Dog Identification App

Definition

Project Overview/Domain Background

The task of assigning breed to dogs from images is considered exceptionally challenging. E*ven* human would have trouble distinguishing between a Brittany and a Welsh Springer Spaniel. Image classification involves assigning a label to an entire image or photograph and task of finding breed of dogs can be framed into image classification problem. In this project, I created a dog identification application capable of classifying more than 100 different kinds of dog breeds.

State of the art in Image Classification

The Large Scale Visual Recognition Challenge (ILSVRC) is an annual competition in which teams compete for the best performance on a range of computer vision tasks on data drawn from the ImageNet database. Many important advancements in image classification have come from papers published on or about tasks from this challenge, most notably early papers on the image classification task.

For example:

- ImageNet Classification With Deep Convolutional Neural Networks, 2012.
- Very Deep Convolutional Networks for Large-Scale Image Recognition, 2014.
- Going Deeper with Convolutions, 2015.
- Deep Residual Learning for Image Recognition, 2015.

Problem Statement

To build an app that takes user-supplied images as input and provides an estimate of the canine's breed of dog if dog is detected in the image. If human is detected in the image, it will provide an estimate of the dog breed that is most resembling. This problem is solved by training a CNN for classification task that given an image classifies it into one of the dogs breeds the network is trained on.

Metrics

Accuracy is one of the common metrics for classifiers. The model is evaluated based on accuracy as described below. Dataset is fairly balanced so accuracy can be used as metric.

Accuracy = (TN + TP)/(TN+TP+FN+FP) = (Number of correct assessments)/Number of all assessments)

Where

TP = True Positives

TN = True Negatives

FP = False Positives

FN = False Negatives

Analysis

Data Exploration

There are 13233 human images in the human dataset and 8351 dog images in the dog dataset. Data is imbalanced as there are more human images compared to dog images. Also the number of dog images for each breed are not very similar as can be seen from the below.

