]:

```
criterion_transfer = nn.CrossEntropyLoss()
optimizer_transfer = optim.SGD(model_transfer.classifier.parameters(), lr=0.021)
```

(IMPLEMENTATION) Train and Validate the Model

Train and validate your model in the code cell below. [Save the final model parameters](#) at filepath `'model_transfer.pt'`.

In [17]:

```
model_transfer = train(14, train_loader_, model_transfer, optimizer_transfer, criterion_transfer, use_cuda, 'model_transfer.pt')
```

```
# load the model that got the best validation accuracy (uncomment the line below)
model_transfer.load_state_dict(torch.load('model_transfer.pt'))
```

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295it [01:53, 2.30it/s]
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297it [01:54, 2.22it/s]
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331it [02:08, 2.29it/s]
332it [02:09, 2.46it/s]
333it [02:09, 2.36it/s]
334it [02:10, 2.57it/s]
```

Epoch: 1 Training Loss: 1.665521 Validation Loss: 0.079908
Validation loss decreased from (inf to 0.079908). Saving model

```
7%|███████|
1:24, 145.00s/it]
0it [00:00, ?it/s]
1it [00:00, 2.82it/s]
```

| 1/14 [02:2

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3it [00:00, 2.97it/s]
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5it [00:01, 2.48it/s]
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7it [00:02, 2.44it/s]
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190it	[01:15,	2.81it/s]
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209it	[01:23,	2.58it/s]
210it	[01:23,	2.65it/s]
211it	[01:23,	2.77it/s]
212it	[01:24,	2.57it/s]
213it	[01:24,	2.69it/s]
214it	[01:24,	2.92it/s]
215it	[01:25,	2.95it/s]
216it	[01:25,	3.04it/s]
217it	[01:25,	3.13it/s]
218it	[01:26,	2.88it/s]
219it	[01:26,	2.74it/s]
220it	[01:26,	2.97it/s]
221it	[01:27,	2.96it/s]
222it	[01:27,	2.87it/s]
223it	[01:28,	2.45it/s]
224it	[01:28,	2.54it/s]
225it	[01:28,	2.49it/s]
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232it	[01:32,	2.46it/s]

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295it [01:57, 2.26it/s]
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332it [02:12, 2.30it/s]
333it [02:12, 2.42it/s]
334it [02:13, 2.50it/s]
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Epoch: 2 Training Loss: 1.131117 Validation Loss: 0.064554
Validation loss decreased from (0.079908 to 0.064554). Saving model

```
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6it [00:02, 2.68it/s]
7it [00:02, 2.48it/s]
8it [00:03, 2.56it/s]
9it [00:03, 2.27it/s]
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11it [00:04, 2.45it/s]
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42it [00:17, 2.50it/s]
43it [00:17, 2.37it/s]
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| 2/14

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Epoch: 3 Training Loss: 1.009095 Validation Loss: 0.056488
Validation loss decreased from (0.064554 to 0.056488). Saving model

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| 3/14

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Epoch: 4 Training Loss: 0.985096 Validation Loss: 0.055064
Validation loss decreased from (0.056488 to 0.055064). Saving model

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318it	[02:12,	2.29it/s]
319it	[02:12,	2.50it/s]
320it	[02:13,	2.63it/s]
321it	[02:13,	2.71it/s]
322it	[02:13,	2.72it/s]
323it	[02:14,	2.72it/s]
324it	[02:14,	2.69it/s]
325it	[02:15,	2.67it/s]
326it	[02:15,	2.75it/s]
327it	[02:15,	2.43it/s]
328it	[02:16,	2.38it/s]
329it	[02:16,	2.32it/s]
330it	[02:17,	2.44it/s]
331it	[02:17,	2.52it/s]
332it	[02:17,	2.62it/s]
333it	[02:18,	2.40it/s]
334it	[02:18,	2.40it/s]

