dog_app

December 23, 2020

1 Convolutional Neural Networks

1.1 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.
## Step 0: Import Datasets
Make sure that you've downloaded the required human and dog datasets:
Note: if you are using the Udacity workspace, you *DO NOT* need to re-download these - they can be found in the `/data` folder as noted in the cell below.

- 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 7zip 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]: import numpy as np
        from glob import glob

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

        # 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

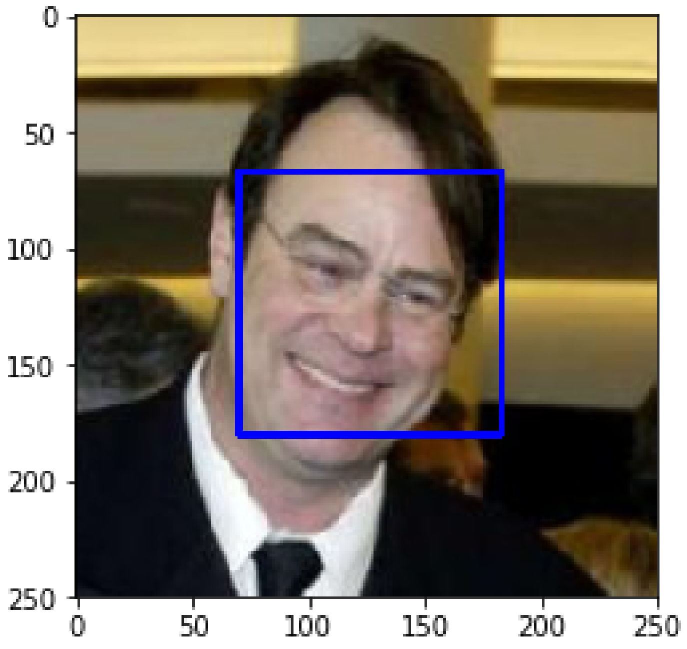
In this section, we use OpenCV's implementation of Haar feature-based cascade classifiers to detect human faces in images.

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.

1.1.1 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):
            img = cv2.imread(img_path)
            gray = cv2.cvtColor(img, cv2.COLOR_BGR2GRAY)
            faces = face_cascade.detectMultiScale(gray)
            return len(faces) > 0
```

1.1.2 (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: There are 98 out of 100 faces (98%) detected in the human images. There are 17 out 100 faces (17%) detected in the dog images.

```
In [4]: from tqdm import tqdm

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

        #-#-# Do NOT modify the code above this line. #-#-#

        ## TODO: Test the performance of the face_detector algorithm
        ## on the images in human_files_short and dog_files_short.
        cnt = 0
        for p in human_files_short:
            if face_detector(p):
                cnt += 1
        print(f'Number of human faces detected {cnt} out of {len(human_files_short)} entries')
        print(f'percentage of human faces detected {cnt*100/len(human_files_short)}')

        cnt = 0
        for p in dog_files_short:
            if face_detector(p):
                cnt += 1
        print(f'Number of human faces detected in dog images {cnt} out of {len(human_files_short
        print(f'percentage of human faces detected in dog images {cnt*100/len(human_files_short)
```

```
Number of human faces detected 98 out of 100 entries
percentage of human faces detected 98.0
```

```
Number of human faces detected in dog images 17 out of 100 entries
percentage of human faces detected in dog images 17.0
```

We suggest the face detector from OpenCV as a potential way to detect human images in your algorithm, but you are free to explore other approaches, especially approaches that make use of deep learning :). Please use the code cell below to design and test your own face detection algorithm. If you decide to pursue this *optional* task, report performance on `human_files_short` and `dog_files_short`.

```
In [ ]: ### (Optional)
        ### TODO: Test performance of anotherface detection algorithm.
        ### Feel free to use as many code cells as needed.
```

## Step 2: Detect Dogs
In this section, we use a pre-trained model to detect dogs in images.

1.1.3 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()
```

```
Downloading: "https://download.pytorch.org/models/vgg16-397923af.pth" to /root/.torch/models/vgg
100%|| 553433881/553433881 [02:07<00:00, 4352112.35it/s]
```

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.

