# Deep Learning Nanodegree - CNN project

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> The following header was left as is. It was created by the main author of this course.

# Artificial Intelligence Nanodegree

## Convolutional Neural Networks

## Project: Write an Algorithm for a Dog Identification App

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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 iPython 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 \n", "**File -> Download as -> HTML (.html)**. Include the finished document along with this notebook as your submission.

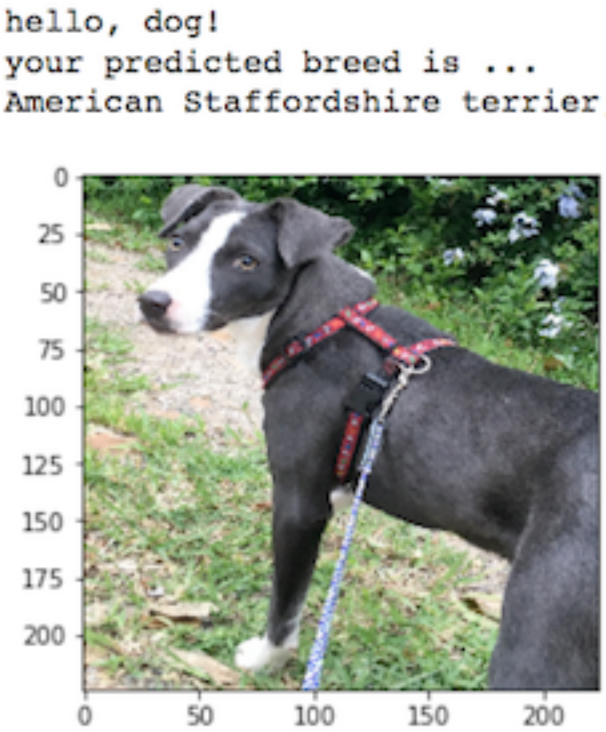
In addition to implementing code, there will be questions that you must answer which relate to the project and your implementation. Each section where you will answer a question is preceded by a **'Question X'** header. Carefully read each question and provide thorough answers in the following text boxes 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 IPython 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!).



```
hello, dog!
your predicted breed is ...
American Staffordshire terrier
```

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: Use a CNN to Classify Dog Breeds (using Transfer Learning)
- Step 5: Create a CNN to Classify Dog Breeds (using Transfer Learning)
- Step 6: Write your Algorithm
- Step 7: Test Your Algorithm

# Step 0: Import Datasets

## Import Dog Dataset

In the code cell below, we import a dataset of dog images. We populate a few variables through the use of the `load_files` function from the scikit-learn library:

- `train_files`, `valid_files`, `test_files` - numpy arrays containing file paths to images
- `train_targets`, `valid_targets`, `test_targets` - numpy arrays containing onehot-encoded classification labels
- `dog_names` - list of string-valued dog breed names for translating labels

In [2]:

```
from sklearn.datasets import load_files
from keras.utils import np_utils
import numpy as np
from glob import glob

# define function to load train, test, and validation datasets
def load_dataset(path):
    data = load_files(path)
    dog_files = np.array(data['filenames'])
    dog_targets = np_utils.to_categorical(np.array(data['target']), 133)
    return dog_files, dog_targets

# load train, test, and validation datasets
train_files, train_targets = load_dataset('dogImages/train')
valid_files, valid_targets = load_dataset('dogImages/valid')
test_files, test_targets = load_dataset('dogImages/test')

# load list of dog names
dog_names = [item[20:-1] for item in sorted(glob("dogImages/train/*/"))]

# print statistics about the dataset
print('There are %d total dog categories.' % len(dog_names))
print('There are %s total dog images.\n' % len(np.hstack([train_files, valid_f
print('There are %d training dog images.' % len(train_files))
print('There are %d validation dog images.' % len(valid_files))
print('There are %d test dog images.'% len(test_files))


```

```
Using TensorFlow backend.

There are 133 total dog categories.
There are 8351 total dog images.

There are 6680 training dog images.
There are 835 validation dog images.
There are 836 test dog images.
```

## Import Human Dataset

In the code cell below, we import a dataset of human images, where the file paths are stored in the numpy array `human_files`.

In [3]:

```python
import random
random.seed(8675309)

# load filenames in shuffled human dataset
human_files = np.array(glob("lfw/*/*"))
random.shuffle(human_files)

# print statistics about the dataset
print('There are %d total human images.' % len(human_files))
```

```
There are 13233 total human images.
```

---

# Step 1: Detect Humans

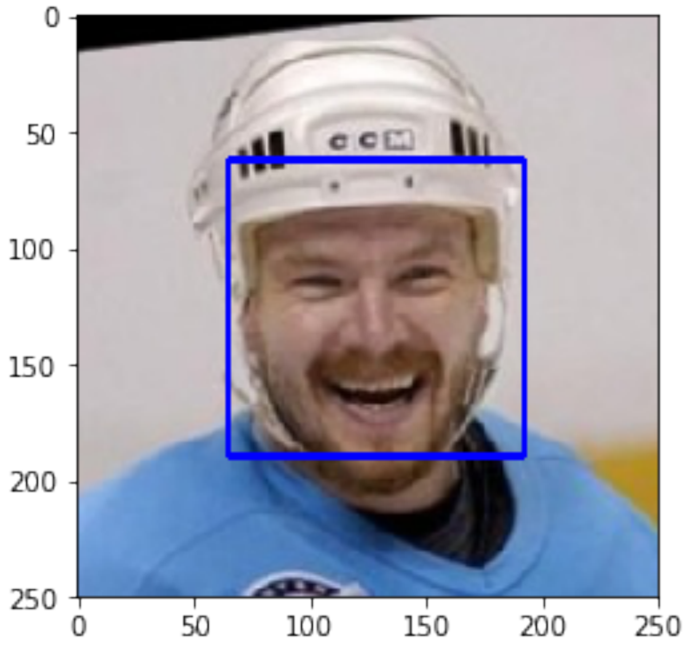
We use OpenCV's implementation of Haar feature-based cascade classifiers (http://docs.opencv.org/trunk/d7/d8b/tutorial_py_face_detection.html) to detect human faces in images. OpenCV provides many pre-trained face detectors, stored as XML files on github (https://github.com/opencv/opencv/tree/master/data/haarcascades). 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 [4]:

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

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

# load color (BGR) image
img = cv2.imread(human_files[6])
# 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 [5]:

```python
# 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
```

## (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:**

In [6]:

```python
human_files_short = human_files[:100]
dog_files_short = train_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.

human_counter = 0
dog_counter = 0
for i in range(100):
    if face_detector(human_files_short[i]):
        human_counter+=1
    if face_detector(dog_files_short[i]):
        dog_counter+=1

print('Performance of face detector is:\n')
print((human_counter/100) * 100, " % for human faces")
print((dog_counter/100) * 100, " % for dog faces as human!!")
```

```
Performance of face detector is:

100.0  % for human faces
12.0  % for dog faces as human!!
```

**Question 2:** This algorithmic choice necessitates that we communicate to the user that we accept human images only when they provide a clear view of a face (otherwise, we risk having unneccessarily frustrated users!). In your opinion, is this a reasonable expectation to pose on the user? If not, can you think of a way to detect humans in images that does not necessitate an image with a clearly presented face?

**Answer:**

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 each of the datasets.

**My answer:**

I believe that the solution developer must do his best to relieve the user. However, developer sometimes throw the burden on the shoulders of the user for one of the following reasons:

- lasiness of the developer
- time constraints on the developer
- shortness of the hardware to cope up with the developer algorithm
- and sometimes it is misunderstanding of the developer to what is the user requirement

Now, what other idea to make it easier for the user? I think utilizing the latest neural networks for face recognition is a the best we can do. So i tried face recognition library from:

https://github.com/ageitgey/face_recognition (https://github.com/ageitgey/face_recognition)

as the author says:

> Built using dlib's state-of-the-art face recognition built with deep learning. The model has an accuracy of 99.38% on the Labeled Faces in the Wild benchmark.