| 7/14 [17:4

Epoch: 7 Training Loss: 0.880929 Validation Loss: 0.055534

1it	[00:00,	2.53it/s]
2it	[00:00,	2.48it/s]
3it	[00:01,	2.63it/s]
4it	[00:01,	2.50it/s]
5it	[00:01,	2.62it/s]
6it	[00:02,	2.50it/s]
7it	[00:02,	2.62it/s]
8it	[00:03,	2.58it/s]
9it	[00:03,	2.25it/s]
10it	[00:04,	2.18it/s]
11it	[00:04,	2.37it/s]
12it	[00:05,	2.12it/s]
13it	[00:05,	1.98it/s]
14it	[00:06,	2.24it/s]
15it	[00:06,	1.98it/s]
16it	[00:06,	2.21it/s]
17it	[00:07,	2.27it/s]
18it	[00:07,	2.51it/s]
19it	[00:07,	2.75it/s]
20it	[00:08,	2.67it/s]
21it	[00:08,	2.24it/s]
22it	[00:09,	2.31it/s]
23it	[00:09,	2.49it/s]
24it	[00:10,	2.50it/s]
25it	[00:10,	2.23it/s]
26it	[00:11,	2.37it/s]
27it	[00:11,	2.44it/s]

27it [00:11, 2.44it/s]
28it [00:11, 2.44it/s]
29it [00:12, 2.59it/s]
30it [00:12, 2.70it/s]
31it [00:13, 2.18it/s]
32it [00:13, 2.32it/s]
33it [00:13, 2.48it/s]
34it [00:14, 2.67it/s]
35it [00:14, 2.73it/s]
36it [00:14, 2.71it/s]
37it [00:15, 2.76it/s]
38it [00:15, 2.27it/s]
39it [00:16, 2.40it/s]
40it [00:16, 2.32it/s]
41it [00:17, 2.45it/s]
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47it [00:19, 2.31it/s]
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65it [00:27, 2.56it/s]
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181it [01:16, 2.36it/s]
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223it [01:34, 2.40it/s]
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225it [01:35, 2.58it/s]
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229it [01:37, 2.17it/s]
230it [01:37, 1.87it/s]
231it [01:38, 2.05it/s]
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249it [01:45, 2.23it/s]
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251it [01:46, 2.54it/s]
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256it [01:48, 2.29it/s]
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274it [01:55, 2.31it/s]
275it [01:55, 2.35it/s]
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278it [01:57, 2.47it/s]
279it [01:57, 2.51it/s]
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281it [01:58, 2.57it/s]
282it [01:58, 2.64it/s]
283it [01:59, 2.52it/s]
284it [01:59, 2.64it/s]
285it [01:59, 2.72it/s]
286it [02:00, 2.52it/s]
287it [02:00, 2.56it/s]
288it [02:01, 2.46it/s]
289it [02:01, 2.50it/s]
290it [02:01, 2.58it/s]
291it [02:02, 2.51it/s]
292it [02:02, 2.67it/s]
293it [02:02, 2.88it/s]
294it [02:03, 2.51it/s]
295it [02:03, 2.54it/s]
296it [02:04, 2.50it/s]
297it [02:04, 2.41it/s]
298it [02:04, 2.51it/s]
299it [02:05, 2.72it/s]
300it [02:05, 2.81it/s]
301it [02:05, 2.78it/s]
302it [02:06, 2.61it/s]
303it [02:06, 2.56it/s]
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305it [02:07, 2.63it/s]
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313it [02:10, 2.73it/s]
314it [02:10, 2.68it/s]
315it [02:11, 2.19it/s]
316it [02:11, 2.36it/s]
317it [02:12, 2.55it/s]
318it [02:12, 2.66it/s]
319it [02:12, 2.64it/s]
320it [02:13, 2.54it/s]
321it [02:13, 2.58it/s]
322it [02:14, 2.70it/s]
323it [02:14, 2.05it/s]
324it [02:15, 2.23it/s]
325it [02:15, 2.38it/s]
326it [02:15, 2.61it/s]
327it [02:16, 2.69it/s]
328it [02:16, 2.78it/s]
329it [02:17, 2.56it/s]
330it [02:17, 2.57it/s]
331it [02:17, 2.57it/s]
332it [02:18, 2.38it/s]
333it [02:18, 2.52it/s]
334it [02:19, 2.40it/s]

