MACHINE LEARNING ENGINEER NANODEGREE

Fruit Images Recognition

Capstone Proposal

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Introduction

- **We want to build a Classifier that could distinguish between different classes of Fruits given their images.**

Domain Background

the domain from which the project is proposed

1

Like we said we want to build a classifier that could classify images of fruits.

such classifier will be based on a very important field in machine learning called deep learning.

2

Deep Learning:

1. Deep learning is a class of machine learning algorithms that use multiple layers that contain nonlinear processing units .
2. Each level learns to transform its input data into a slightly more abstract and composite representation.
3. Deep neural networks have managed to outperform other machine learning algorithms.
4. They also achieved the first superhuman pattern recognition in certain domains.
5. This is further reinforced by the fact that deep learning is considered as an important step towards obtaining Strong AI.
6. deep neural networks - specifically convolutional neural networks - have been proved to obtain great results in the field of image recognition.

Continue Domain Background

the domain from which the project is proposed

- ## Convolutional neural networks

1. Convolutional neural networks (CNN) are part of the deep learning models. Such a network can be composed of convolutional layers, pooling layers, ReLU layers, fully connected layers and loss layers.
2. In a typical CNN architecture, each convolutional layer is followed by a Rectified Linear Unit (ReLU) layer, then a Pooling layer then one or more convolutional layer and finally one or more fully connected layer.
3. A characteristic that sets apart the CNN from a regular neural network is taking into account the structure of the images while processing them. Note that a regular neural network converts the input in a one dimensional array which makes the trained classifier less sensitive to positional changes.

Motivation

the motivation for why this problem is considered important (the paper writers' point of view)

1 **Such network that we want to build would have numerous applications across multiple domains like autonomous navigation, modeling objects, controlling processes or human-robot interactions.**

2 **The area proposed that paper is most interested in is creating an autonomous robot that can perform more complex tasks than a regular industrial robot.**

1. An example of this is a robot that can perform inspections on the aisles of stores in order to identify out of place items or under-stocked shelves.
2. Furthermore, this robot could be enhanced to be able to interact with products so that it can solve the problems on its own.

3 **Another area in which this research can provide benefits is autonomous fruit harvesting.**

- While there are several papers on this topic already, from the best of our knowledge, they focus on few species of fruits or vegetables.
- In this paper we attempt to create a network that can classify a variety of species of fruit, thus making it useful in many more scenarios.

4 **we chose the task of identifying fruits for several reasons.**

1. fruits have certain categories that are hard to differentiate, like the citrus genus, that contains oranges and grapefruits. Thus we want to see how well can an artificial intelligence complete the task of classifying them.
2. fruits can be found in stores very often, so they serve as a good starting point for the previously mentioned project.

Continue Motivation

the motivation for why this problem is considered important (my point of view)

1 **hands-on experience in using deep learning**

2 **Fruit classification using computer vision can be helpful in many ways**

1. Fruit markets nowadays have more responsibility to distribute variety of fruits. The demand for fruit classification has been increased as different varieties of fruits come to the market in large quantities and distributed immediately to various retail shops.
2. Manual classification is time consuming and is a tedious repetitive job to classify tons of fruits in a shorter time. Hence there is a need for vision based fruit classification which also assists in packaging of fruits by using optimal packaging configuration.
3. It also reduces the labor and packaging expenses.
4. The classification of fruits also provides benefits in quality evaluation and defect finding.

3 **fruit classification using computer vision makes sense**

- Since Color and shape are primary properties of fruit images which help for better classification.

4 **The plenty of available data provided.**

helps a lot in building a good deep-learning classifier

Problem Statement

the problem that is to be solved

- ## The problem

  we want to build a good classifier that could classify a fruit to different classes up to 81 distinguishable classes given an image of that fruit.

- ## The Solution

  we will build a deep-learning convolutional network based classifier, since their great performance in image classification and computer vision .. the classifier will be trained by large and high quality data set to receive good results.

Datasets and Inputs

Information such as how the dataset or input was obtained, and the characteristics of the dataset.

- **Obtaining the input set**
  1. The images were obtained by filming the fruits while they are rotated by a motor and then extracting frames.
  2. Behind the fruits, a white sheet of paper is placed as background.
  3. due to the variations in the lighting conditions, the background was not uniform.. so an algorithm(flood fill type) was written to extract fruit from background.
  4. images were resized to 100x100 pixels.
  5. labels are given in next slide, some fruits have multiple varieties such as apples each of them being considered as a separate object. but since no scientific/popular name was found for each apple so it's labeled with digits (e.g. apple red 1, apple red 2 etc).