In [7]:

```
## (Optional) TODO: Report the performance of another
## face detection algorithm on the LFW dataset
### Feel free to use as many code cells as needed.



# The following library is taken form:
# https://github.com/ageitgey/face_recognition
# This might not work well because it needs special installation on the runnin
# it required that Cmake is already installed


import face_recognition



human_counter = 0
dog_counter = 0
for i in range(100):
    image = face_recognition.load_image_file(human_files_short[i])
    face_locations = face_recognition.face_locations(image)
    if face_locations:
        human_counter+=1
    image = face_recognition.load_image_file(dog_files_short[i])
    face_locations = face_recognition.face_locations(image)
    if face_locations:
        dog_counter+=1

print('Performance of (ageitgey/face_recognition) is:\n')
print((human_counter/100) * 100, " % for human faces")
print((dog_counter/100) * 100, " % for dog faces as human!!")
```

```
Performance of (ageitgey/face_recognition) is:

100.0  % for human faces
10.0  % for dog faces as human!!
```

So this seems better than the first face detector since it detected less dogs as human. i.e 10% vs 10%

### The following cell contains my methods for face detection and drawing

They will be used later in the algorithm (step 6)

In [8]:

```python
import matplotlib.patches as patches

# Ref:
# https://github.com/ageitgey/face_recognition
# This might not work well because it needs special installation on the runnin
# it required that Cmake is already installed

# Also how to draw a rectangle on matplotlib:
# https://stackoverflow.com/questions/37435369/matplotlib-how-to-draw-a-rectan


def detect_human_face(image_path):
    img = face_recognition.load_image_file(image_path)

    face_locations = face_recognition.face_locations(img)
    if face_locations:
        return True, face_locations
    return False, face_locations


def draw_image(image_path):
    img = face_recognition.load_image_file(image_path)
    # Create figure and axes
    fig,ax = plt.subplots(1)
    # Display the image
    ax.imshow(img)

    face_locations = face_recognition.face_locations(img)
    if face_locations:
        for i in face_locations:
            top,right,buttom,left = i
            # Create a Rectangle patch
            rect = patches.Rectangle((left,top),(right-left),(buttom-top),line
            ax.add_patch(rect)
        plt.show()




```

In [10]:

```
draw_image(human_files_short[5])
```

---

## Step 2: Detect Dogs

In this section, we use a pre-trained [ResNet-50 (http://ethereon.github.io/netscope/#/gist/db945b393d40bfa26006)](http://ethereon.github.io/netscope/#/gist/db945b393d40bfa26006) model to detect dogs in images. Our first line of code downloads the ResNet-50 model, along with weights that have been trained on [ImageNet (http://www.image-net.org/)](http://www.image-net.org/), 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 (https://gist.github.com/yrevar/942d3a0ac09ec9e5eb3a)](https://gist.github.com/yrevar/942d3a0ac09ec9e5eb3a). Given an image, this pre-trained ResNet-50 model returns a prediction (derived from the available categories in ImageNet) for the object that is contained in the image.

In [11]:

```
from keras.applications.resnet50 import ResNet50

# define ResNet50 model
ResNet50_model = ResNet50(weights='imagenet')
```

## Pre-process the Data

When using TensorFlow as backend, Keras CNNs require a 4D array (which we'll also refer to as a 4D tensor) as input, with shape

$$(\text{nb\_samples}, \text{rows}, \text{columns}, \text{channels}),$$

where `nb_samples` corresponds to the total number of images (or samples), and `rows`, `columns`, and `channels` correspond to the number of rows, columns, and channels for each image, respectively.

The `path_to_tensor` function below takes a string-valued file path to a color image as input and returns a 4D tensor suitable for supplying to a Keras CNN. The function first loads the image and resizes it to a square image that is $224 \times 224$ pixels. Next, the image is converted to an array, which is then resized to a 4D tensor. In this case, since we are working with color images, each image has three channels. Likewise, since we are processing a single image (or sample), the returned tensor will always have shape

$$(1, 224, 224, 3).$$

The `paths_to_tensor` function takes a numpy array of string-valued image paths as input and returns a 4D tensor with shape

$$(\text{nb\_samples}, 224, 224, 3).$$

Here, `nb_samples` is the number of samples, or number of images, in the supplied array of image paths. It is best to think of `nb_samples` as the number of 3D tensors (where each 3D tensor corresponds to a different image) in your dataset!

In [12]:

```python
from keras.preprocessing import image
from tqdm import tqdm

def path_to_tensor(img_path):
    # loads RGB image as PIL.Image.Image type
    img = image.load_img(img_path, target_size=(224, 224))
    # convert PIL.Image.Image type to 3D tensor with shape (224, 224, 3)
    x = image.img_to_array(img)
    # convert 3D tensor to 4D tensor with shape (1, 224, 224, 3) and return 4D
    return np.expand_dims(x, axis=0)

def paths_to_tensor(img_paths):
    list_of_tensors = [path_to_tensor(img_path) for img_path in tqdm(img_paths
    return np.vstack(list_of_tensors)
```

## Making Predictions with ResNet-50

Getting the 4D tensor ready for ResNet-50, and for any other pre-trained model in Keras, requires some additional processing. First, the RGB image is converted to BGR by reordering the channels. All pre-trained models have the additional normalization step that the mean pixel (expressed in RGB as $[103.939, 116.779, 123.68]$ and calculated from all pixels in all images in ImageNet) must be subtracted from every pixel in each image. This is implemented in the imported function `preprocess_input`. If you're curious, you can check the code for `preprocess_input` here (https://github.com/fchollet/keras/blob/master/keras/applications/imagenet_utils.py).

Now that we have a way to format our image for supplying to ResNet-50, we are now ready to use the model to extract the predictions. This is accomplished with the `predict` method, which returns an array whose $i$-th entry is the model's predicted probability that the image belongs to the $i$-th ImageNet category. This is implemented in the `ResNet50_predict_labels` function below.

By taking the argmax of the predicted probability vector, we obtain an integer corresponding to the model's predicted object class, which we can identify with an object category through the use of this dictionary (https://gist.github.com/yrevar/942d3a0ac09ec9e5eb3a).

In [13]:

```python
from keras.applications.resnet50 import preprocess_input, decode_predictions

def ResNet50_predict_labels(img_path):
    # returns prediction vector for image located at img_path
    img = preprocess_input(path_to_tensor(img_path))
    return np.argmax(ResNet50_model.predict(img))
```

## Write a Dog Detector

While looking at the dictionary (https://gist.github.com/yrevar/942d3a0ac09ec9e5eb3a), 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 ResNet-50 model, we need only check if the `ResNet50_predict_labels` function above returns a value between 151 and 268 (inclusive).

We 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 [14]:

```python
### returns "True" if a dog is detected in the image stored at img_path
def dog_detector(img_path):
    prediction = ResNet50_predict_labels(img_path)
    return ((prediction <= 268) & (prediction >= 151))
```

## (IMPLEMENTATION) Assess the Dog Detector

**Question 3:** 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:**

In [15]:

```
### TODO: Test the performance of the dog_detector function
### on the images in human_files_short and dog_files_short.

imgNumber = 100
human_counter = 0
dog_counter = 0
for i in range(imgNumber):
    if dog_detector(human_files_short[i]):
        human_counter+=1
    if dog_detector(dog_files_short[i]):
        dog_counter+=1

print('Performance of DOG detector is:\n')
print((human_counter/imgNumber) * 100, " % for human faces")
print((dog_counter/imgNumber) * 100, " % for dog faces")
```

```
Performance of DOG detector is:

0.0  % for human faces
100.0  % for dog faces
```

---

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

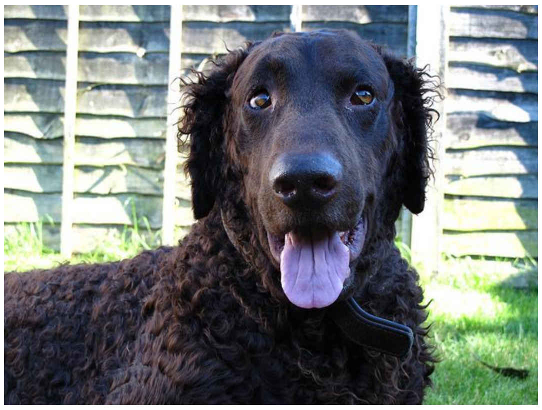
Now that we have functions for detecting humans and dogs in images, we need a way to predict breed from images. In this step, you will create a CNN that classifies dog breeds. You must create your CNN *from scratch* (so, you can't use transfer learning *yet*!), and you must attain a test accuracy of at least 1%. In Step 5 of this notebook, you will have the opportunity to use transfer learning to create a CNN that attains greatly improved accuracy.