1.1.4 (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, ImageFile
        import torchvision.transforms as transforms
        # Add this to avoid error on truncated images
        # https://stackoverflow.com/questions/12984426/python-pil-ioerror-image-file-truncated-u
        ImageFile.LOAD_TRUNCATED_IMAGES = True

        def VGG16_predict(img_path):
            '''
            Use pre-trained VGG-16 model to obtain index corresponding to
            predicted ImageNet class for image at specified path

            Args:
                img_path: path to an image

            Returns:
                Index corresponding to VGG-16 model's prediction
            '''

            #
            # load image and convert to RGB. Per the PyTorch documentation, should be RGB
            # and width and height should be at least 224 pixels. Also according to docs
            # should be normalized.
            # https://pytorch.org/docs/stable/torchvision/models.html
            #
            img = Image.open(img_path).convert('RGB')
            normalize = transforms.Normalize(mean=[0.485, 0.456, 0.406],std=[0.229, 0.224, 0.225
            transform = transforms.Compose([transforms.Resize(size=(224)),
                                            transforms.CenterCrop([224,224]),
                                            transforms.ToTensor(),
                                            normalize])
            img_transformed = transform(img)[:3,:,:].unsqueeze(0)

            if use_cuda:
                img_transformed = img_transformed.cuda()

            #
            # Use the VGG16 model to detect the dog, and then
            # find the index of that image
            #
```

```
    output = VGG16(img_transformed)
    idx = torch.max(output,1)[1].item()

    return idx
```

1.1.5 (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):
            breed = VGG16_predict(img_path)

            #
            # Dog breeds are with the range of 15-268 inclusive,
            # so only True if within that range
            #
            return breed >= 151 and breed <= 268
```

1.1.6 (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: * Out of 100 human images, there was 1 dog detected, so 1% * Out of 100 dog images, there were 100 dogs detected, so 100%

```
In [8]: dogs_detected = 0
        human_detected = 0

        for img in human_files_short:
            if dog_detector(img):
                human_detected += 1

        for img in dog_files_short:
            if dog_detector(img):
                dogs_detected += 1

        print(f'Number of dogs detected in human images {human_detected} out of {len(human_files
        print(f'Number of dogs detected in dog images {dogs_detected} out of {len(dog_files_shor
```

```
Number of dogs detected in human images 2 out of 100 total
Number of dogs detected in dog images 100 out of 100 total
```

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`.

```
In [ ]: ### (Optional)
        ### TODO: Report the performance of another pre-trained network.
        ### Feel free to use as many code cells as needed.
```

## 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.

Brittany	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).

Curly-Coated Retriever	American Water Spaniel

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.

Yellow Labrador	Chocolate Labrador

We also mention that random chance presents an exceptionally low bar: setting aside the fact that the classes are slightly imabalanced, 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!

1.1.7 (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

        #
        # Set all variables
        #
        dog_images_dir = '/data/dog_images/'
        img_dir = {}
        img_dir['train'] = os.path.join(dog_images_dir, 'train')
        img_dir['test'] = os.path.join(dog_images_dir, 'test')
        img_dir['valid'] = os.path.join(dog_images_dir, 'valid')
        batch_size = 20
        num_workers = 0

