Homework 4
BSysE 530
Edge Detection and Hyper-Spectral Image Analysis

Abhijay Ghildyal

EECS Washington State University
abhijay.ghildyal@wsu.edu

8^{th} April 2019

Contents

1 Introduction

In this homework we shall be dealing with edge detection in hyperspectral images.

1.1 Hyper-Spectral Images

There are only certain regions of the electromagnetic spectrum or a certain array of electro magnetic waves that is visible to the human eye. These waves are called electromagnetic because they consist of combined electric and magnetic waves that result when a charged particle i.e. an electron accelerates. The electro magentic spectrum has been divided into distinct discriptive regions as follows:

1. Gamma rays : shortest wavelengths ($\leq$ 0.01 nanometers)
2. X-Rays : range in wavelength from 0.01 - 10 nm
3. Ultraviolet(UV) : range in wavelengths of 10 - 310 nm; futher sub-divided into A, B and C
4. Visible light (BGR) : range in wavelengths from 400 - 700 nm
5. Infrared : ranges from 0.7 μm - 100 μm in wavelength. It has 3 main regions
    (a) Near Infrared (NIR) : 0.7 - 1.3 μm
    (b) Shortwave Infrared (SWIR) : 1.3 - 3 μm
    (c) Far or Thermal Infrared : 3 - 100 μm

    This is used extensively in remote sensing and can also be helpful in observing vegetation health, soil composition and moisture content.
6. Microwaves : range from 1mm to 1m; essentially high frequency radio waves
7. Radio waves : Approximately 1mm to several hundred meters

By capturing information from parts of the electro magnetic spectrum other than the visible light more information about an object can be assesed. Hence, **hyperspectral images have a higher level of spectral detail and with this information the parts of an image which otherwise is unseen to the human eye can also be analyzed.** Landsat-8 satellite imagery uses multi-spectral images which in general uses 3-10 bands (not specific to Landsat-8) which are wider but hyperspectral images use 100s of bands which are narrower, containing more information. Hyperspectral imagery has been useful to map invasive species and also in mineral exploration.

In agriculture hyperspectral and multispectral images have several real world applications. It ranges from Crop monitoring for nutrients, water-stress, disease, attack by insects to overall health of the plants. These operations can be performed by visual examination of crops from the ground or air. These tasks are difficult when performed by human eye as it is sometimes not possible to accurately determine or discriminate between healthy foliage and foliage suffering various kinds of stress. A number of times it has been seen that a specific condition can be detected at an early stage which otherwise would be well-advanced before visual symptoms become noticeable, even to experienced observers.

Benefits of using hyperspectral and multispectral imaging include: these technologies are low cost when compared with the using human resources for scouting, provide consistent results, simpler than many other techniques, faster analysis, non-destructive, highly accurate, and can be applied to a broad range of applications.

1.2 Edge Detection

In early stages of vision processing or pre-processing it may be important to identify features. These features in images can be relevant to estimating the structural properties of objects in a scene. Edges are one such feature and define the boundary between two different regions in an image. It can be said to be a significant local change in the image intensity, which is like a discontinuity in either the image intensity or the first derivative of the image intensity. These can be step discontinuities, where the image intensity changes abruptly or a line discontinuities, where the image intensity changes abruptly in value but then returns to the starting value after a short distance. Hence, gradients are used for measurement as it is a change and helpful in detecting the amount of change in function of image intensity. **Even in deep learning techniques edges play a major role in generating features for identifying, localizing and classifying objects.**

Modern precision agriculture techniques rely on site-specific tactics like in the case of trying to reduce environmental impact from over application of fertilizers and pesticides, and crop health monitoring. Edge detection can be useful as an important pre-processing to pin-pointing objects for such applications.

2 Materials and Methods

This assignment was done using python 3 and opencv

2.1 Gaussian Blurring

Gaussian blurring also goes by the name two-dimensional Weierstrass transform. In mathematical terms the application of a gaussian blur to an image is also the same as applying a filter or convolving the image with a Gaussian function. By using a cicular filter or convolving by a circle is more accurate and produces a bokeh effect. As we know that the Fourier transform of a Gaussian is another Gaussian, the application of this blurring leads to the reduction of the image's high-frequency components and thus, gaussian blurring is a low pass filter.