Be careful with adding too many trainable layers! More parameters means longer training, which means you are more likely to need a GPU to accelerate the training process. Thankfully, Keras provides a handy estimate of the time that each epoch is likely to take; you can extrapolate this estimate to figure out how long it will take for your algorithm to train.

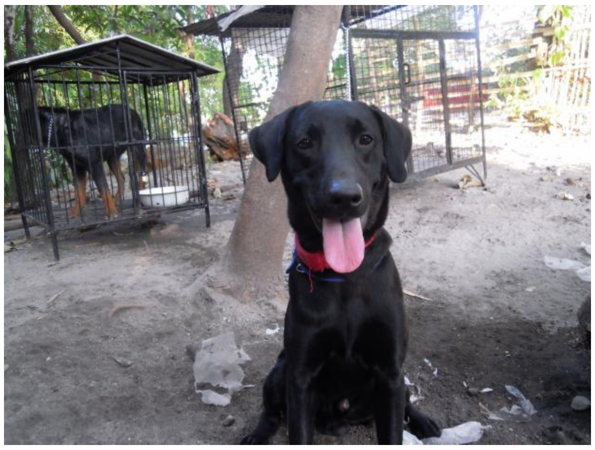
We mention that the task of assigning breed to dogs from images is considered exceptionally challenging. To see why, consider that *even a human* would have great difficulty in distinguishing between a Brittany and a Welsh Springer Spaniel.

| 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 | Black Labrador |
|---|---|---|
|  |  <br>1782991 [RF] © www.visualphotos.com |  |

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!

## Pre-process the Data

We rescale the images by dividing every pixel in every image by 255.

In [16]:

```python
from PIL import ImageFile
ImageFile.LOAD_TRUNCATED_IMAGES = True

# pre-process the data for Keras
train_tensors = paths_to_tensor(train_files).astype('float32')/255
valid_tensors = paths_to_tensor(valid_files).astype('float32')/255
test_tensors = paths_to_tensor(test_files).astype('float32')/255
```

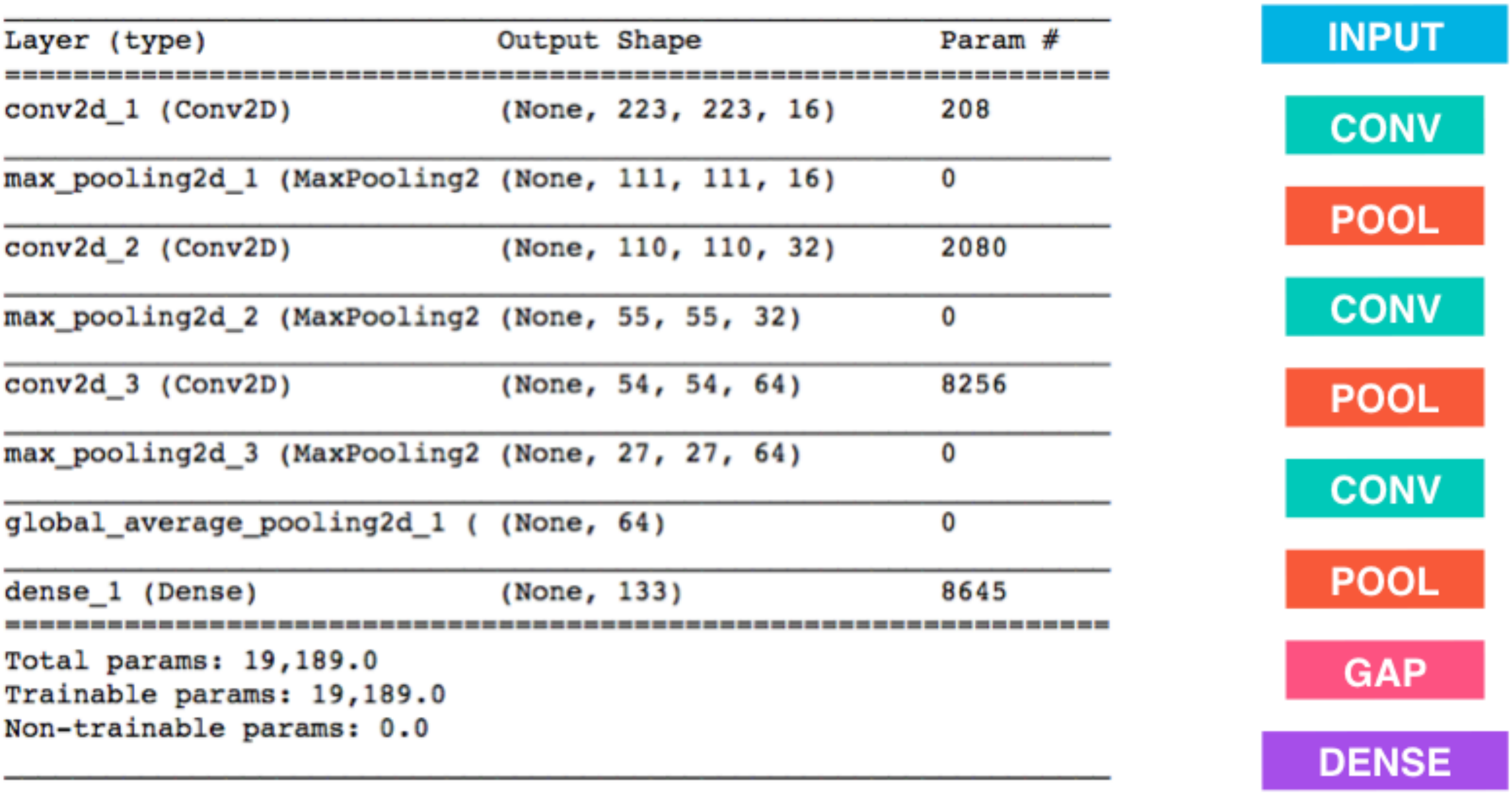
```
100%|██████████| 6680/6680 [02:16<00:00, 48.97it/s]
100%|██████████| 835/835 [00:14<00:00, 57.51it/s]
100%|██████████| 836/836 [00:14<00:00, 57.86it/s]
```

## (IMPLEMENTATION) Model Architecture

Create a CNN to classify dog breed. At the end of your code cell block, summarize the layers of your model by executing the line:

```
model.summary()
```

We have imported some Python modules to get you started, but feel free to import as many modules as you need. If you end up getting stuck, here's a hint that specifies a model that trains relatively fast on CPU and attains >1% test accuracy in 5 epochs:



```
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_1 (Conv2D)            (None, 223, 223, 16)      208
_________________________________________________________________
max_pooling2d_1 (MaxPooling2 (None, 111, 111, 16)      0
_________________________________________________________________
conv2d_2 (Conv2D)            (None, 110, 110, 32)      2080
_________________________________________________________________
max_pooling2d_2 (MaxPooling2 (None, 55, 55, 32)        0
_________________________________________________________________
conv2d_3 (Conv2D)            (None, 54, 54, 64)        8256
_________________________________________________________________
max_pooling2d_3 (MaxPooling2 (None, 27, 27, 64)        0
_________________________________________________________________
global_average_pooling2d_1 ( (None, 64)                0
_________________________________________________________________
dense_1 (Dense)              (None, 133)               8645
=================================================================
Total params: 19,189.0
Trainable params: 19,189.0
Non-trainable params: 0.0
_________________________________________________________________
```

**Question 4:** Outline the steps you took to get to your final CNN architecture and your reasoning at each step. If you chose to use the hinted architecture above, describe why you think that CNN architecture should work well for the image classification task.