        #
        # For each image set, crop to 224, center crop and do a random horizontal flip
        #
        dset = {}
        loaders_scratch = {}
        normalize = transforms.Normalize(mean=[0.485, 0.456, 0.406],std=[0.229, 0.224, 0.225])
        for D in ['train', 'test', 'valid']:
            if D == 'train':
                shuffle = True
                arglist = [transforms.RandomResizedCrop(224), transforms.CenterCrop((224,224)),
                    transforms.RandomHorizontalFlip(), transforms.ToTensor(), normalize]
            else:
                shuffle = False
                arglist = [transforms.Resize(size=(224,224)), transforms.ToTensor(), normalize]

            compose = transforms.Compose(arglist)
            dset[D] = datasets.ImageFolder(img_dir[D], compose)
            loaders_scratch[D] = torch.utils.data.DataLoader(dset[D], batch_size = batch_size, n
```

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: * VGG16 takes in 224 square so I crop the images to 224, and also do a center crop. So the tensor size will be (3,224,244) where the 3 is the RGB and 224 is the height and width * I did a horizontal flip in the training and normalization to give better input images to work with, to avoid overfitting and helps with generaliztion.

1.1.8 (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):
             ### TODO: choose an architecture, and complete the class

             ## See lesson 1.34 in the CNN lesson for how arch is constructed

             def __init__(self):
                 super(Net, self).__init__()
                 ## Define layers of a CNN

                 # define convolutional layers
                 # nn.Conv2d(in_channels, out_channels, kernel_size, stride=1, padding=0)
                 self.conv1 = nn.Conv2d(3, 32, 3, stride=1, padding=1)
                 self.conv2 = nn.Conv2d(32, 64, 3, stride=1, padding=1)
                 self.conv3 = nn.Conv2d(64, 128, 3, stride=1, padding=1)

                 # Define the MaxPool layer
                 # MaxPool(kernel_size, stride)
                 self.pool = nn.MaxPool2d(2,2)

                 # define the fully connected layers
                 self.fc1 = nn.Linear(128 * 28 * 28, 512)
                 self.fc2 = nn.Linear(512, 133)

                 # define dropout
                 self.dropout = nn.Dropout(0.25)

             def forward(self, x):
                 ## Define forward behavior
                 # conv1 -> relu -> MaxPool -> conv2 -> relu -> MaxPool -> conv3 -> relu -> MaxP
                 x = self.pool(F.relu(self.conv1(x)))
                 x = self.pool(F.relu(self.conv2(x)))
                 x = self.pool(F.relu(self.conv3(x)))

                 # flatten - WxHxChannels
                 x = x.view(-1, 28*28*128)

                 # add 1st hidden layer, with relu activation function
```

```
            x = F.relu(self.fc1(x))
            x = self.dropout(x)
            # add 2nd hidden layer
            x = self.fc2(x)
            return x

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

    # instantiate the CNN
    model_scratch = Net()

    # move tensors to GPU if CUDA is available
    if use_cuda:
        model_scratch.cuda()
```

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

Answer: I am using 3 convolutional layers, with a MaxPool and relu between each conv layer. I am using stride of 1, and padding of 1. The first convolutional layer takes in 3 channels, and goes to 32. The end number that we get is 128 channels after the third convolutional layer. Since the MaxPools half the size of the image at each iteration, we end up with an image the size of 28. When we are done with the convolutional, relu and MaxPool layers, we flatten it. Then we feed that into the 2 fully connected layers, each with a relu as well. In the end, we add a dropout of 0.25 to avoid overfitting.

1.1.9 (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=0.02)
```

1.1.10 (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 [22]: 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 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 enumerate(loaders['train']):
    # move to GPU
    if use_cuda:
        data, target = data.cuda(), target.cuda()
    ## find the loss and update the model parameters accordingly
    ## record the average training loss, using something like
    ## train_loss = train_loss + ((1 / (batch_idx + 1)) * (loss.data - train_lo

    # clear the gradients of all optimized variables
    optimizer.zero_grad()
    # forward pass: compute predicted outputs by passing inputs to the model
    output = model(data)
    # calculate the batch loss
    loss = criterion(output, target)
    # backward pass: compute gradient of the loss with respect to model paramet
    loss.backward()
    # perform a single optimization step (parameter update)
    optimizer.step()
    # update training loss
    train_loss = train_loss + ((1 / (batch_idx + 1)) * (loss.data - train_loss)

######################
# validate the model #
######################
model.eval()
for batch_idx, (data, target) in enumerate(loaders['valid']):
    # move to GPU
    if use_cuda:
        data, target = data.cuda(), target.cuda()
    ## update the average validation loss

    # forward pass: compute predicted outputs by passing inputs to the model
    output = model(data)
    # calculate the batch loss
    loss = criterion(output, target)
    # update average validation loss
    valid_loss = valid_loss + ((1 / (batch_idx + 1)) * (loss.data - valid_loss)


# 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 model if validation loss has decreased
                if valid_loss <= valid_loss_min:
                    print('Validation loss decreased ({:.6f} --> {:.6f}).  Saving model ...'.fo
                    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(10, loaders_scratch, model_scratch, optimizer_scratch, criterion_

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