- **Characteristics**

  the set contains 55244 images of 81 fruits and it is constantly updated with images of new fruits as soon as the authors have accesses to them.

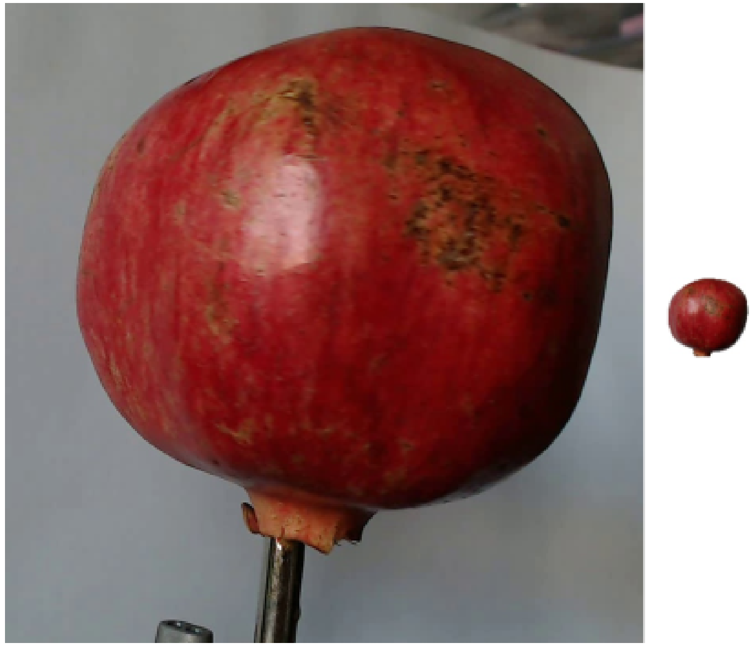

Figure 1: Left-side: original image. Notice the background and the motor shaft. Right-side: the fruit after the background removal and after it was scaled down to 100x100 pixels.

1

Label	Number of training images	Number of test images
Apple Braeburn	492	164
Apple Golden 1	492	164
Apple Golden 2	492	164
Apple Golden 3	481	161
Apple Granny Smith	492	164
Apple Red 1	492	164
Apple Red 2	492	164
Apple Red 3	429	144
Apple Red Delicious	490	166
Apple Red Yellow	492	164
Apricot	492	164
Avocado	427	143
Avocado ripe	491	166
Banana	490	166
Banana Red	490	166
Cactus fruit	490	166
Cantaloupe 1	492	164
Cantaloupe 2	492	164
Carambula	490	166
Cherry 1	492	164
Cherry 2	738	246
Cherry Rainier	738	246

2

Label	Number of training images	Number of test images
Cherry Wax Black	492	164
Cherry Wax Red	492	164
Cherry Wax Yellow	492	164
Clementine	490	166
Cocos	490	166
Dates	490	166
Granadilla	490	166
Grape Pink	492	164
Grape White	490	166
Grape White 2	490	166
Grapefruit Pink	490	166
Grapefruit White	492	164
Guava	490	166
Huckleberry	490	166
Kaki	490	166
Kiwi	466	156
Kumquats	490	166
Lemon	492	164
Lemon Meyer	490	166
Limes	490	166
Lychee	490	166
Mandarine	490	166
Mango	490	166
Maracuja	490	166
Melon Piel de Sapo	738	246
Mulberry	492	164
Nectarine	492	164
Orange	479	160
Papaya	492	164
Passion Fruit	490	166
Peach	492	164
Peach Flat	492	164
Pear	492	164
Pear Abate	490	166

3

Label	Number of training images	Number of test images
Pear Monster	490	166
Pear Williams	490	166
Pepino	490	166
Physalis	492	164
Physalis with Husk	492	164
Pineapple	490	166
Pineapple Mini	493	163
Pitahaya Red	490	166
Plum	447	151
Pomegranate	492	164
Quince	490	166
Rambutan	492	164
Raspberry	490	166
Salak	490	162
Strawberry	492	164
Strawberry Wedge	738	246
Tamarillo	490	166
Tangelo	490	166
Tomato 1	738	246
Tomato 2	672	225
Tomato 3	738	246
Tomato 4	479	160
Tomato Cherry Red	492	164
Tomato Maroon	367	127
Walnut	735	249

images from paper are provided to show us labels of classes provided in dataset and to give us an idea of sampling the date to train and test, the number in my own implementation may vary.