In my assignment it was helpful in making the image better after thresholding, as all the parts after blurring get connected Figure 1

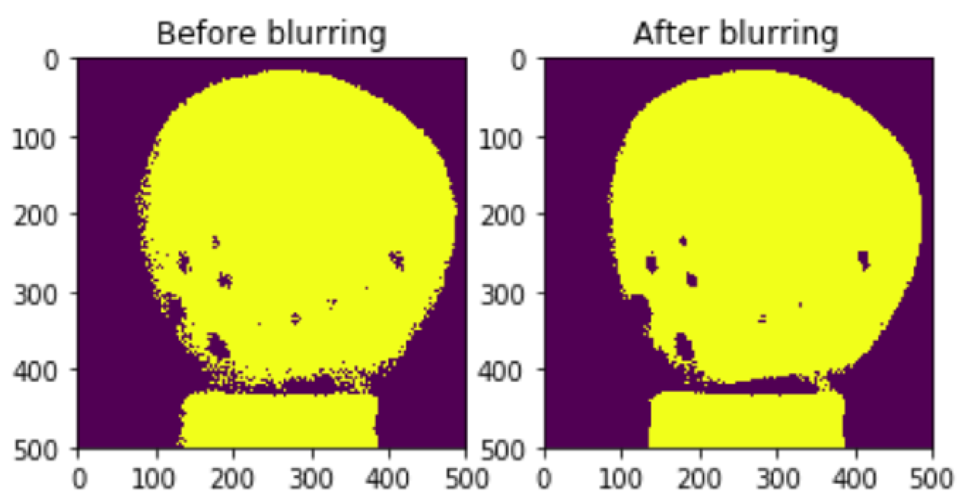

Figure 1: Before and After blurring

2.2 Canny Edge Detection

A technique which was developed by John F Canny is one of the most popular edge detection algorithm. It is a multi-stage algorithm:

1. Noise Reduction: Removing noise in the image with a 5x5 Gaussian filter
2. Finding Intensity Gradient of the Image : Gradient direction is perpendicular to the edges
3. Non-maximum Suppression : Check pixels if it is a local maximum in its neighborhood in the direction of gradient
4. Hysteresis Thresholding : Use thresholding and pixel connectivity for finding if the pixels are really edges or not.

The parameters in Canny edge detection are upper and lower thresholds. Now if the intensity gradient of a pixel is greater than the higher threshold, it will get added as an edge pixel in the output image and will be rejected if its intensity gradient value is lower than the lower threshold. It will be added as an edge pixel if a pixel has a intensity between the lower and higher threshold. Also only those pixels having values higher than the higher threshold and which are connected to the edge be considered as an edge pixel.

2.3 Histogram Equalization

Histogram is a graphical representation of the intensity distribution of an image. In simple terms, it represents the number of pixels for each intensity value considered. Histogram Equalization is an image processing technique used to improve contrast in images. This is achieved by stretching out the intensity range of the image. It increases the global contrast of images and usable data is represented by close contrast values.

In my assignment it was helpful in making the contrast of the image better Figure 2

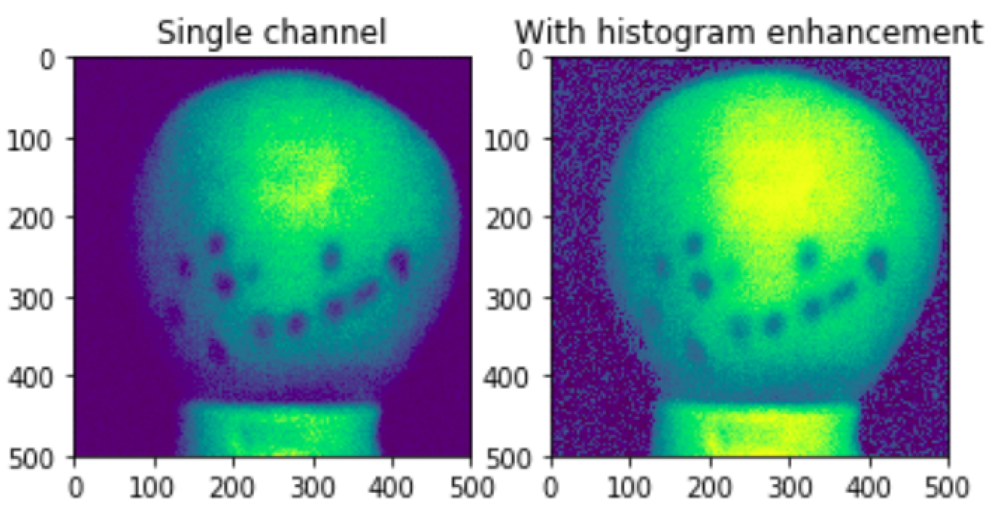

Figure 2: Image enhancement using histogram equalization

2.4 Thresholding using color histogram

Color histogram of the image was also used for finding an appropriate threshold to identify the pixels forming the apple more distinctly Figure 3