```
Epoch: 1 	Training Loss: 4.226553 	Validation Loss: 4.157310
Validation loss decreased (inf --> 4.157310).  Saving model ...
Epoch: 2 	Training Loss: 4.200882 	Validation Loss: 4.171130
Epoch: 3 	Training Loss: 4.167844 	Validation Loss: 4.095766
Validation loss decreased (4.157310 --> 4.095766).  Saving model ...
Epoch: 4 	Training Loss: 4.127714 	Validation Loss: 4.052520
Validation loss decreased (4.095766 --> 4.052520).  Saving model ...
Epoch: 5 	Training Loss: 4.079391 	Validation Loss: 4.014988
Validation loss decreased (4.052520 --> 4.014988).  Saving model ...
Epoch: 6 	Training Loss: 4.021532 	Validation Loss: 4.061293
Epoch: 7 	Training Loss: 3.981056 	Validation Loss: 3.982687
Validation loss decreased (4.014988 --> 3.982687).  Saving model ...
Epoch: 8 	Training Loss: 3.911129 	Validation Loss: 4.001010
Epoch: 9 	Training Loss: 3.888556 	Validation Loss: 3.981170
Validation loss decreased (3.982687 --> 3.981170).  Saving model ...
Epoch: 10 	Training Loss: 3.849724 	Validation Loss: 3.923756
Validation loss decreased (3.981170 --> 3.923756).  Saving model ...
```

1.1.11 (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 [23]: def test(loaders, model, criterion, use_cuda):

             # monitor test loss and accuracy
             test_loss = 0.
             correct = 0.
             total = 0.

             model.eval()
             for batch_idx, (data, target) in enumerate(loaders['test']):
                 # 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(loaders_scratch, model_scratch, criterion_scratch, use_cuda)
```

```
Test Loss: 3.841492


Test Accuracy: 12% (104/836)
```

## 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.

1.1.12 (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.

```
In [24]: ## TODO: Specify data loaders
         loaders_transfer = loaders_scratch.copy()
```

1.1.13 (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 [25]: import torchvision.models as models
         import torch.nn as nn

         ## TODO: Specify model architecture
         # will use resnet-101 pre-train model
         model_transfer = models.resnet50(pretrained=True)

         # we don't want back propagation of the parameters, so set each parameter to False
         for param in model_transfer.parameters():
             param.requires_grad = False

         # We want to make sure the last fully connected layer corresponds to the number of dog
         model_transfer.fc = nn.Linear(2048, 133, bias=True)

         if use_cuda:
             model_transfer = model_transfer.cuda()
```

```
Downloading: "https://download.pytorch.org/models/resnet50-19c8e357.pth" to /root/.torch/models/
100%|| 102502400/102502400 [00:09<00:00, 11371964.19it/s]
```

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: Using a pre-trained model makes sense, since training can take time, and if someone has already optimized the training, then it is better to use something already fully tested. I used the resnet 101, which has 101 layers deep, which seemed very thorough.

I had to convert the features from the resnet101 to our case, which is 133, corresponding to the differenct dog breeds.

1.1.14 (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 [26]: criterion_transfer = nn.CrossEntropyLoss()
         optimizer_transfer = optim.SGD(model_transfer.fc.parameters(), lr=0.02)
```