**Answer:**

In [17]:

```python
# to have an idea of the data shape
train_tensors.shape
```

Out[17]:

```
(6680, 224, 224, 3)
```

In [18]:

```python
from keras.layers import Conv2D, MaxPooling2D, GlobalAveragePooling2D, Average
from keras.layers import Dropout, Flatten, Dense
from keras.models import Sequential

model = Sequential()

### TODO: Define your architecture.
model.add(Conv2D(8 , (3,3) , input_shape=(224,224,3), activation ='relu'))
model.add(MaxPooling2D(pool_size = (2,2)))
model.add(Conv2D( 16, (3,3) , activation ='relu'))
model.add(MaxPooling2D(pool_size = (2,2)))
model.add(Conv2D(32 , (3,3) , activation ='relu'))
model.add(MaxPooling2D(pool_size = (2,2)))
model.add(Conv2D(64 , (3,3) , activation ='relu'))
```

```
model.add(MaxPooling2D(pool_size = (2,2)))
model.add(Flatten())
model.add(Dense(400, activation='relu'))
model.add(Dense(133, activation='softmax'))

model.summary()



print('''
Answer : why I chose this architecture:
I used the model suggested in this document and also I referred to the
book 'Hands-on Machine Learning with Scikit-Learn & TensorFlow'
by Aurelien Geron. There he showed different architectures
including : LeNet-5 and AlexNet.

In all these models usually we will use alternating conv2D layer and MaxPoolin
to reduce dimensionalities and simplify calculations.


I also tried the AveragePooling layer without real improvement.

I also opted to leave the default Keras value for padding and stride.
Then I started to play with the kernel, I changed the filter size
from 5x5 to 2x2 to 3x3

Also the last layer activation I used softamx.

Afterall I was thwarted to experiment allot because of
the time taken to train in every epoch.

''')
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
conv2d_1 (Conv2D)            (None, 222, 222, 8)       224       
_________________________________________________________________
max_pooling2d_2 (MaxPooling2 (None, 111, 111, 8)       0         
_________________________________________________________________
conv2d_2 (Conv2D)            (None, 109, 109, 16)      1168      
_________________________________________________________________
max_pooling2d_3 (MaxPooling2 (None, 54, 54, 16)        0         
_________________________________________________________________
conv2d_3 (Conv2D)            (None, 52, 52, 32)        4640      
_________________________________________________________________
max_pooling2d_4 (MaxPooling2 (None, 26, 26, 32)        0         
_________________________________________________________________
conv2d_4 (Conv2D)            (None, 24, 24, 64)        18496     
_________________________________________________________________
max_pooling2d_5 (MaxPooling2 (None, 12, 12, 64)        0         
_________________________________________________________________
flatten_2 (Flatten)          (None, 9216)              0         
_________________________________________________________________
```

```
dense_1 (Dense)              (None, 400)               3686800
_________________________________________________________________
dense_2 (Dense)              (None, 133)               53333
=================================================================
Total params: 3,764,661
Trainable params: 3,764,661
Non-trainable params: 0
_________________________________________________________________
```

```
Answer : why I chose this architecture:
I used the model suggested in this document and also I referred to the
book 'Hands-on Machine Learning with Scikit-Learn & TensorFlow'
by Aurelien Geron. There he showed different architectures
including : LeNet-5 and AlexNet.

In all these models usually we will use alternating conv2D layer and M
axPooling layer
to reduce dimensionalities and simplify calculations.


I also tried the AveragePooling layer without real improvement.

I also opted to leave the default Keras value for padding and stride.
Then I started to play with the kernel, I changed the filter size
from 5x5 to 2x2 to 3x3

Also the last layer activation I used softamx.

Afterall I was thwarted to experiment allot because of
the time taken to train in every epoch.
```

## Compile the Model

In [19]:

```
model.compile(optimizer='rmsprop', loss='categorical_crossentropy', metrics=['
```

## (IMPLEMENTATION) Train the Model

Train your model in the code cell below. Use model checkpointing to save the model that attains the best validation loss.

You are welcome to augment the training data (https://blog.keras.io/building-powerful-image-classification-models-using-very-little-data.html), but this is not a requirement.

In [20]:

```
from keras.callbacks import ModelCheckpoint
```

```
### TODO: specify the number of epochs that you would like to use to train the

epochs = 10

### Do NOT modify the code below this line.

checkpointer = ModelCheckpoint(filepath='saved_models/weights.best.from_scratc
                               verbose=1, save_best_only=True)

model.fit(train_tensors, train_targets,
          validation_data=(valid_tensors, valid_targets),
          epochs=epochs, batch_size=20, callbacks=[checkpointer], verbose=1)
```

```
Train on 6680 samples, validate on 835 samples
Epoch 1/10
6680/6680 [==============================] - 182s 27ms/step - loss: 4.
7871 - acc: 0.0234 - val_loss: 4.4779 - val_acc: 0.0395

Epoch 00001: val_loss improved from inf to 4.47786, saving model to sa
ved_models/weights.best.from_scratch.hdf5
Epoch 2/10
6680/6680 [==============================] - 179s 27ms/step - loss: 4.
1971 - acc: 0.0768 - val_loss: 4.2336 - val_acc: 0.0695

Epoch 00002: val_loss improved from 4.47786 to 4.23362, saving model t
o saved_models/weights.best.from_scratch.hdf5
Epoch 3/10
6680/6680 [==============================] - 179s 27ms/step - loss: 3.
3543 - acc: 0.2186 - val_loss: 4.5474 - val_acc: 0.0886

Epoch 00003: val_loss did not improve from 4.23362
Epoch 4/10
6680/6680 [==============================] - 172s 26ms/step - loss: 1.
9260 - acc: 0.5234 - val_loss: 5.4063 - val_acc: 0.0826

Epoch 00004: val_loss did not improve from 4.23362
Epoch 5/10
6680/6680 [==============================] - 213s 32ms/step - loss: 0.
6729 - acc: 0.8199 - val_loss: 8.0563 - val_acc: 0.0862

Epoch 00005: val_loss did not improve from 4.23362
Epoch 6/10
6680/6680 [==============================] - 420s 63ms/step - loss: 0.
2357 - acc: 0.9332 - val_loss: 9.1136 - val_acc: 0.0850

Epoch 00006: val_loss did not improve from 4.23362
Epoch 7/10
6680/6680 [==============================] - 412s 62ms/step - loss: 0.
1712 - acc: 0.9591 - val_loss: 9.9218 - val_acc: 0.0814

Epoch 00007: val_loss did not improve from 4.23362
Epoch 8/10
6680/6680 [==============================] - 885s 132ms/step - loss: 0
```

```
.1333 - acc: 0.9645 - val_loss: 11.2482 - val_acc: 0.0659

Epoch 00008: val_loss did not improve from 4.23362
Epoch 9/10
6680/6680 [==============================] - 190s 28ms/step - loss: 0.
1129 - acc: 0.9711 - val_loss: 11.2624 - val_acc: 0.0790

Epoch 00009: val_loss did not improve from 4.23362
Epoch 10/10
6680/6680 [==============================] - 190s 29ms/step - loss: 0.
1035 - acc: 0.9749 - val_loss: 11.5650 - val_acc: 0.0814

Epoch 00010: val_loss did not improve from 4.23362
```

Out[20]:

```
<keras.callbacks.History at 0x1a2dcbbd30>
```

### Load the Model with the Best Validation Loss

In [21]:

```python
model.load_weights('saved_models/weights.best.from_scratch.hdf5')
```

### Test the Model

Try out your model on the test dataset of dog images. Ensure that your test accuracy is greater than 1%.

In [22]:

```python
# get index of predicted dog breed for each image in test set
dog_breed_predictions = [np.argmax(model.predict(np.expand_dims(tensor, axis=0

# report test accuracy
test_accuracy = 100*np.sum(np.array(dog_breed_predictions)==np.argmax(test_tar
print('Test accuracy: %.4f%%' % test_accuracy)
```

```
Test accuracy: 8.1340%
```

---

## Step 4: Use a CNN to Classify Dog Breeds

To reduce training time without sacrificing accuracy, we show you how to train a CNN using transfer learning. In the following step, you will get a chance to use transfer learning to train your own CNN.

### Obtain Bottleneck Features

In [25]:

```
bottleneck_features = np.load('bottleneck_features/DogVGG16Data.npz')
train_VGG16 = bottleneck_features['train']
valid_VGG16 = bottleneck_features['valid']
test_VGG16 = bottleneck_features['test']
```

In [26]:

```
bottleneck_features.keys()
```

Out[26]:

```
['test',
 'train',
 'valid_OH',
 'valid',
 'train_OH',
 'filenames_train',
 'test_OH',
 'filenames_test',
 'filenames_valid']
```

In [98]:

```
train_VGG16.shape
```

Out[98]:

```
(6680, 7, 7, 512)
```

## Model Architecture

The model uses the the pre-trained VGG-16 model as a fixed feature extractor, where the last convolutional output of VGG-16 is fed as input to our model. We only add a global average pooling layer and a fully connected layer, where the latter contains one node for each dog category and is equipped with a softmax.