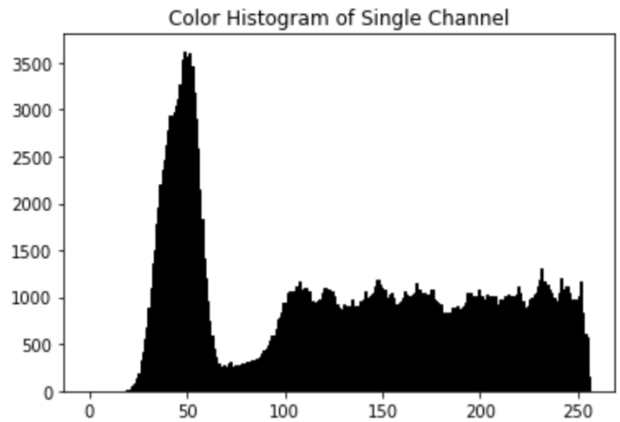

Figure 3: Color Histogram

2.5 Feature distance of pixels to a mean pattern vector

The spectral distances to the mean vector will help in getting an approximate measure of the object from all the images.

In my assignment it was helpful in collecting spatial features from the various channels available in the hyper-spectral image and get a collective understanding of the details of the object Figure 4

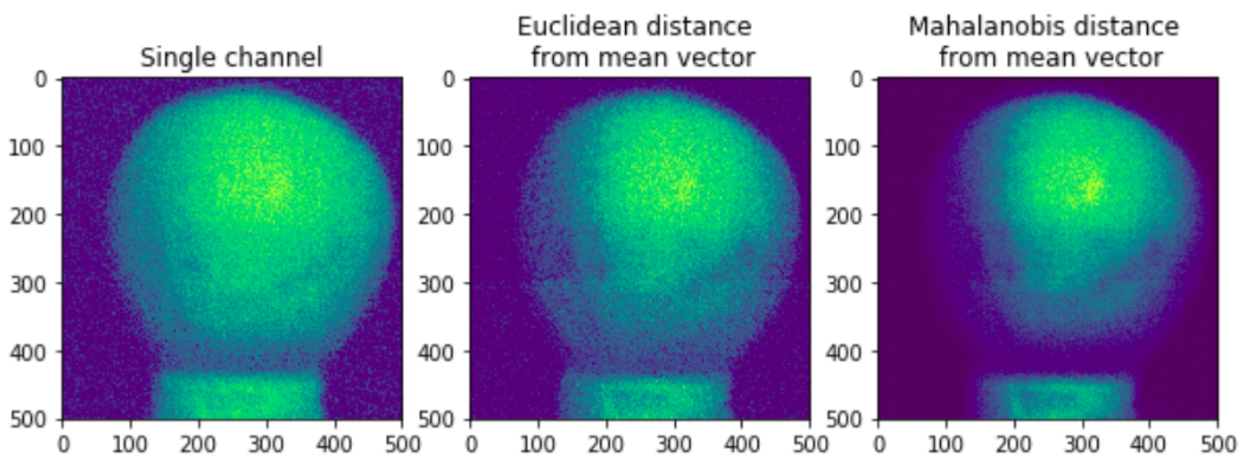

Figure 4: Feature Distance from mean vector

3 Results and Discussions

3.1 Single Channel