Epoch: 8 Training Loss: 0.874844 Validation Loss: 0.051676
Validation loss decreased from (0.053476 to 0.051676). Saving model

57%

| 8/14 [20:1

<15:20, 153.35s/it]
0it [00:00, ?it/s]
1it [00:00, 1.93it/s]
2it [00:01, 1.91it/s]
3it [00:01, 2.10it/s]
4it [00:01, 2.04it/s]
5it [00:02, 2.16it/s]
6it [00:02, 2.39it/s]
7it [00:03, 2.44it/s]
8it [00:03, 2.55it/s]
9it [00:03, 2.62it/s]
10it [00:04, 2.76it/s]
11it [00:04, 2.81it/s]
12it [00:04, 2.56it/s]
13it [00:05, 2.52it/s]
14it [00:05, 2.62it/s]
15it [00:06, 2.12it/s]
16it [00:07, 1.87it/s]
17it [00:07, 1.83it/s]
18it [00:07, 2.15it/s]
19it [00:08, 2.30it/s]
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25it [00:10, 2.56it/s]
26it [00:10, 2.39it/s]
27it [00:11, 2.38it/s]
28it [00:11, 2.51it/s]
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30it [00:12, 2.75it/s]
31it [00:12, 2.93it/s]
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69it [00:28, 2.54it/s]

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Epoch: 10 Training Loss: 0.864229 Validation Loss: 0.048349
Validation loss decreased from (0.051676 to 0.048349). Saving model

71% 
[25:29<10:19, 154.89s/it]
0it [00:00, ?it/s]
1it [00:00, 2.06it/s]

| 10/14

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4it [00:01, 2.15it/s]
5it [00:02, 2.30it/s]
6it [00:02, 2.61it/s]
7it [00:02, 2.65it/s]
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15it [00:05, 2.77it/s]
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219it	[01:31,	2.27it/s]
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221it	[01:32,	2.10it/s]
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223it	[01:33,	2.44it/s]
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314it	[02:11,	2.50it/s]
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322it	[02:15,	1.80it/s]
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332it	[02:19,	2.35it/s]
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334it	[02:20,	2.38it/s]

Epoch: 11 Training Loss: 0.859111 Validation Loss: 0.048841

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| 12/14 [30:4

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Epoch: 12 Training Loss: 0.820223 Validation Loss: 0.052413

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11it [00:04, 2.64it/s]

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13/14

Epoch: 13 Training Loss: 0.869029 Validation Loss: 0.051258

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23it	[00:09,	2.51it/s]
24it	[00:10,	2.68it/s]
25it	[00:10,	2.68it/s]
26it	[00:10,	2.78it/s]
27it	[00:11,	2.24it/s]
28it	[00:11,	2.18it/s]
29it	[00:12,	2.25it/s]
30it	[00:12,	2.41it/s]
31it	[00:12,	2.59it/s]
32it	[00:13,	2.73it/s]
33it	[00:13,	2.62it/s]
34it	[00:14,	2.32it/s]
35it	[00:14,	2.43it/s]
36it	[00:14,	2.61it/s]
37it	[00:15,	2.36it/s]
38it	[00:16,	2.09it/s]
39it	[00:16,	2.26it/s]
40it	[00:16,	2.32it/s]
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44it	[00:18,	2.66it/s]
45it	[00:18,	2.44it/s]
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53it	[00:22,	2.11it/s]
54it	[00:22,	2.09it/s]

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197it [01:23, 2.46it/s]
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205it [01:27, 1.89it/s]
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212it [01:30, 2.40it/s]
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233it [01:38, 2.59it/s]
234it [01:38, 2.60it/s]
235it [01:39, 2.33it/s]
236it [01:39, 2.36it/s]
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246it [01:43, 2.62it/s]
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254it [01:47, 2.21it/s]
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256it [01:48, 2.43it/s]
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274it [01:55, 2.28it/s]
275it [01:56, 2.47it/s]
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277it [01:57, 2.60it/s]
278it [01:57, 2.68it/s]
279it [01:57, 2.78it/s]
280it [01:58, 2.83it/s]
281it [01:58, 2.73it/s]
282it [01:59, 2.25it/s]
283it [01:59, 2.41it/s]
284it [01:59, 2.57it/s]
285it [02:00, 2.63it/s]

In [19]:

```
test(test_loader_, model_transfer, criterion_transfer, use_cuda)
```

Test Loss: 0.440166

Test Accuracy: 86% (720/836)

(IMPLEMENTATION) Predict Dog Breed with the Model

Write a function that takes an image path as input and returns the dog breed (`Affenpinscher`, `Afghan hound`, etc) that is predicted by your model.