Pros and Cons of such dataset

- ## Strengths

1. dataset is large, that would help to build good classifier that is able to generalize and avoid overfitting, since deep learning algorithms perform a lot better with large datasets.
2. high quality images, low noise helps a lot in training a good classifier.
3. variety of classes of fruits, makes it useful application.
4. small size of images 100*100 lowers computation power and training time overhead.

- ## Weaknesses

1. large dataset means a lot of computation power and training time needed.
2. resizing images to small size like 100*100 can affect accuracy of classification badly, small size is detrimental when you have too similar objects (a red cherry looks very similar to a red apple in small images).
3. also a bad effect of using small size images is that it prevents us from using pre-trained models(having min limits of image size) until we resize images to bigger size which affects quality of the images.
4. labeling some fruits such as apples with apple1,apple2 .. etc , though it's valid but it's considered a vague labeling for data.

Solution Statement

description of solution to the problem.

- **as previously mentioned building deep-learning based classifier is the main solution.**

1. since deep-learning algorithms outperformed some other supervised algorithms in classification , specifically in image classification problem like we have in hand.
2. we will not use MLPs since it's expected to get low accuracy, no surprise since in order to feed an image to MLP we first need to convert the image matrix to a vector with no special structure, it has no knowledge that these numbers were spatially arranged in a grid.. another issue is MLPs use a lot of parameters, even small size images can contain over 50 millions parameters, you can imagine that the computational complexity for even moderately sized images with large dataset could get out of control pretty fast..
3. we will use CNN's with typical structure .. that extracts patterns and lower dimensionality.
4. CNNs can detect patterns such as edges,shapes and particular characteristics such as colors gradient since they preserve spatial structure in your input data, by using windows-like (filters) to analyze images..
5. we will add image augmentation to increase accuracy even more.
6. then we will use pre-trained models that already trained over millions of images of different classes that would give us even higher accuracy.

Benchmark Model

existing methods or known information in the domain and problem given, which can then be objectively compared to my solution.

1 **Compare the current stage of project with previous stages.**

- transfer learning phase compared to usage of image augmentation compared to basic CNN implementation.

2 **Comparison to the paper results.**

3 **Comparisons to other implementations on Kaggle.**

Table 3: Results of training the neural network on fruits-360 dataset.

Scenario	Accuracy on training set	Accuracy on test set
Grayscale	99.53%	91.91%
RGB	99.51%	95.59%
HSV	99.32%	95.22%
HSV + Grayscale	98.72%	94.17%
HSV + Grayscale + hue/saturation change + flips	99.46%	96.41%

The images demonstrate accuracy gained in Paper.

Evaluation Metrics

evaluation metric that can be used to quantify the performance of both the benchmark model and the solution model presented.

- **Metric used:**
  - accuracy metric: is the number of correct predictions made as a ratio of all predictions made.
  - This is the most common evaluation metric for classification problems.
  - it's used since our data in each class is nearly balanced.

- **Loss function used:**

  categorical loss function: because we have multiclassification problem(81 class).

Project Design

Start

Data Exploration

1- read data

2- visualization of data (distribution and samples review)

Data Pre-processing

1- Normalization

2- RGB , BGR or Grayscaling images

Model Implementation

implementation of basic CNN

Model Evaluation 1

Tuning basic model

Model Evaluation 2

compare to evaluation 1

Adding Image Augmentation

Model Evaluation 3

compare to previous evaluations

Using Transfer Learning

Model Evaluation 4

1- compare to previous evaluations and benchmark models.

2- test real life data (less ideal more messy)

End

Resources

1. **Published research paper:**

   Horea Muresan, Mihai Oltean, Fruit recognition from images using deep learning, Acta Univ. Sapientiae, Informatica Vol. 10, Issue 1, pp. 26-42, 2018.

2. **Dataset can be downloaded from:**

   Fruits 360 Dataset on GitHub.

   Fruits 360 Dataset on Kaggle.

3. **A Study on Image Processing Methods for Fruit Classification**

   Link

4. **Evaluation Metric used**

   metrics-evaluate-machine-learning-algorithms

5. **Sklearn Documentation**

6. **Keras Documentation**