Machine Learning Engineer Nanodegree

CAPSTONE PROJECT

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Dog Breed Classification Using Convolutional Neural Networks (CNN)

Project Overview:

The Dog breed classification problem is a well-known problem in Machine Learning. We can find it on Kaggle https://www.kaggle.com/c/dog-breed-identification/overview/description. The problem here is to identify the breed of dog if dog image is given as an input, and suppose if we gave an image of a humans as an input to the classifier, we have to identify the resembling dog breed to that human. The idea is to build a pipeline that can process real world user supplied images and identify an estimate of the canine's breed. This is a multi-class classification problem where we can use supervised machine learning to solve this problem.

Problem Statement:

The main aim of the project is to build a machine learning model that can be used within web app to process real-world, user-supplied images. The model has to perform two tasks:

- **Dog face detection**: Suppose if we gave any dog image as an input to the model, then that model will predict the canine's breed.
- **Human face detection:** Suppose if we gave any dog image as an input to the model, then that model will predict the resembling dog breed.

Metrics:

The data is split into train, test and valid dataset. The model is trained using the train dataset.
We validate our model by using the validation dataset. We use the testing data to predict the performance of the model on the unseen test data. We will use accuracy as a performance metric to evaluate our model on test data.

Accuracy=Number of correctly classified images / total classified images

Also, during model the training, we compare the test data predictions with validation dataset and calculate Multi class log loss to find the best performing model. Log loss takes into the account of uncertainty of prediction based on how much it varies from actual label and this will help in evaluating the model.

Data Exploration:

For this project, the input format must be of image type, because we want to input an image and identify the breed of the dog. All data for this project is provided by Udacity. We have pictures of dogs and pictures of humans.

- **Dog images dataset**: The dog image dataset has 8351 total images which are sorted into train (6,680 Images), test (836 Images) and valid (835 Images) directories. Each of this directory (train, test, valid) have 133 folders corresponding to dog breeds. The images are of different sizes and different backgrounds, some images are not full-sized. The data is not balanced because the number of images provided for each breed varies. Few have 4 images while some have 8 images.

Dog images

- **Human images dataset**: The human dataset contains 13233 total human images which are sorted by names of human (5750 folders). All images are of size 250x250. Images have different background and different angles. The data is not balanced because we have 1 image for some people and many images for some.

Human Images

Algorithms and techniques:

For performing this multiclass classification, we can use Convolutional Neural Network to solve the problem. A **Convolutional Neural Network (CNN)** is a Deep Learning algorithm which can take in an input image, assign importance (learnable weights and biases) to various aspects/objects in the image and be able to differentiate one from the other. The solution involves three steps. First, to detect human images, we can use existing algorithm like OpenCV's implementation of Haar feature based cascade classifiers. Second, to detect dog-images we will use a pre-trained VGG16 model. Finally, after the image is identified as dog/human, we can pass this image to CNN which will process the image and predict the breed that matches the best out of 133 breeds.

Benchmark:

For our benchmark model, we will use the Convolutional Neural Networks (CNN) model created from scratch with an accuracy of more than 10%. This should be enough to confirm that our model is working because random guess would be 1 in 133 breeds which are less than 1% if we don't consider unbalanced data for our dog images. The CNN model created using transfer learning must have accuracy of 60% and above.

Data Preprocessing:

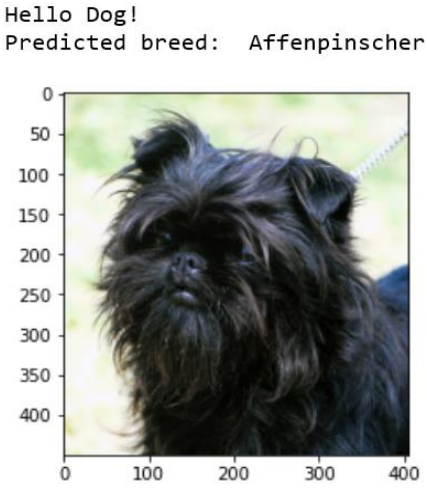
All the images are resized to 224*224, then the normalization is applied to all the images (train, valid and test datasets). For the training data, Image augmentation is done to reduce overfitting. The train data images are randomly rotated and random horizontal flip is applied. Finally, all the images are converted into tensor before passing into the model.