In [27]:

```
VGG16_model = Sequential()
VGG16_model.add(GlobalAveragePooling2D(input_shape = train_VGG16.shape[1:]))
VGG16_model.add(Dense(133, activation='softmax'))

VGG16_model.summary()
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
global_average_pooling2d_1 ( (None, 512)               0         
_________________________________________________________________
dense_3 (Dense)              (None, 133)               68229     
=================================================================
Total params: 68,229
Trainable params: 68,229
Non-trainable params: 0
_________________________________________________________________
```

## Compile the Model

In [28]:

```
VGG16_model.compile(loss='categorical_crossentropy', optimizer='rmsprop', metr
```

## Train the Model

In [29]:

```
checkpointer = ModelCheckpoint(filepath='saved_models/weights.best.VGG16.hdf5'
                               verbose=1, save_best_only=True)

VGG16_model.fit(train_VGG16, train_targets,
          validation_data=(valid_VGG16, valid_targets),
          epochs=50, batch_size=20, callbacks=[checkpointer], verbose=1)
```

```
Train on 6680 samples, validate on 835 samples
Epoch 1/50
6680/6680 [==============================] - 3s 399us/step - loss: 12.
0025 - acc: 0.1403 - val_loss: 10.4119 - val_acc: 0.2335

Epoch 00001: val_loss improved from inf to 10.41191, saving model to s
aved_models/weights.best.VGG16.hdf5
Epoch 2/50
6680/6680 [==============================] - 1s 146us/step - loss: 9.7
454 - acc: 0.2990 - val_loss: 9.6615 - val_acc: 0.3066

Epoch 00002: val_loss improved from 10.41191 to 9.66148, saving model
to saved_models/weights.best.VGG16.hdf5
Epoch 3/50
6680/6680 [==============================] - 1s 143us/step - loss: 9.1
468 - acc: 0.3617 - val_loss: 9.3383 - val_acc: 0.3269

Epoch 00003: val_loss improved from 9.66148 to 9.33826, saving model t
o saved_models/weights.best.VGG16.hdf5
```

## Load the Model with the Best Validation Loss

In [30]:

```
VGG16_model.load_weights('saved_models/weights.best.VGG16.hdf5')
```

## Test the Model

Now, we can use the CNN to test how well it identifies breed within our test dataset of dog images. We print the test accuracy below.

In [31]:

```
# get index of predicted dog breed for each image in test set
VGG16_predictions = [np.argmax(VGG16_model.predict(np.expand_dims(feature, axi

# report test accuracy
test_accuracy = 100*np.sum(np.array(VGG16_predictions)==np.argmax(test_targets
print('Test accuracy: %.4f%%' % test_accuracy)
```

```
Test accuracy: 55.2632%
```

## Predict Dog Breed with the Model

In [32]:

```
from extract_bottleneck_features import *

def VGG16_predict_breed(img_path):
    # extract bottleneck features
    bottleneck_feature = extract_VGG16(path_to_tensor(img_path))
    # obtain predicted vector
    predicted_vector = VGG16_model.predict(bottleneck_feature)
    # return dog breed that is predicted by the model
    return dog_names[np.argmax(predicted_vector)]
```

In [33]:

```
VGG16_predict_breed('images/Labrador_retriever_06449.jpg')
```

Out[33]:

```
'Labrador_retriever'
```

---

## Step 5: 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.

In Step 4, we used transfer learning to create a CNN using VGG-16 bottleneck features. In this section, you must use the bottleneck features from a different pre-trained model. To make things easier for you, we have pre-computed the features for all of the networks that are currently available in Keras:

- VGG-19 (https://s3-us-west-1.amazonaws.com/udacity-aind/dog-project/DogVGG19Data.npz) bottleneck features
- ResNet-50 (https://s3-us-west-1.amazonaws.com/udacity-aind/dog-project/DogResnet50Data.npz) bottleneck features
- Inception (https://s3-us-west-1.amazonaws.com/udacity-aind/dog-project/DogInceptionV3Data.npz) bottleneck features
- Xception (https://s3-us-west-1.amazonaws.com/udacity-aind/dog-project/DogXceptionData.npz) bottleneck features

The files are encoded as such:

```
Dog{network}Data.npz
```

where `{network}`, in the above filename, can be one of `VGG19`, `Resnet50`, `InceptionV3`, or `Xception`. Pick one of the above architectures, download the corresponding bottleneck features, and store the downloaded file in the `bottleneck_features/` folder in the repository.

### (IMPLEMENTATION) Obtain Bottleneck Features

In the code block below, extract the bottleneck features corresponding to the train, test, and validation sets by running the following:

```
bottleneck_features = np.load('bottleneck_features/Dog{network}Data.npz')
train_{network} = bottleneck_features['train']
valid_{network} = bottleneck_features['valid']
test_{network} = bottleneck_features['test']
```

In [34]:

```
### TODO: Obtain bottleneck features from another pre-trained CNN.

bottleneck_features = np.load('bottleneck_features/DogResnet50Data.npz')
train_Resnet50 = bottleneck_features['train']
valid_Resnet50 = bottleneck_features['valid']
test_Resnet50 = bottleneck_features['test']

```

In [35]:

```

print(train_Resnet50.shape)
print(valid_Resnet50.shape)
print(test_Resnet50.shape)
```

```
(6680, 1, 1, 2048)
(835, 1, 1, 2048)
(836, 1, 1, 2048)
```

## (IMPLEMENTATION) Model Architecture

Create a CNN to classify dog breed. At the end of your code cell block, summarize the layers of your model by executing the line:

```
<your model's name>.summary()
```

**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:**

In [39]:

```
### TODO: Define your architecture.

resnet_dog = Sequential()
resnet_dog.add(GlobalAveragePooling2D(input_shape = train_Resnet50.shape[1:]))
resnet_dog.add(Dense(133, activation='softmax'))

resnet_dog.summary()


print('''

The main concept of learning transfer is using the CNN that was trained
on the best hardware for long time and proved to be excellent in prediction.
Then you take the network that doesn't need training and input your data in it
notice that seond last layer output; then plug this output into your new neura
that shouldn't be complex
mainly one or two dense layers (flat) that output to your new targets
```

```
mainly one or two dense layers (flat) that output to your new targets
So now we have the benifit of the well trained CNN with minimal time training
new composed network.

I tried MaxPooling but that resulted in error..

I run into a problem in this network that I will clarify down
''')
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
global_average_pooling2d_5 ( (None, 2048)              0         
_________________________________________________________________
dense_7 (Dense)              (None, 133)               272517    
=================================================================
Total params: 272,517
Trainable params: 272,517
Non-trainable params: 0
_________________________________________________________________


The main concept of learning transfer is using the CNN that was traine
d
on the best hardware for long time and proved to be excellent in predi
ction.
Then you take the network that doesn't need training and input your da
ta in it and
notice that seond last layer output; then plug this output into your n
ew neural network
that shouldn't be complex
mainly one or two dense layers (flat) that output to your new targets
So now we have the benifit of the well trained CNN with minimal time t
raining the
new composed network.

I tried MaxPooling but that resulted in error..

I run into a problem in this network that I will clarify down
```

### (IMPLEMENTATION) Compile the Model

In [40]:

```
### TODO: Compile the model.

resnet_dog.compile(loss='categorical_crossentropy', optimizer='rmsprop', metri
```

## (IMPLEMENTATION) Train the Model

Train your model in the code cell below. Use model checkpointing to save the model that attains the best validation loss.

You are welcome to [augment the training data (https://blog.keras.io/building-powerful-image-classification-models-using-very-little-data.html)](https://blog.keras.io/building-powerful-image-classification-models-using-very-little-data.html), but this is not a requirement.