1.1.15 (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 [29]: # train the model
         model_transfer = train(5, loaders_transfer, model_transfer, optimizer_transfer, criteri
         # load the model that got the best validation accuracy (uncomment the line below)
         model_transfer.load_state_dict(torch.load('model_transfer.pt'))
```

```
Epoch: 1         Training Loss: 0.875529        Validation Loss: 0.514783
Validation loss decreased (inf --> 0.514783).  Saving model ...
Epoch: 2         Training Loss: 0.860108        Validation Loss: 0.515059
Epoch: 3         Training Loss: 0.849715        Validation Loss: 0.516171
Epoch: 4         Training Loss: 0.825264        Validation Loss: 0.489031
Validation loss decreased (0.514783 --> 0.489031).  Saving model ...
Epoch: 5         Training Loss: 0.807393        Validation Loss: 0.508982
```

1.1.16 (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 60%.

```
In [30]: test(loaders_transfer, model_transfer, criterion_transfer, use_cuda)
```

```
Test Loss: 0.479565


Test Accuracy: 85% (715/836)
```

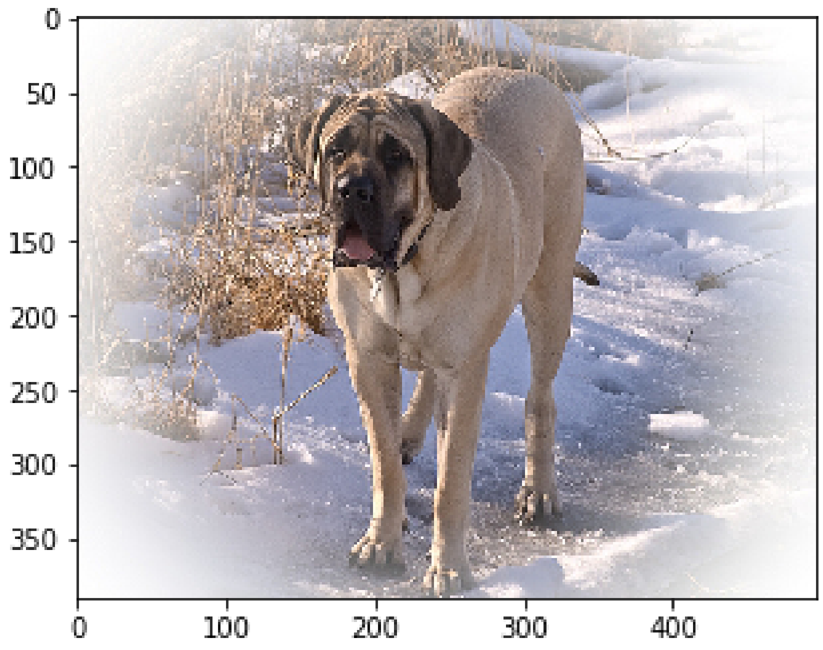
1.1.17 (IMPLEMENTATION) Predict Dog Breed with the Model

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.

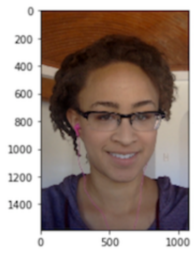
```
In [49]: ### TODO: Write a function that takes a path to an image as input
         ### and returns the dog breed that is predicted by the model.

         # list of class names by index, i.e. a name can be accessed like class_names[0]
         class_names = [item[4:].replace("_", " ") for item in loaders_transfer['train'].dataset

         def predict_breed_transfer(img_path):
             # load the image and return the predicted breed

             img = Image.open(img_path).convert('RGB')
             normalize = transforms.Normalize(mean=[0.485, 0.456, 0.406],std=[0.229, 0.224, 0.22
             transform = transforms.Compose([transforms.Resize(size=(224)),
                                                    transforms.CenterCrop([224,224]),
                                                    transforms.ToTensor(),
                                                    normalize])
            img_transformed = transform(img)[:3,:,:].unsqueeze(0)

            if use_cuda:
                img_transformed = img_transformed.cuda()