In [20]:

```
class_names = [item[4:].replace("_", " ") for item in train_loader_.dataset.classes]

def predict_breed_transfer(img_path):
    image_ = Image.open(img_path).convert('RGB')
    pred_transform = transforms.Compose([transforms.Resize(size=(224, 224)),
                                         transforms.ToTensor(),
                                         transforms.Normalize(mean=[0.485, 0.456, 0.406], std=[0.229, 0.224, 0.225])])

    image_ = pred_transform(image_)[:3, :, :].unsqueeze(0)
    image_ = image_.cuda()

    model_transfer.eval()
    idx_ = torch.argmax(model_transfer(image_))
    return class_names[idx_]
```

In [21]:

```
print(predict_breed_transfer('./images/Brittany_02625.jpg'))
print(predict_breed_transfer('./images/Labrador_retriever_06455.jpg'))
print(predict_breed_transfer('./images/American_water_spaniel_00648.jpg'))
```

Brittany
Labrador retriever
Curly-coated retriever

Step 5: Write your Algorithm

Write an algorithm that accepts a file path to an image and first determines whether the image contains a human, dog, or neither. Then,

- if a **dog** is detected in the image, return the predicted breed.
- if a **human** is detected in the image, return the resembling dog breed.
- if **neither** is detected in the image, provide output that indicates an error.

You are welcome to write your own functions for detecting humans and dogs in images, but feel free to use the `face_detector` and `human_detector` functions developed above. You are **required** to use your CNN from Step 4 to predict dog breed.

Some sample output for our algorithm is provided below, but feel free to design your own user experience!



(IMPLEMENTATION) Write your Algorithm

In [22]:

```
def run_app(img_path):
    img = Image.open(img_path)
    plt.imshow(img)
```

```
plt.show()

if(face_detector(img_path)):
    print("hello , human!")
    similarity = predict_breed_transfer(img_path)
    print("\nYou look like a... \n", similarity)

elif(dog_detector(img_path)):
    breed_ = predict_breed_transfer(img_path)
    print("Detected a Dog of the breed : ", breed_)

else:
    print("Error : Neither human nor dog is detected")
```

Step 6: Test Your Algorithm

In this section, you will take your new algorithm for a spin! What kind of dog does the algorithm think that *you* look like? If you have a dog, does it predict your dog's breed accurately? If you have a cat, does it mistakenly think that your cat is a dog?

(IMPLEMENTATION) Test Your Algorithm on Sample Images!

Test your algorithm at least six images on your computer. Feel free to use any images you like. Use at least two human and two dog images.

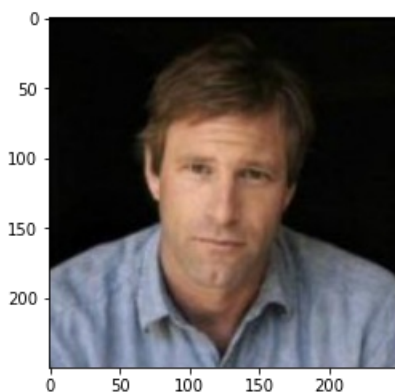
Question 6: Is the output better than you expected :) ? Or worse :(? Provide at least three possible points of improvement for your algorithm.

Answer:

- The output is similar to what I have expected.
- According to me Deep learning is all about choosing right hyperparameters so I think by trying different Hyperparameters we can improve the results.
- We can implement Learning rate scheduler type function in our model which will have an adaptive learning rate. This may improve the results.
- Data augmentations can improve the results.