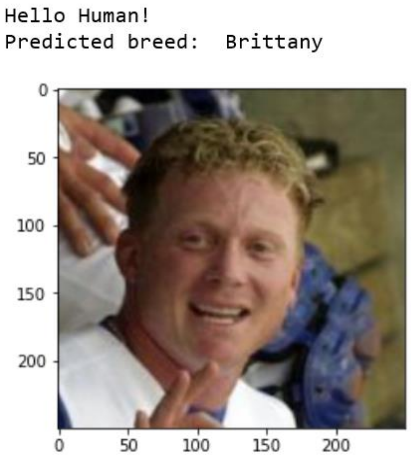
Implementation:

I have built a CNN model from scratch using pytorch to solve the problem. The model has 3 convolutional layers. All convolutional layers have kernel size of 3 and stride 1. The first conv layer (conv1) takes the 224*224 input image and the final conv layer (conv3) produces an output size of 128*128. ReLU activation function is used here. The pooling layer of (2, 2) is used which will reduce the input size by 2. We have two fully connected layers that finally produces 133-dimensional output. A dropout of 0.25 is added to avoid over overfitting.

Refinement:

The CNN model I have created from scratch got the accuracy of 24%. Although it meets the benchmarking, the model can be significantly improved by using transfer learning. To create CNN with transfer learning, I have selected the Resnet101 architecture which is pre-trained on ImageNet dataset, the Resnet101 architecture have 101 layers deep. The last convolutional output of Resnet101 is fed as input to our model. We only need to add a fully connected layer to produce 133-dimensional output (one for each dog category). The model performed extremely well when compared to CNN from scratch. With just 20 epochs, the model got 84% accuracy.





Sample outputs predicted by using the model

Model Evaluation and Validation:

- **Human Face detector***:* The human face detector function was created using OpenCV's implementation of Haar feature based cascade classifiers. 96% of human faces were detected in first 100 images of human face dataset and 18% of human faces detected in first 100 images of dog dataset.

- **Dog Face detector**: The dog detector function was created using pre-trained VGG16 model. 95% of dog faces were detected in first 100 images of dog dataset and 0% of dog faces detected in first 100 images of human dataset.

- **CNN using transfer learning:** The CNN model that we have created using transfer learning with ResNet101 architecture was trained for 20 epochs, and the final model produced an accuracy of 84% on test data. The model correctly predicted breeds for 703 images out of 836 total images.

  Accuracy on test data: 84% (703/836)

Justification:

I think the model performance is better than expected. The model created using transfer learning have an accuracy of 84% compared to the CNN model created from scratch which had only 24% accuracy.

Improvement:

If we train our model with more training data, that might be useful to improve model performance. Model can be improved by adding more training and test data, currently the model is created using only 133 breeds of dog. Also, by performing more image augmentation, we can avoid overfitting and improve the accuracy. I have tried only with ResNet 101 architecture for feature extraction, May be the model can be improved using different architecture. Hyper parameter tuning will also help in improving the model performance. It really helpful to get the good results. More image augmentation can be tried to improve accuracy.

References:

- CNN Wikipedia: https://en.wikipedia.org/wiki/Convolutional_neural_network

- Original repo for Project - GitHub: https://github.com/udacity/deep-learning-v2-pytorch/blob/master/project-dog-classification/

- Resnet101:

https://pytorch.org/docs/stable/_modules/torchvision/models/resnet.html#resnet101

- https://towardsdatascience.com/a-comprehensive-guide-to-convolutional-neural-networks-the-eli5-way-3bd2b1164a53
- http://wiki.fast.ai/index.php/Log_Loss