            #
            # Use the VGG16 model to detect the dog, and then
            # find the index of that image
            #
            output = model_transfer(img_transformed)
            idx = torch.max(output,1)[1].item()
            return class_names[idx]
```

```
In [50]: # test it out
         ex1 = predict_breed_transfer(dog_files_short[50])
         dog_img1 = Image.open(dog_files_short[50])
         plt.imshow(dog_img1)
         print(f'predicted dog breed is {ex1}')
```

```
predicted dog breed is Mastiff
```



```
hello, human!
```



```
You look like a ...
Chinese_shar-pei
```

Sample Human Output

## 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!

1.1.18 (IMPLEMENTATION) Write your Algorithm

```
In [53]: ### TODO: Write your algorithm.
         ### Feel free to use as many code cells as needed.
         def show_image(img_path):
             img = Image.open(img_path)
             plt.imshow(img)
             plt.show()

         def run_app(img_path):
             ## handle cases for a human face, dog, and neither
             if dog_detector(img_path):
                 print('There is a dog in the image')
                 breed = predict_breed_transfer(img_path)
                 print("The predicted breed is a: ", breed)
                 show_image(img_path)
             elif face_detector(img_path):
                 print('There is a human in the image')
                 breed = predict_breed_transfer(img_path)
                 print("The predicted breed of the human is a: ", breed)
                 show_image(img_path)
             else:
                 print('Could not find a dog or human in the image')
                 show_image(img_path)
```

## 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?

1.1.19 (IMPLEMENTATION) Test Your Algorithm on Sample Images!

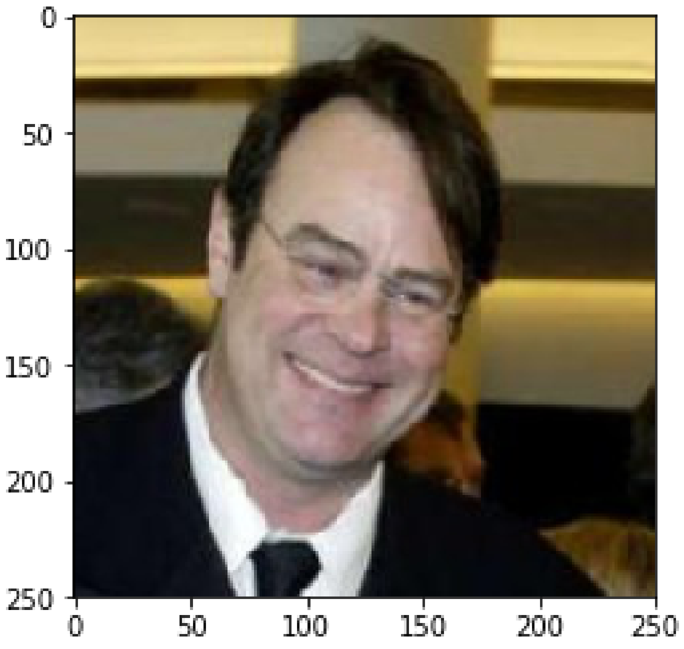
Test your algorithm at least six images on your computer. Feel free to use any images you like. Use at least two human and two dog images.

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

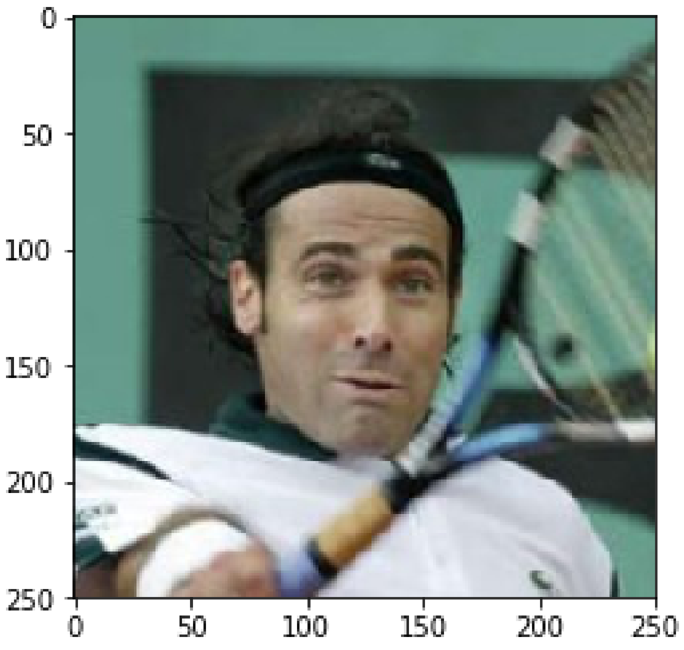
Answer: (Three possible points for improvement) It's actually better than I expected, especially given that the model from scratch was so poor. I am surprised how much improvement that transfer learning had on the accuracy. 1. Adding more training data will help. Especially if the data becomes more balanced between the breeds. 2. Do some more data augmentation, to get the data in a better input state. For example, could possibly try doing a random flip of the images, in addition to the other data augmentation. 3. Could add more epochs to the training runs, so refine the accuracy and log loss. 4. Could experiment with other pre-trained models as well. I chose resnet 101, but could try others to see how they perform.