In [23]:

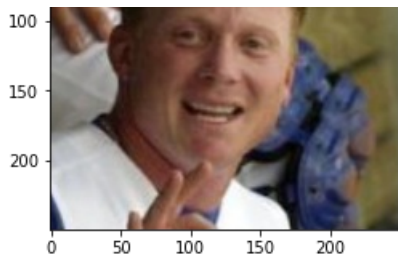
```
for file in np.hstack((human_files[:4], dog_files[:4])):
    run_app(file)
```



hello , human!

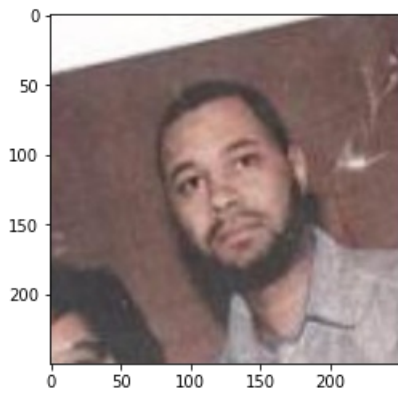
You look like a...
Chinese crested



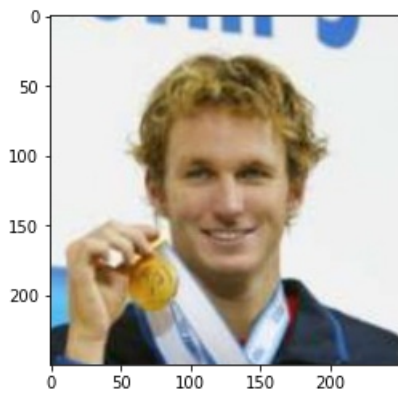


hello , human!

You look like a...
Cavalier king charles spaniel

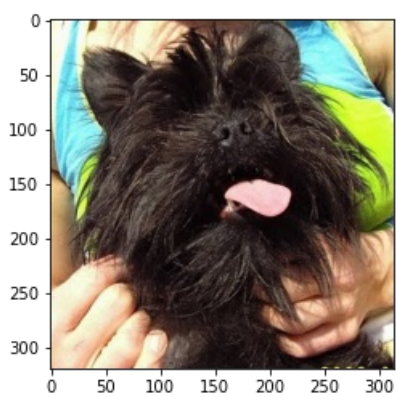


Error : Neither human nor dog is detected

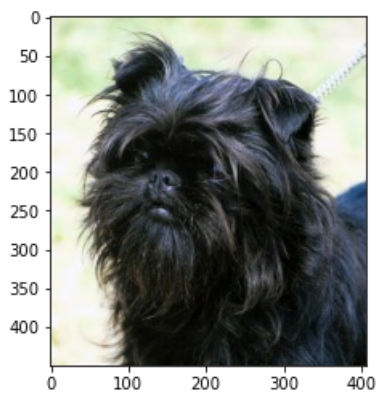


hello , human!

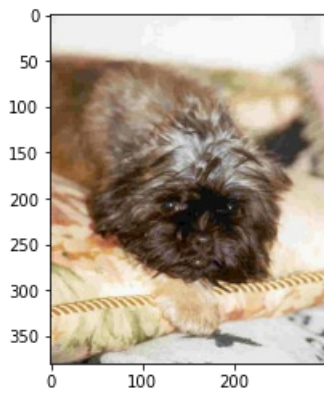
You look like a...
Dachshund



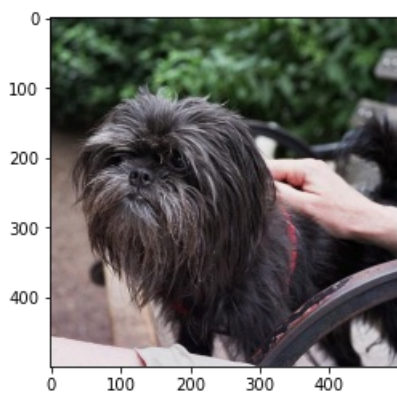
Error : Neither human nor dog is detected



Error : Neither human nor dog is detected



Detected a Dog of the breed : Affenpinscher



Detected a Dog of the breed : Affenpinscher