# *Honors Project: Fruit Image Classification Using Neural Networks*

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GitHub:https://github.com/GeigerCarl/Honors-Project-Fruit-Image-Classification-Using-Neural-Networks

**Abstract**

In this paper I detail how I used neural networks to classify what fruit is in a selected image. I also describe the results and difficulties of using a pretrained model to classify images with multiple fruits.

**Introduction**

As machine learning continues to envelop the technological landscape, more and more products have relied on image classification to create solutions. In the autonomous vehicle industry, for example, correctly classifying objects is crucial in keeping an automated vehicle from causing an accident. Commerce also benefits from image classification. With the proper technology, checkout aisles can use cameras to classify the product rather than requiring a barcode scan. This is especially useful for fruits, which often do not have a barcode sticker added and as a result force the user to manually enter information to correctly have it added to the total. With image classification, the checkout aisle can recognize the fruit itself and automatically weigh and price it without any user input.

With this project, I hope to bring this hypothetical invention closer to reality. Previous attempts have been made in the machine learning community to correctly categorize fruits in an image. Horea Mureşan and Mihai Oltean's paper[1] on the subject utilized thousands of images of fruits taken in a lab setting to train a neural network model. While their focus was on single fruit images, my goal is to use a neural network model to also analyze how it will classify "field" images, or images that were taken outside a lab setting such as in a tree or clumped up with other fruit of the same type.

The rest of this paper will be split into four sections: methodology, experiment setup, results, and conclusion. Methodology will detail what software I chose to use and the neural network configuration. Experiment will explain what my data was and how I utilized my model to predict fruit. Results will detail my findings and conclusion will detail my final thoughts and possible improvements.

**Methodology**

The main tool I utilized for training my data was the PyTorch library[2]. PyTorch is an open-source Python library built to handle machine learning problems much like TensorFlow, but what sets the tool apart is its ease of use. Though it has much of the same capabilities as Google's TensorFlow library, its easy-to-create neural networks and clear error messages allow for users to quickly get started in research. This factor became crucial for my project, as I had limited time to create a functioning, trained neural network. PyTorch simplified the process: a network is represented as a class, and layers can be built through various function calls depending on what layer the user wishes to add. Due to this straightforward approach, I was able to quickly construct a neural network once I familiarized myself with the concepts of machine learning.

The neural network I eventually constructed was a Convolutional Neural Network. These networks often consist of Rectified Linear Unit (ReLU) layers, convolutional layers, pooling layers and one or more fully connected linear layers. Each layer is key for the model to properly learn and classify images. ReLU is a type of activation function that triggers only with non-negative outputs, allowing for quick neuron computations. Convolution layers are the main architecture behind the neural network, compromising of activation maps that control how neurons are activated (using activation functions such as ReLU for reference). Pooling layers simplify the image given by reducing the number of pixels that need to be computed. For example, if given 4 pixels, pooling layers are able to reduce this to one pixel, thus both controlling overfitting as well as reducing the amount of calculations needed per image. The final fully connected layer simply connects the nodes together such that the output of one layer is the input of the next layer. Most neural networks also possess a loss layer, which penalize the network for erroneous outputs.

My final neural network consisted of three convolutional layers. Each convolutional layer uses ReLU as its activation function, and is followed by a max2D pool layer that halves the image size. These three convolutional layers are followed by two linear layers, one with 1024 input channels and 512 output channels, and a second with 512 input channels and 11 output channels where each of the 11 output channels represents a fruit label. Finally, I used cross entropy loss for my loss function. Cross entropy loss utilizes entropy to make wrong choices more expensive to take.

**Experiment**

I utilized 5,883 training images and 1,972 test images to train my model. This data originated from the Fruits-360 dataset[1] and was crucial for my project. The full set of fruits and their image count can be found in Table 1 below.

**Table 1: Image Count**

| Fruit Label | Training Image Count | Test Image Count |
|---|---|---|
| AppleRed (Braeburn) | 492 | 164 |
| AppleGreen (Granny Smith) | 493 | 164 |
| Banana | 490 | 166 |
| GrapeBlue | 984 | 328 |
| GrapeWhite | 490 | 166 |
| Lemon | 492 | 164 |
| Orange | 479 | 160 |
| Pear | 492 | 164 |
| Pineapple | 490 | 166 |
| Raspberry | 490 | 166 |
| Strawberry | 492 | 164 |

I constructed my model by first training the model with the training images, then validating the model with the test images. Fruit images were organized in folders named after their label to allow for the code to determine what the correct label was for each image. Once every image was tested, I then calculated the overall training and test accuracy of the model, as well as the training loss. This process was repeated for 100 epochs total.

Once my model was properly trained, I then used it to classify images outside of the Fruits-360 dataset. These images were collected via DuckDuckGo's image search feature, (the full list of image sources can be found in the references section under Image References). A total of 90 images were collected, yet where they differ from the Fruits-360 database is in their level of noise. Whereas Fruits-360 had only one single fruit covering the entire picture, the images I collected often involved fruits still in trees, in a table, or all clumped together in batches. By using these images, I was able to test whether the model could properly classify images in a real-world setting.