In [41]:

```python
### TODO: Train the model.

checkpointer = ModelCheckpoint(filepath='saved_models/weights.best.resnet.hdf5
                               verbose=1, save_best_only=True)

resnet_dog.fit(train_Resnet50, train_targets,
          validation_data=(valid_Resnet50, valid_targets),
          epochs=50, batch_size=20, callbacks=[checkpointer], verbose=1)
```

```
Train on 6680 samples, validate on 835 samples
Epoch 1/50
6680/6680 [==============================] - 2s 357us/step - loss: 1.6
037 - acc: 0.5994 - val_loss: 0.8228 - val_acc: 0.7413

Epoch 00001: val_loss improved from inf to 0.82281, saving model to sa
ved_models/weights.best.resnet.hdf5
Epoch 2/50
6680/6680 [==============================] - 2s 230us/step - loss: 0.4
362 - acc: 0.8665 - val_loss: 0.7368 - val_acc: 0.7641

Epoch 00002: val_loss improved from 0.82281 to 0.73679, saving model t
o saved_models/weights.best.resnet.hdf5
Epoch 3/50
6680/6680 [==============================] - 2s 246us/step - loss: 0.2
620 - acc: 0.9201 - val_loss: 0.7109 - val_acc: 0.7892

Epoch 00003: val_loss improved from 0.73679 to 0.71090, saving model t
o saved_models/weights.best.resnet.hdf5
```

## (IMPLEMENTATION) Load the Model with the Best Validation Loss

In [42]:

```python
### TODO: Load the model weights with the best validation loss.

resnet_dog.load_weights('saved_models/weights.best.resnet.hdf5')
```

## (IMPLEMENTATION) Test the Model

Try out your model on the test dataset of dog images. Ensure that your test accuracy is greater than 60%.

In [44]:

```
### TODO: Calculate classification accuracy on the test dataset.


# get index of predicted dog breed for each image in test set
resnet_predictions = [np.argmax(resnet_dog.predict(np.expand_dims(feature, axi

# report test accuracy
test_accuracy = 100*np.sum(np.array(resnet_predictions)==np.argmax(test_target
print('Test accuracy: %.4f%%' % test_accuracy)
```

```
Test accuracy: 81.9378%
```

## (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.

Similar to the analogous function in Step 5, your function should have three steps:

1. Extract the bottleneck features corresponding to the chosen CNN model.
2. Supply the bottleneck features as input to the model to return the predicted vector. Note that the argmax of this prediction vector gives the index of the predicted dog breed.
3. Use the `dog_names` array defined in Step 0 of this notebook to return the corresponding breed.

The functions to extract the bottleneck features can be found in `extract_bottleneck_features.py` , and they have been imported in an earlier code cell. To obtain the bottleneck features corresponding to your chosen CNN architecture, you need to use the function

```
extract_{network}
```

where `{network}` , in the above filename, should be one of `VGG19` , `Resnet50` , `InceptionV3` , or `Xception` .

# Very Important note

After downloading the bottleneck features from the web as suggested by the instructor from the following link:

[https://s3-us-west-1.amazonaws.com/udacity-aind/dog-project/DogResnet50Data.npz (https://s3-us-west-1.amazonaws.com/udacity-aind/dog-project/DogResnet50Data.npz)](https://s3-us-west-1.amazonaws.com/udacity-aind/dog-project/DogResnet50Data.npz)

I tried to find the shape of the data:

```
print(train_Resnet50.shape)
print(valid_Resnet50.shape)
print(test_Resnet50.shape)
```

to my surprise this came as:

```
(6680, 1, 1, 2048)
(835, 1, 1, 2048)
(836, 1, 1, 2048)
```

My neural network worked well and i got more than 80% accuracy. I was happy but then...

When I wrote my algorithm down I had to use

```
 from extract_bottleneck_features import *
bottleneck_features = extract_Resnet50(path_to_tensor(img_path))
```

for any new image i want to predict. But I notice that these features come in different shape than what my nn expects.

My nn expects input shape of [1,1,1,2048]
while this method `extract_Resnet50` returns shape of [1,7,7,2048]

It took my many hours to find a solution, and I thought of two solutions:

- 1 - I need to create a new nn just to use MaxPooling layer to change the shape.
- 2 - I have to do my own MaxPoolying method. and the 2nd solution is what I did

I tested it and it worked find and I could now forward the features to my neural network.

In [46]:

```

def myMaxPooling(bottleneck_features):
    l =[]
    for i in range(bottleneck_features.shape[3]):
        l.append(np.max(bottleneck_features[:,:,:,i]))

    features = np.array(l)
    features = np.expand_dims(features,axis=0)
    features = np.expand_dims(features,axis=0)
    features = np.expand_dims(features,axis=0)

    return features
```

In [47]:

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





from extract_bottleneck_features import *

def resnet_predict_breed(img_path):
    # extract bottleneck features
    bottleneck_features = extract_Resnet50(path_to_tensor(img_path))


    #Use the MaxPooling method to have acceptable input shape
    bottleneck_features = myMaxPooling(bottleneck_features)

    # obtain predicted vector
    predicted_vector = resnet_dog.predict(bottleneck_features)



    # return dog breed that is predicted by the model
    return dog_names[np.argmax(predicted_vector)]



```

In [48]:

```
resnet_predict_breed('images/Welsh_springer_spaniel_08203.jpg')
```

Out[48]:

```
'Welsh_springer_spaniel'
```

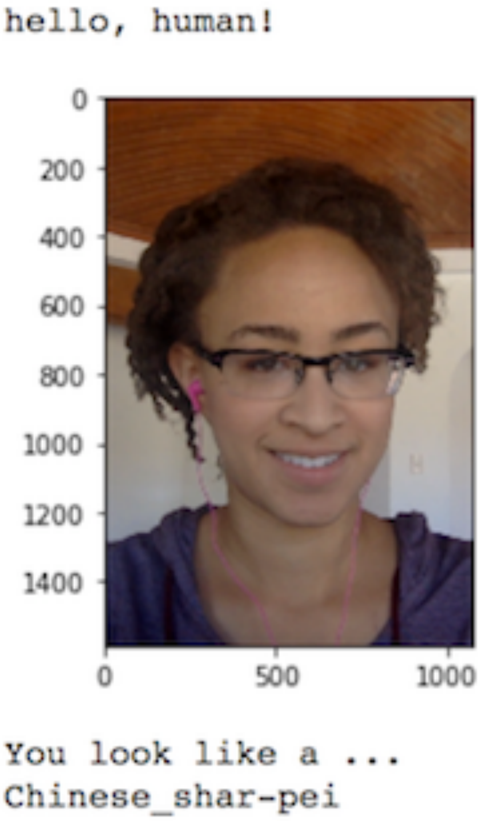
## Step 6: Write your Algorithm

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 `dog_detector` functions developed above. You are **required** to use your CNN from Step 5 to predict dog breed.

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



```
hello, human!
```

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

## (IMPLEMENTATION) Write your Algorithm

In [49]:

```
### TODO: Write your algorithm.
### Feel free to use as many code cells as needed.


'''
Pseudocode:

take the image path
try to find human faces
try to find dog face
```

```

if there are no faces: throw an error

if the human face was detected then
    count how many human faces found?
    if many faces then
        try to predict the breed of one of them (Any).
    if only one human face then
        try to predict what dog breed s/he look like

if dog face detected then
    try to predict its breed


'''
def find_face(img_path):
    hFace, locations = detect_human_face(img_path)
    dFace = dog_detector(img_path)


    draw_image(img_path)
    if not hFace and not dFace:
        print('Error: There is no face detected in the image !!')

        return False

    breed = resnet_predict_breed(img_path)

    if len(locations) > 1:

        print('this photo contains multiple faces and it contains ',
              breed, ' dog breed probably !!')
    else:
        if hFace:
            print('Hello Human.. :) ')
            print('You look like a ', breed, ' breed !!')


        if dFace:
            print ('What a nice dog \nit looks to be a ',breed,' breed !!')



    return True

```

---

# Step 7: 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:**

In [ ]:

```
## 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.
```

**Here is my testing plan:**

1. I used collage image of dogs.
2. One dog
3. a very famous human :)
4. two person with their profile pose images => failed
5. a famous human ( Actress)
6. a famous Saudi actor in 4 pictures:

```
    - smiling alone
    - smiling with other far audience
    - another photo when he had different person role ( eye closed almost)
    - another group image (multiple persons)
```

7. a cat image
8. a mouse image
9. another cat image
10. another dog

One of the cat images (7) showed human face !! Which is a faulty face recognition The mouse and the cats were not recognised as human nor as dogs.

Also I noticed that when it is guessing it use the breed (Silky_terrier).

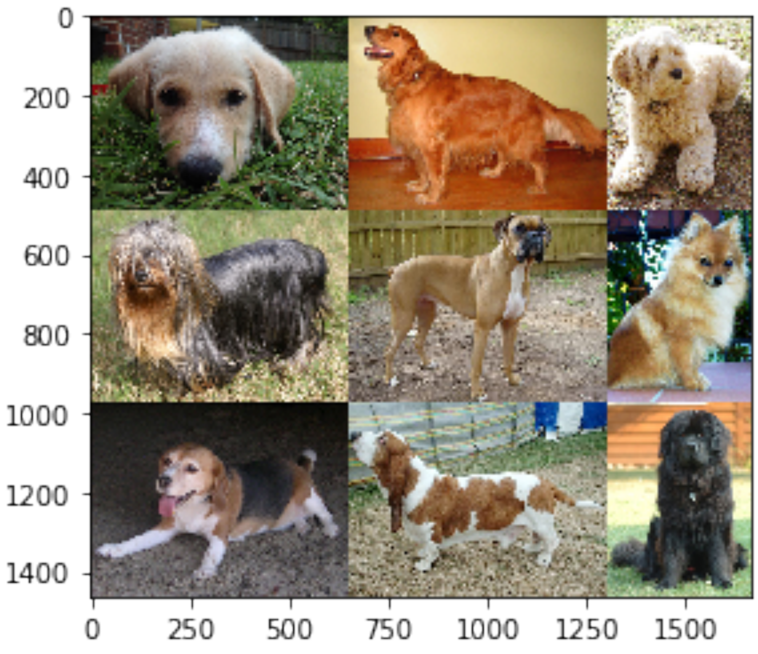
In [50]:

```
find_face('Images/Collage_of_Nine_Dogs.jpg')
```

```
What a nice dog
it looks to be a  Brittany  breed !!
```

Out[50]:

```
True
```



In [51]:

```
find_face('images/Labrador_retriever_06449.jpg')
```

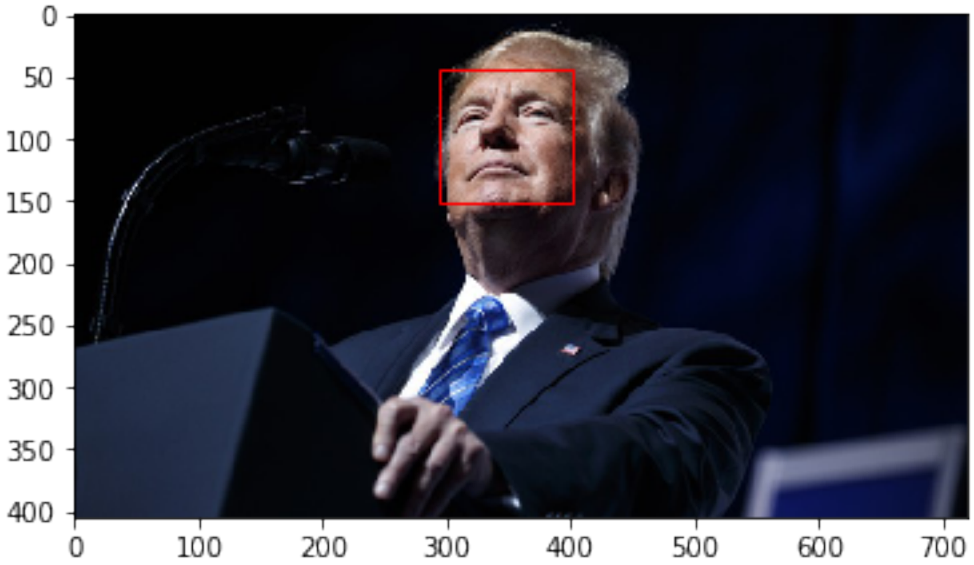
```
What a nice dog
it looks to be a  Labrador_retriever  breed !!
```

Out[51]:

```
True
```

In [52]:

```
find_face('Images/trump.jpg')
```



```
Hello Human.. :)
You look like a  Dachshund  breed !!
```

Out[52]:

```
True
```

In [53]:

```
find_face('Images/trump_putin.jpg')
```

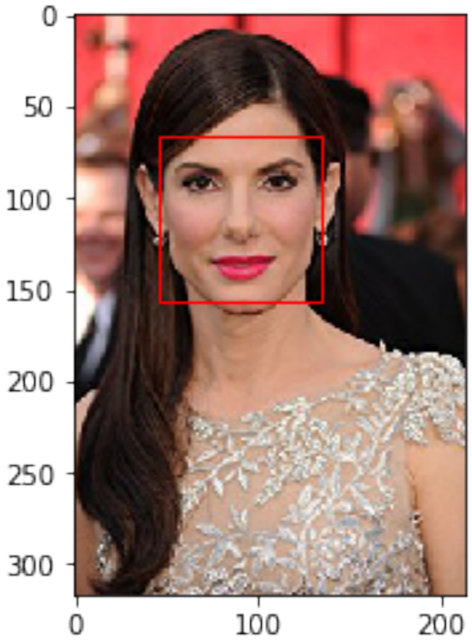
```
Error: There is no face detected in the image !!
```

Out[53]:

```
False
```

In [54]:

```
find_face('Images/sandra_bullock.jpg')
```



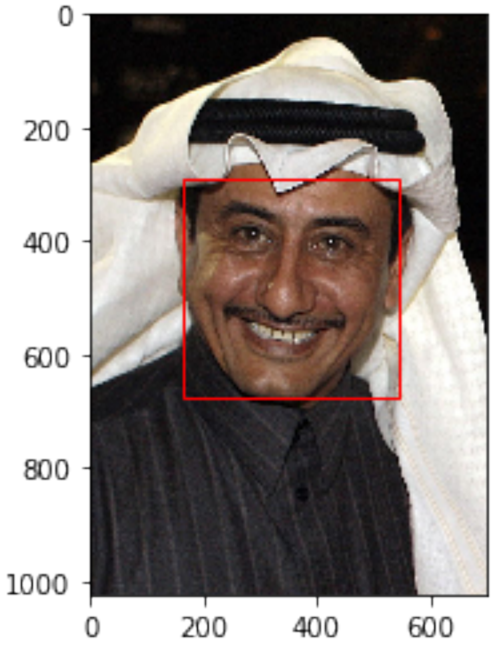
```
Hello Human.. :)
You look like a  Japanese_chin  breed !!
```

Out[54]:

```
True
```

In [55]:

```
find_face('Images/qasabi.jpg')
```



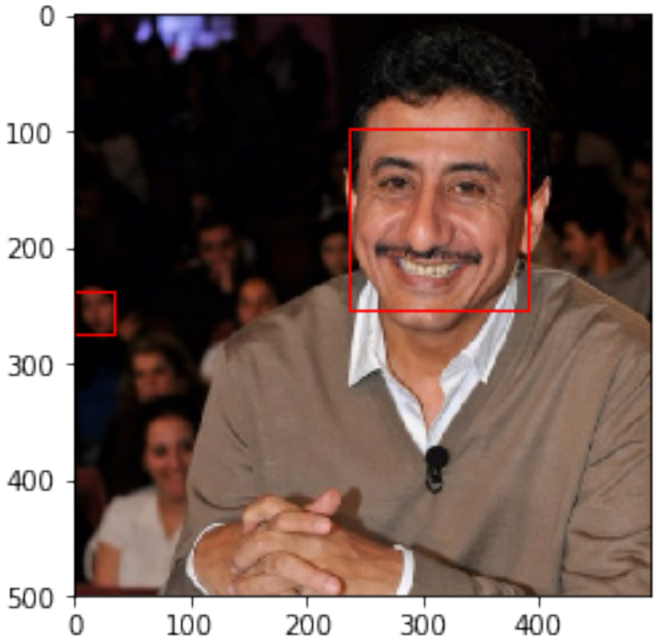
```
Hello Human.. :)
You look like a  Pointer  breed !!
```

Out[55]:

```
True
```

In [264]:

```
find_face('Images/qasabi2.jpg')
```



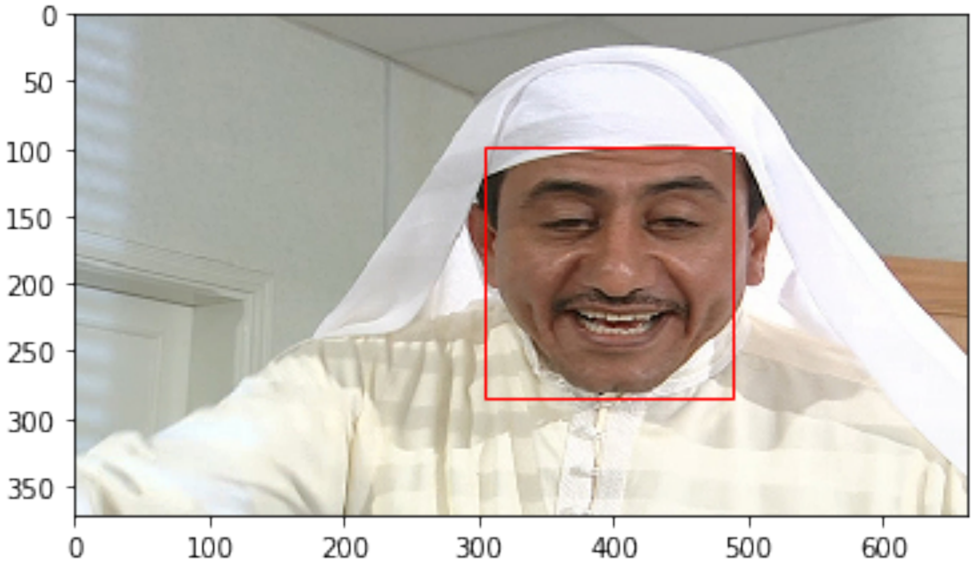
```
2  locations length
this photo contains multiple faces and it contains  Silky_terrier  dog
breed probably !!
```

Out[264]:

```
True
```

```
In [256]:
```

```python
find_face('Images/fouad.jpg')
```



```
Hello Human.. :)
You look like a  Maltese  breed !!
```

```
Out[256]:
```

```
True
```

```
In [263]:
```

```python
find_face('Images/group.jpg')
```

```
4  locations length
this photo contains multiple faces and it contains  Silky_terrier  dog
breed probably !!
```

```
Out[263]:
```

```
True
```

In [56]:

```python
find_face('Images/cat.jpg')
```

```
Hello Human.. :)
You look like a  Chihuahua  breed !!
```

Out[56]:

```
True
```

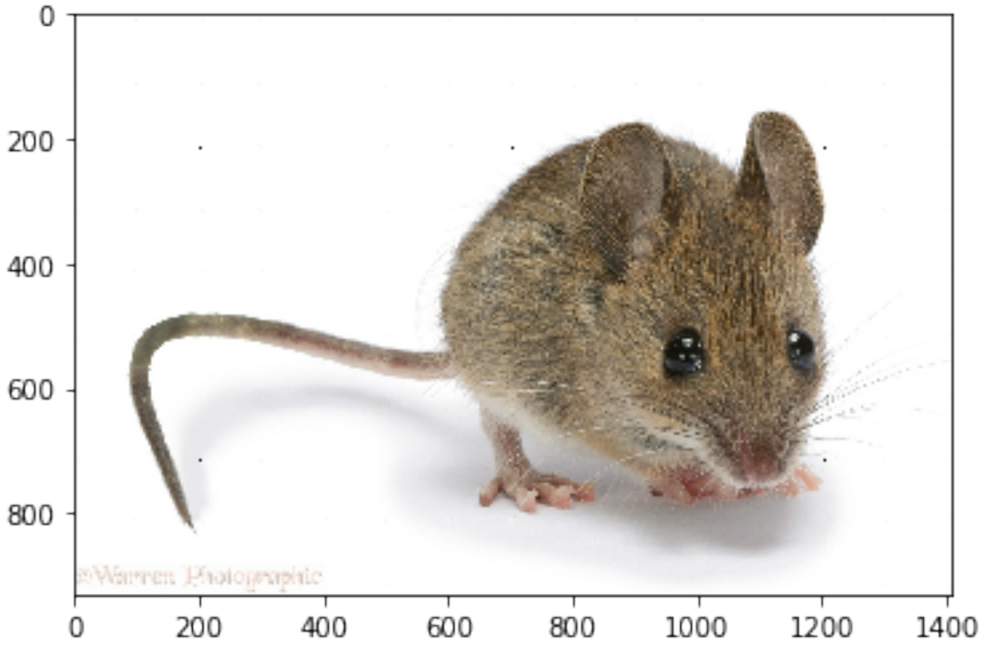
In [57]:

```python
find_face('Images/Mouse.jpg')
```

```
Error: There is no face detected in the image !!
```

Out[57]:

```
False
```



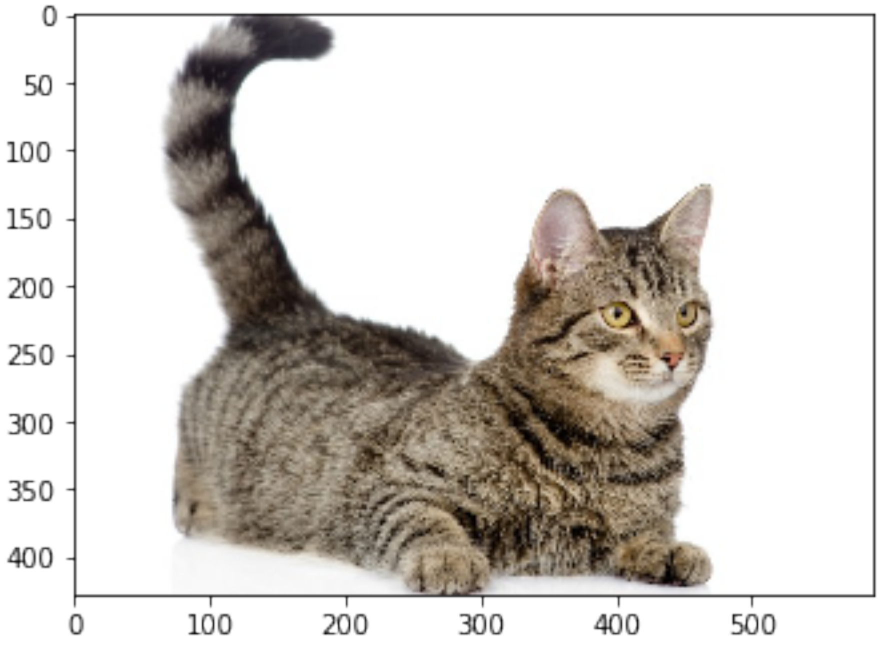
In [58]:

```
find_face('Images/cat-tail.jpg')
```

```
Error: There is no face detected in the image !!
```

Out[58]:

```
False
```



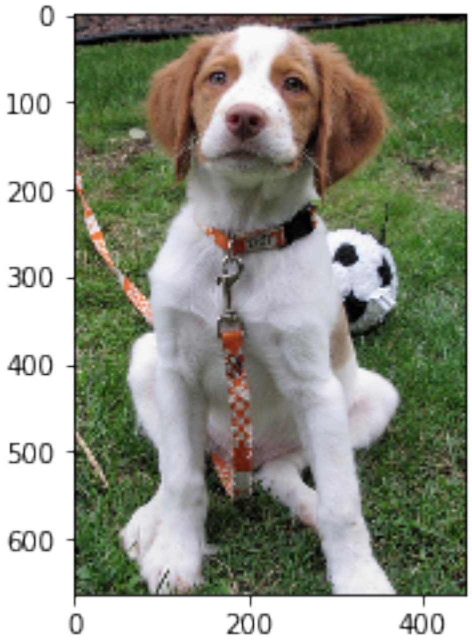
In [59]:

```
find_face('images/Brittany_02625.jpg')
```

```
What a nice dog
it looks to be a  Brittany  breed !!
```

Out[59]:

```
True
```



**My Answer:**

The output of the algorithm is acceptable reaching my expectations.

To improve the algorithm I would do the following:

1 - make the algorithm specify how many faces
2 - if there are many faces then specify prediction for each face
3 - use face detector that have a better accuracy so it won't mix human with dogs.
4 - Deal with the case when there are mixed faces (human and dogs) 5 - The algorithm should deal with the profile pose images.

May be some of these improvements could be done by cropping the photo on the face and then reinput it on both the human and dog detector. The keystone here is that you have to have a good neural network that predict accurately.