3.1.1 Without Histogram Equalization

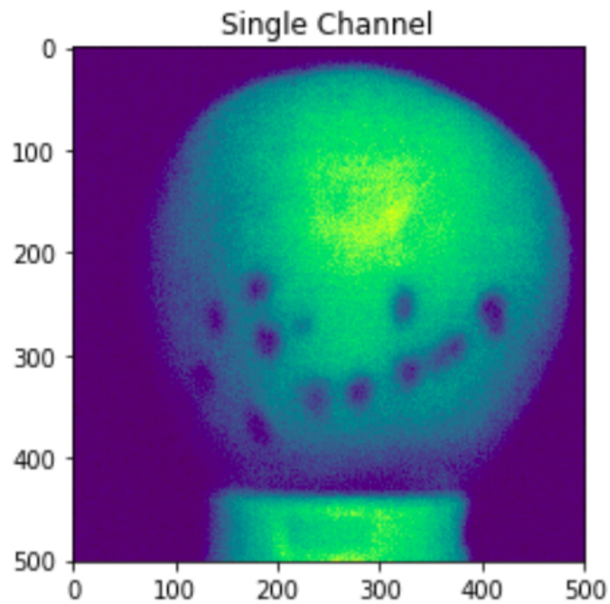

Figure 5: Single Channel

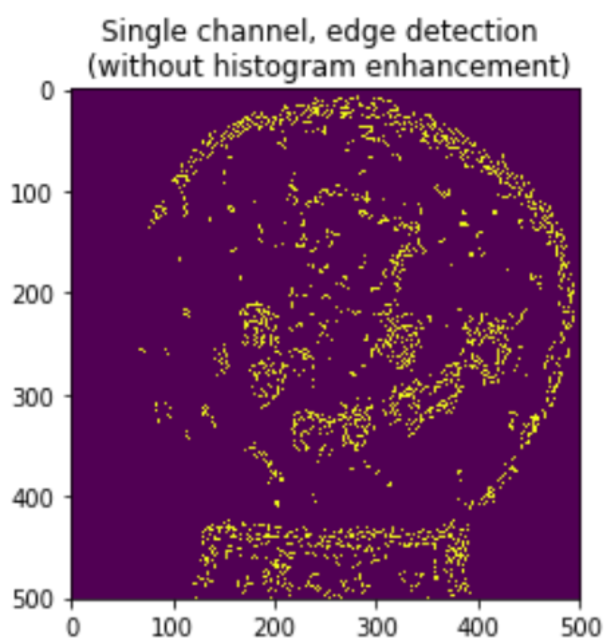

Figure 6: After gaussian blurring and edge detection

3.1.2 With Histogram Equalization

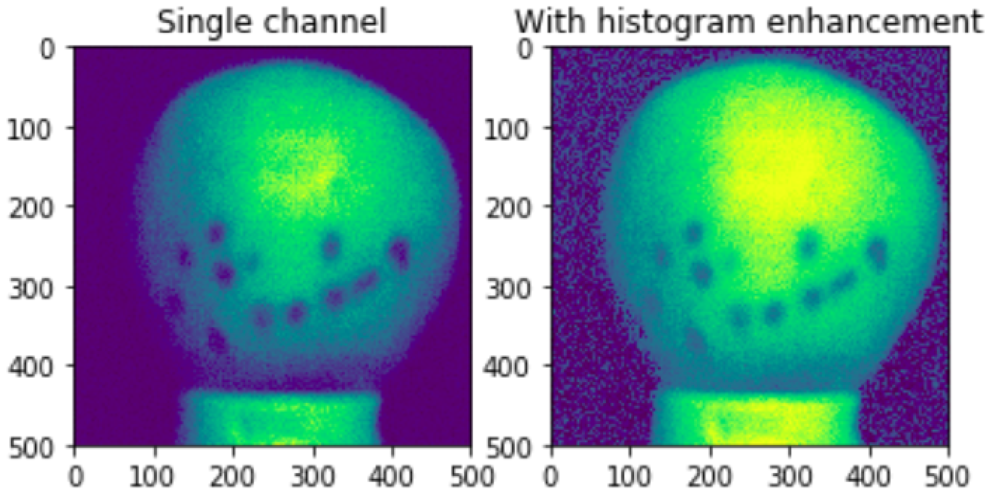

Figure 7: After histogram enhancement

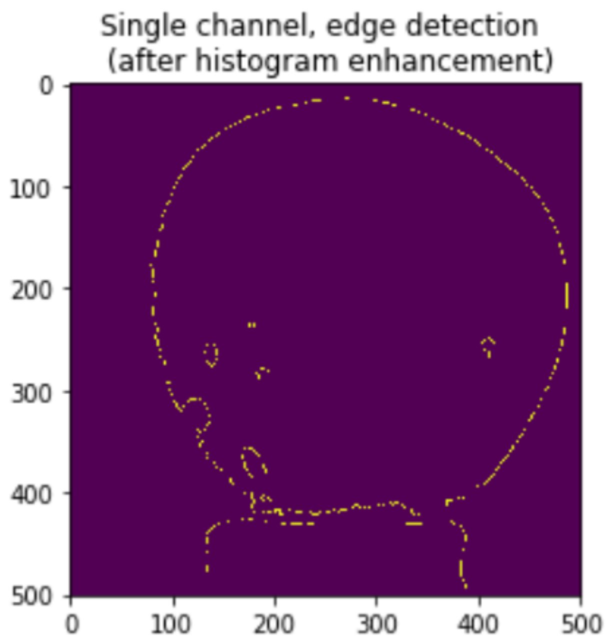

Figure 8: Edges detected after thresholding, blurring and histogram enhancement

3.2 Fifty Channels

Fifty-dimensional (every other channel from 650 to 750) feature distance of pixels to a mean pattern vector

