RipeOrWrong: Using Deep Learning Networks to Determine the Quality of Fruits and Vegetables Using Thermal Imaging

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Motivation

- US Dept. of Agriculture estimates that retailers lose ~$15 billion in fruit and ~$18 billion in vegetables due to quality standards. (2011)
- 25% of fruits and vegetables are thrown out in the US, 2/3 of which are due to poor quality
- Poor Fruit Quality = waste of time and money

Goal

- Prevent consumers from wasting time and money on un-ripened and/or blemished fruits and vegetables

Related Work

1. Visual Detection:
   - Machine Learning successful at identifying visible blemishes
   - Visual spectrum is not sufficient for bruising/ripeness detection
2. Spectral Detection:
   - Use multispectral + hyperspectral imaging → "chemometrics"
3. Thermal Detection:
   - Measure heat capacity over 4 minutes to determine ripeness
   - Convert radiant flux into a measure of thermal emissivity
4. Consumer Applications:
   - WISci + Scio: hardware project to make portable spectrometers
   - Determine chlorophyll composition → ripeness
   - No ML + Spectrometers are expensive and not portable

Approach

1. Combine mobile thermal imaging technology and machine learning capabilities to improve the detection of poor fruit quality
2. Initially focus just on apples
3. Develop a modularized framework to seamlessly add new fruits and vegetables to the model and application

Conclusions

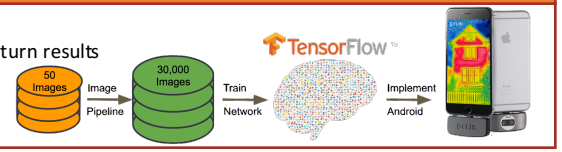
- Works with similarly shaped fruits (peaches, plums, pears, apples)
- Accurate in reporting that a bad piece of fruit is undesirable
- Prone to report good apple as bad due to heat signatures in the background of the image such as hands and other people
- Unable to truly determine the ripeness of the fruit without metadata or better dataset

Future Work

- Background stripping algorithm to eliminate some noise and heated objects in the background
- Utilize the TensorFlow NDK to perform native inference
- Create graded ripeness dataset and use image thermal metadata

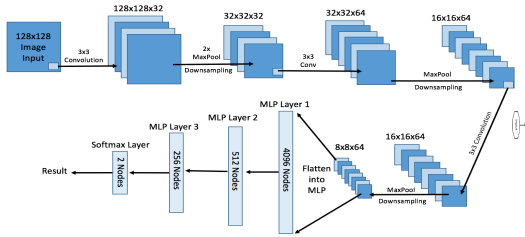
Designing the Classifier

- Python server running on AWS EC2 instance
- Open socket → read image→ resize → run through net → return results
- Two important issues:
  1. Which model to use: FruitNet vs. GoogLeNet
  2. How to train the model



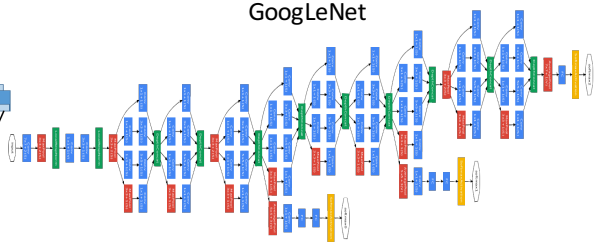
Implementing the classifier: selecting the model

FruitNet



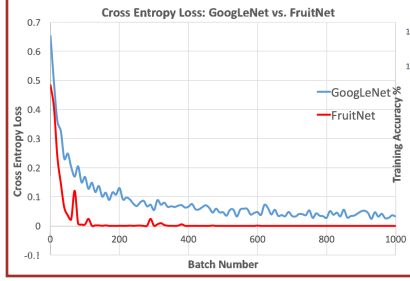
FruitNet is a custom neural network developed as a part of RipeOrWrong and it gets inspiration from AlexNet. It has 3 layers of convolution / pooling followed by 3 layers of a Multilayer perceptron. It uses 3 x 3 kernels in its' convolutions and has a softmax output of size 2.

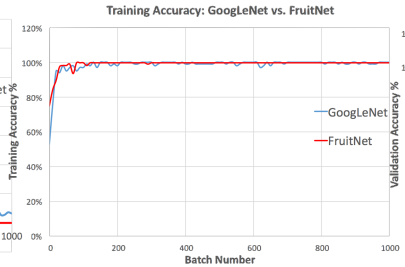
GoogLeNet

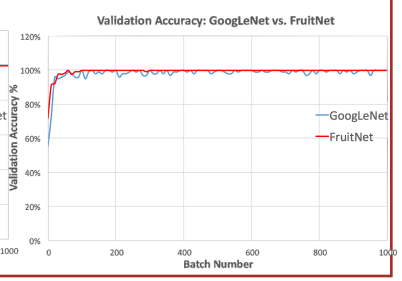


GoogLeNet is a pre-trained inception graph developed by Google. It is 22 layers deep, employs a range of kernel sizes for its convolutions, and fully leverages parallelism. Furthermore, the model comes fully trained and a script can be used to re-train the model

Results







Strengths of FruitNet

1. FruitNet is more specifically tailored to read in thermal images.
2. FruitNet achieves a lower cross entropy loss.

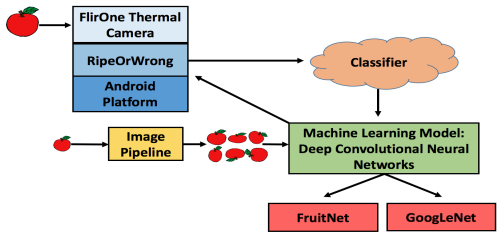
Strengths of GoogLeNet

1. Achieves an identical error rate on both the training and validation set.
2. Takes only 20 minutes to train
3. Superior generalization performance due to its diversity of kernel sizes

Conclusion

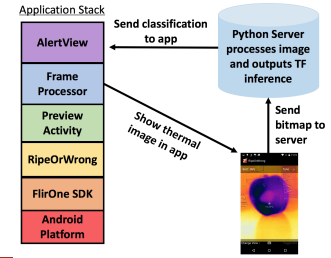
GoogLeNet was for RipeOrWrong due to its ease of use. Re-training a model with fully functional feature maps enables the seamless addition of new fruits and vegetables into the application.

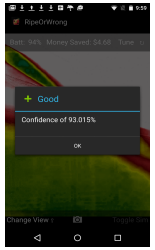
Overall System Architecture



Designing Mobile Application

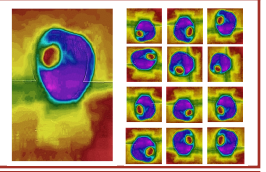
Once receiving the frame stream from the FlirOne camera, the application encodes a thermal snapshot of the fruit and sends it to the server through a socket, before waiting for a response. An alert view presents the user with the application's recommendation





Implementing the Image Pipeline

- Create a dataset of several thousand images
- Perform 100 iterations of randomly sized seams carves on images
- Rotate and translate images



Abstract:

This presentation details the design, development, and evaluation of RipeOrWrong, an Android application that identifies bruised or under/over-ripened fruits and vegetables. The application utilizes the FlirOne thermal imaging camera as well as a deep neural net. Although RipeOrWrong focusses on apples, it has been designed and documented so that the implementation of other fruits and vegetables is seamless. This application aims to save people money by leveraging both thermal imaging and modern machine learning.