```
In [54]: ## TODO: Execute your algorithm from Step 6 on
         ## at least 6 images on your computer.
         ## Feel free to use as many code cells as needed.

         ## suggested code, below
         for file in np.hstack((human_files[:3], dog_files[:3])):
             run_app(file)
```

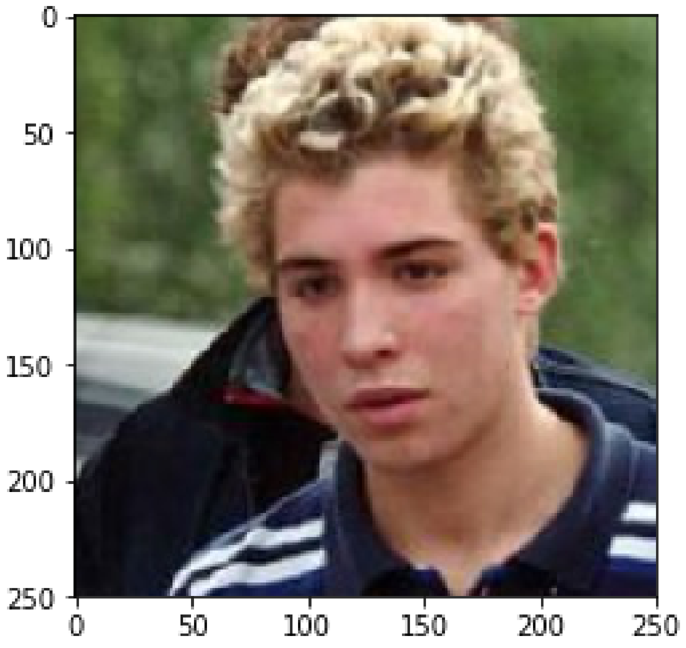
```
There is a human in the image
The predicted breed of the human is a:  Beagle
```



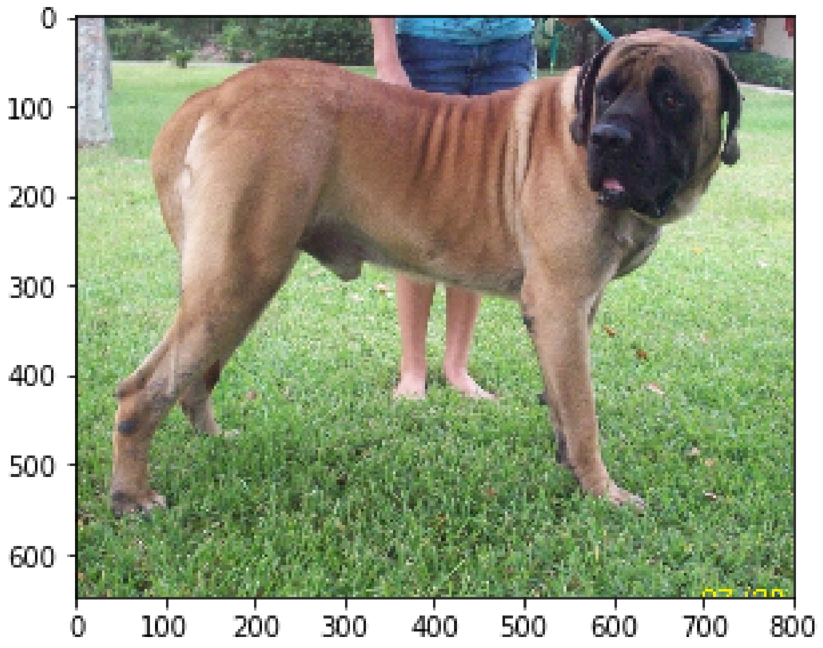
```
There is a human in the image