- The number of images in train, valid, test are: 'train': 6680, 'valid': 835, 'test': 836.
- The label distribution can be seen below. Alaskan_malamute has highest number of images of 78 and Norwegian_buhund has least number of images with 27.
- Images are of shape (648, 800, 3).

```
root@942bf67450f6:/data/dog_images/train# du -a | cut -d/ -f2 | sort | uniq -c | sort -nr

    78 005.Alaskan_malamute

    75 029.Border_collie

    74 015.Basset_hound

    72 057.Dalmatian

    70 041.Bullmastiff

    70 039.Bull_terrier

    70 014.Basenji

    68 046.Cavalier_king_charles_spaniel

    67 087.Irish_terrier

    67 012.Australian_shepherd

    67 011.Australian_cattle_dog

    67 008.American_staffordshire_terrier

    66 056.Dachshund

    66 036.Briard
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66 032.Boston_terrier

66 023.Bernese_mountain_dog

65 076.Golden_retriever

65 044.Cane_corso

65 034.Boxer

65 027.Bloodhound

65 021.Belgian_sheepdog

65 006.American_eskimo_dog

65 001.Affenpinscher

64 115.Papillon

64 068.Flat-coated_retriever

64 042.Cairn_terrier

64 004.Akita

63 071.German_shepherd_dog

63 051.Chow_chow

63 024.Bichon_frise

63 020.Belgian_malinois

63 017.Bearded_collie

62 082.Havanese

62 061.English_cocker_spaniel

61 060.Dogue_de_bordeaux

60 079.Great_pyrenees

60 016.Beagle

59 103.Mastiff
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59 090.Italian_greyhound

59 002.Afghan_hound

58 091.Japanese_chin

58 054.Collie

58 038.Brussels_griffon

57 081.Greyhound

57 031.Borzoi

55 112.Nova_scotia_duck_tolling_retriever

55 048.Chihuahua

55 047.Chesapeake_bay_retriever

54 118.Pembroke_welsh_corgi

54 089.Irish_wolfhound

54 086.Irish_setter

54 063.English_springer_spaniel

54 062.English_setter

54 045.Cardigan_welsh_corgi

54 040.Bulldog

54 035.Boykin_spaniel

53 030.Border_terrier

53 003.Airedale_terrier

52 088.Irish_water_spaniel

52 069.French_bulldog

51 124.Poodle

51 106.Newfoundland

51 097.Lakeland_terrier

51 084.Icelandic_sheepdog

51 058.Dandie_dinmont_terrier

51 055.Curly-coated_retriever

51 050.Chinese_shar-pei

51 049.Chinese_crested

51 043.Canaan_dog

51 037.Brittany

51 018.Beauceron

51 010.Anatolian_shepherd_dog

51 007.American_foxhound

50 095.Kuvasz

50 052.Clumber_spaniel

49 129.Tibetan_mastiff

49 117.Pekingese

49 101.Maltese

49 072.German_shorthaired_pointer

49 019.Bedlington_terrier

48 070.German_pinscher

48 059.Doberman_pinscher

48 053.Cocker_spaniel

48 022.Belgian_tervuren

47 107.Norfolk_terrier

47 098.Leonberger

47 083.Ibizan_hound

47 080.Greater_swiss_mountain_dog

47 013.Australian_terrier

46 109.Norwegian_elkhound

46 033.Bouvier_des_flandres

45 130.Welsh_springer_spaniel

45 123.Pomeranian

45 111.Norwich_terrier

45 094.Komondor

45 092.Keeshond

45 075.Glen_of_imaal_terrier

44 096.Labrador_retriever

44 077.Gordon_setter

43 104.Miniature_schnauzer

43 099.Lhasa_apso

43 073.German_wirehaired_pointer

43 065.Entlebucher_mountain_dog

42 127.Silky_terrier

42 074.Giant_schnauzer

42 026.Black_russian_terrier

41 078.Great_dane

40 120.Pharaoh_hound

40 113.Old_english_sheepdog

40 064.English_toy_spaniel

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38 085.Irish_red_and_white_setter
38 025.Black_and_tan_coonhound
36 114.Otterhound
36 093.Kerry_blue_terrier
36 028.Bluetick_coonhound
35 125.Portuguese_water_dog
35 100.Lowchen
35 067.Finnish_spitz
35 009.American_water_spaniel
34 110.Norwegian_lundehund
34 066.Field_spaniel
33 122.Pointer
32 119.Petit_basset_griffon_vendeen
32 105.Neapolitan_mastiff
31 133.Yorkshire_terrier
31 131.Wirehaired_pointing_griffon
31 128.Smooth_fox_terrier
31 126.Saint_bernard
31 116.Parson_russell_terrier
30 102.Manchester_terrier
29 121.Plott
27 132.Xoloitzcuintli
27 108.Norwegian_buhund
```

Exploratory visualization

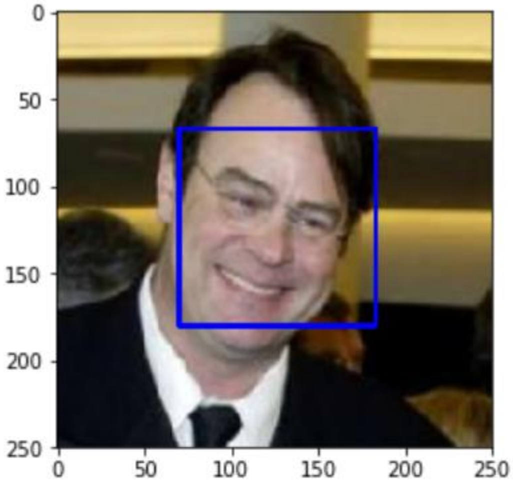
Dog Images

Brittany	Welsh Springer Spaniel

Curly-Coated Retriever	American Water Spaniel

Yellow Labrador	Chocolate Labrador	Black Labrador

Human images



Algorithms and Techniques

1. Convolutional neural networks were used.

    a. Convolutional neural networks are inspired by the brain.

    b. In mathematics, convolution is a mathematical operation of two functions that produces a third function expressing how the shape of the one is modified by the other.

    c. Traditional neural networks don't take any advantage of spatial information and might be helpful in using this especially when working with images and CNN's takes advantage of this.

    d. CNN's also have much smaller number of parameters compared to traditional neural networks as the kernel parameters are shared across the image.

    e. The lower layers in CNN architecture learns much lower features like edges, lines whereas higher layers of CNN learn much higher-level features like ears, nose, legs etc in case of a dog.

    f. The most important hyper params that CNN has are.

        i. Number of convolutional layers. Deeper networks usually learn complex features.

        ii. Number of kernels, size of the kernel in each layer

        iii. Number of Fully connected layers (usually 2) that are present at the end of the architecture.

        iv. Other common ones in any machine learning problem are

        1. batch size – usually the entire dataset does not fit into memory and hence networks are trained in batches. Some of the commonly used values are 16,32,64 based on available memory size and size of each sample.