**Results**

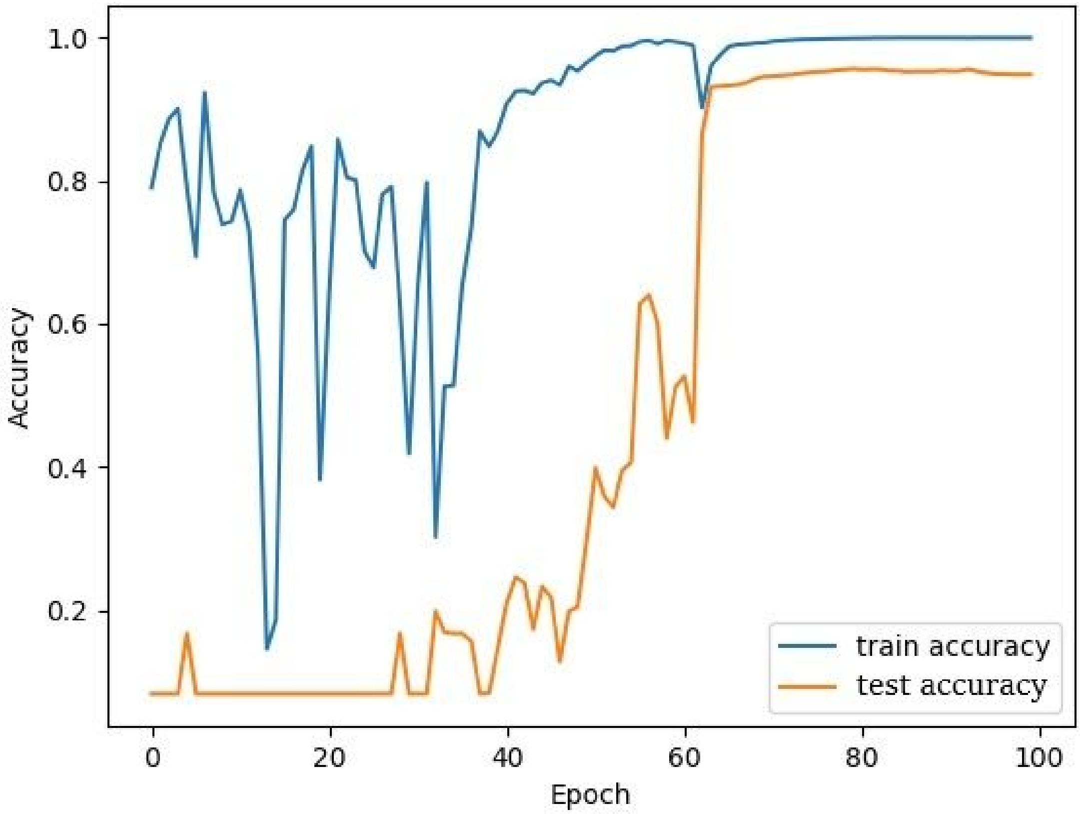


**Table 2: Fruit Accuracy From Fruits-360**

| Fruit Label | Test Accuracy |
|---|---|
| AppleRed | 68.902% |
| AppleGreen | 100.0% |
| Banana | 79.518% |
| GrapeBlue | 100.0% |
| GrapeWhite | 100.0% |
| Lemon | 100.0% |
| Orange | 100.0% |

| | |
|---|---|
| Pear | 100.0% |
| Pineapple | 99.398% |
| Raspberry | 100.0% |
| Strawberry | 100.0% |

Overall, the neural network performed well with the Fruits-360 database, achieving over 93% test accuracy after just 80 epochs. However, this accuracy was not equally balanced. As shown in Table 2, the model struggled with discerning between Braeburn apples and other fruits. The likely explanation for this is overfitting. When analyzing fruit, the model most likely makes oversimplifications that weigh the classifications heavily towards a certain number of fruits, thus causing most fruits to be labeled correctly 100% of the time at the expense of some fruits having lower accuracy.

While the model succeeds overall in recognizing fruit if it encompasses the entire image, it struggles heavily when the image is more complex. This is clearly found when testing the model with images found using a search engine. When analyzing each image individually, it was found that in nearly every image that involved a fruit in a tree or clumped with other fruits of the same class, the model suffers to correctly label the fruit in the image. This is mainly due to limitations in the training data. Since the model is unprepared for more intricate images, it oversimplifies its classification techniques, thus causing the accuracy to suffer when images become more complex. As a result, while the Fruits-360 database is crucial in introducing a model to fruits, it fails to prepare the model for real-life scenarios.

**Table 3: Fruit Accuracy From Search**

| Fruit Label | Test Accuracy |
|---|---|
| AppleRed | 0.0 % |
| AppleGreen | 0.0 % |

| | |
|---|---|
| Banana | 11.11 % |
| GrapeBlue | 0.0 % |
| GrapeWhite | 40% |
| Lemon | 20% |
| Orange | 0.0 % |
| Pear | 0.0 % |
| Pineapple | 10.0 % |
| Raspberry | 40 % |
| Strawberry | 27.27 % |

**Conclusion**

In this paper I showcased the power of Convolution Neural Networks to classify images as well as its shortcomings. Though my trained model did succeed in classifying most images, it struggled when the image increased in complexity. Further work would involve adding more training images that encompass more real-world scenarios such as fruit on trees or fruit in baskets. This will help the model learn to properly classify fruits even if they are grouped together. Another interesting problem that I was unable to implement is having the classifier differentiate between multiple fruits in one image. Though the problem is much more complex to solve, it could also greatly benefit commerce at large by allowing customers to scan items even when they are mixed in with other items in a checkout aisle.

**Acknowledgements**

I give my sincerest thanks to John Olafenwa for his incredibly informative article[3] on PyTorch, as well as Horea Mureșan and Mihai Oltean's for creating the Fruits-360 database that I used so heavily during this project.

**References**

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