The predicted breed of the human is a:  Brittany
```



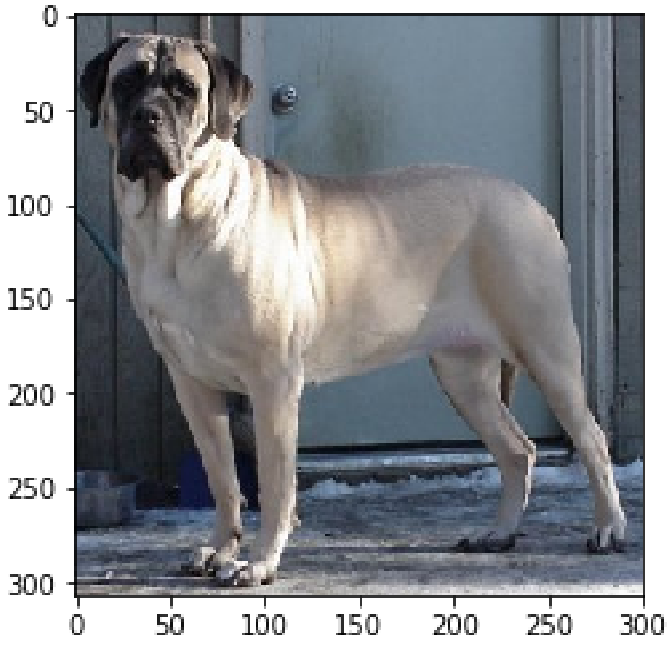
```
There is a human in the image
The predicted breed of the human is a:  Black russian terrier
```



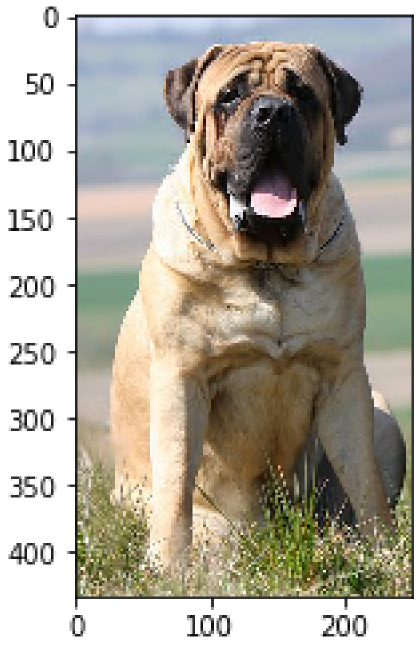
```
There is a dog in the image
The predicted breed is a:  Mastiff
```



```
There is a dog in the image
The predicted breed is a:  Mastiff
```



```
There is a dog in the image
The predicted breed is a:  Bullmastiff
```



```
In [ ]:
```