        2. number of epochs – Epoch is one complete iteration over the dataset during the training.

        3. learning rate – how big of step to take based on gradient.

        4. loss function – A value that tells how bad the model is performing or how far the predictions are.

        5. optimizer – the algorithm to be used in finding gradients.

2. Initially a custom CNN architecture with 4 CNN layers and 2 FC layers was used.

    a. Drop out was applied between FC layers to avoid overfitting.

3. Then transfer learning technique was used.

    a. Pretrained resnet 50 is taken as network.

Benchmark

- Custom CNN trained with 4 CNN layers and 2 FC layers is used as benchmark model.

Methodology

Data Preprocessing

Train data:

1. Random resized crop of 224x244 is chosen.

2. Horizontal flip is done.

3. Images are normalized with mean and standard deviation values used for pretrained models as mentioned in PyTorch documentation.

Valid & Test data:

1. Images are resized to 256x256.

2. Center crop of 224x224 is taken.

3. Images are normalized with mean and standard deviation values used for pretrained models as mentioned in PyTorch documentation.

Implementation

Created a custom CNN from scratch.

1. Has 4 conv layers with filters of 16, 32, 64, 128 respectively. Padding is set to 1.

2. 2 fully connected layers with 1000, 133 nodes respectively to classify dog breeds.

3. Last fc layer has 133 nodes since we have 133 classes to distinguish from Drop out was applied between fc layers to avoid overfitting.

4. CrossEntropyLoss is used as loss function and Stochastic gradient descent is used as optimizer. A learning rate of 0.6 is used.

5. Model is trained for 20 epochs and batch size of 16 is used.

Refinement

Used transfer learning technique and trained a resnet50 model. Resnet is one of the classic architectures from Microsoft and have shown to do well for classification tasks.

1. Since resnet50 is trained on ImageNet dataset that has many different dog images, we can be confident that the parameters learned for resnet on ImageNet dataset would generalize well for our dataset too.

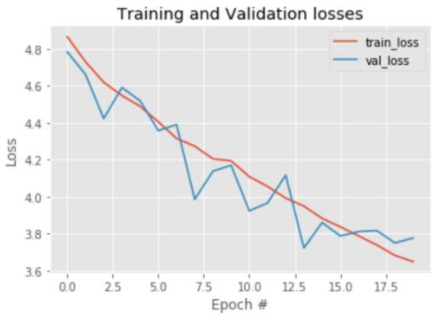
2. Cross entropy is used as loss function and Adam is used as optimizer with learning rate of 0.01.

3. Model is trained for 6 epochs.

Model evaluation and validation

Custom CNN

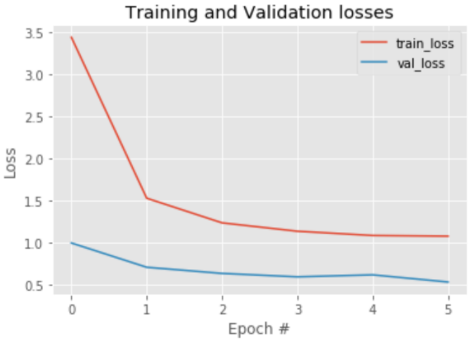
1. Obtained test accuracy of 17% on test set after training for 20 epochs.



Transfer learning resnet

1. Obtained test accuracy of 83% on test set after training for 6 epochs.

2. Since resnet is of much bigger architecture, it can represent and encode complex patterns and performs well.



Custom CNN is the benchmark here as mentioned in benchmark section. So compared to that resnet seems to have achieved much higher accuracy of 83%.

Justification

The transferr learned resnet obtains an accuracy of 83% which is not bad given the variation in dogs (133 classes). Also, its much higher than the accuracy of 17% that we got with benchmark model.