3.2.1 Without Histogram Equalization

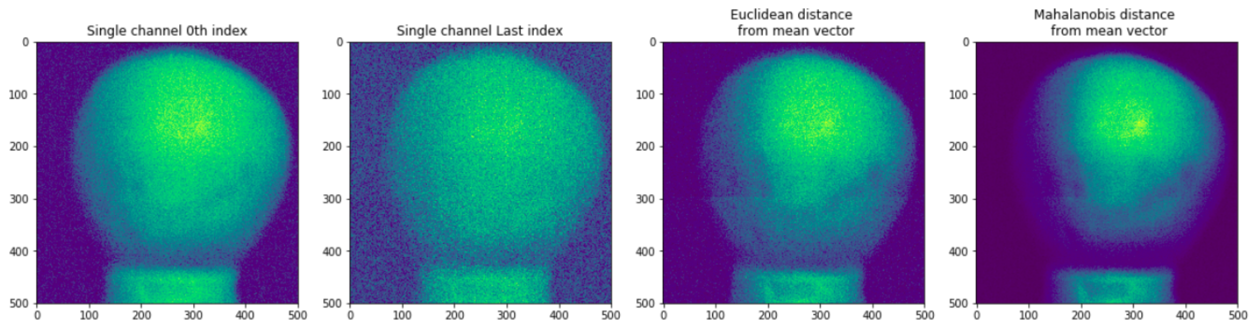

Figure 9: Feature Distance from mean vector

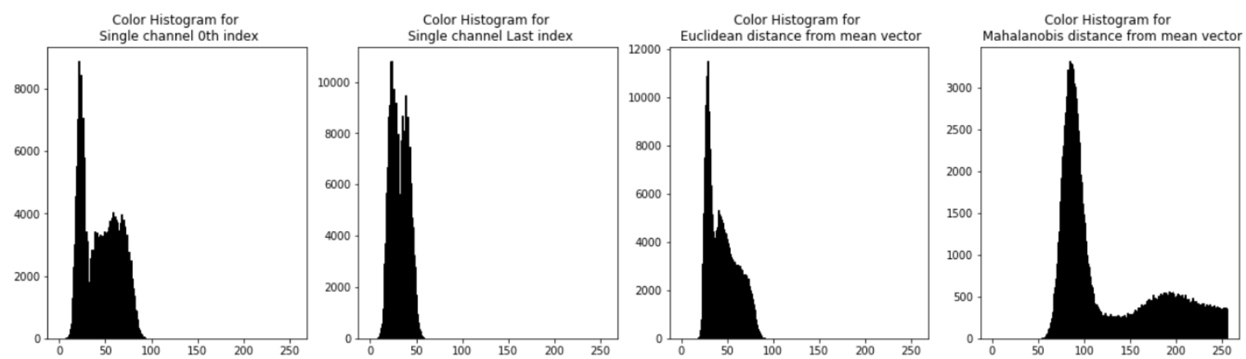

Figure 10: Color Histograms of the images

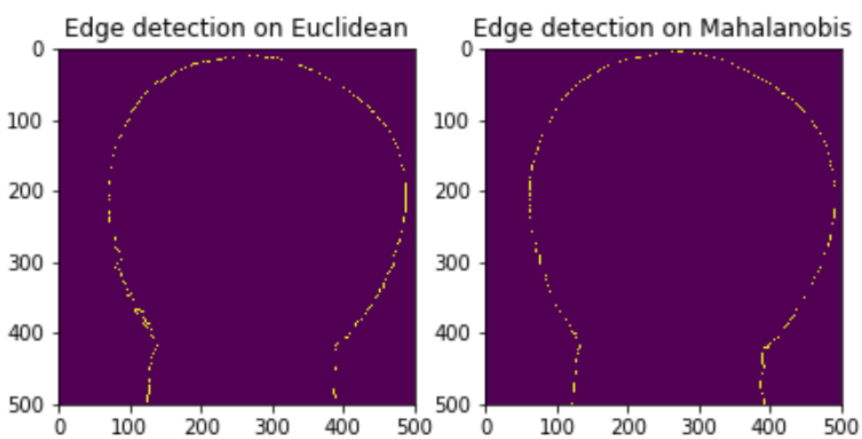

Figure 11: Edges detected

3.3 With Histogram Equalization

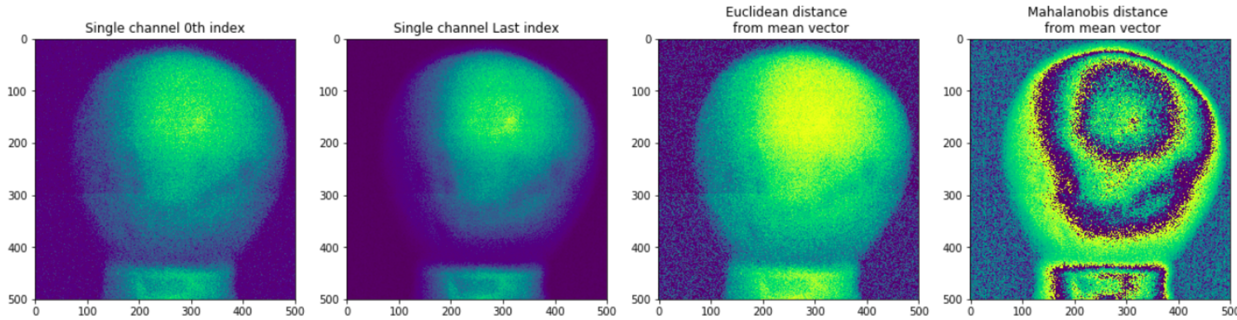

Figure 12: Feature Distance from mean vector

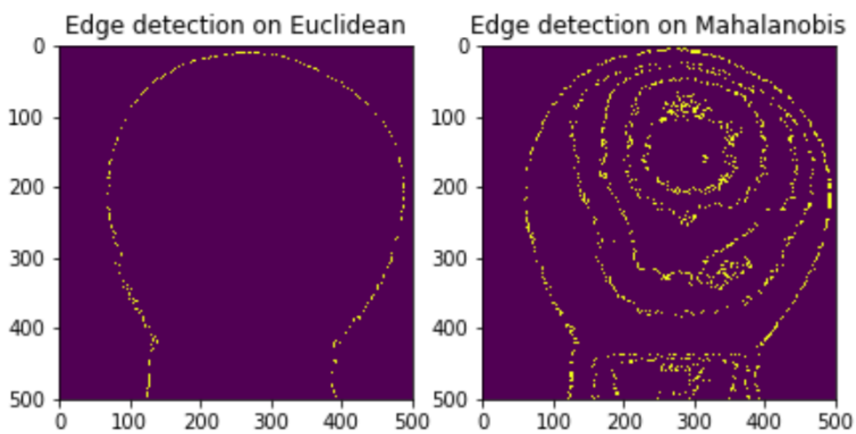

Figure 13: Edges detected

4 Conclusion

From Section 3.1.1 we can see that the edge detection could not perform well on a single channel image while in section 3.1.2 with histogram enhancement the results were much better for detecting the edge of the apple. In section 3.2 fifty channels were used for the same analysis. From the feature distance from mean vector estimate of the channels a better detailed image is obtained as seen in Figure 9. On observing the color histogram of these newly formed images in figure 10 it is evident that mahalanobis distance was able to smoothen out the pixel values and capture the information well. In figure 11 we see that both the distance techniques were useful to get the edges of the apple correctly. With histogram equalization similar results are seen except with mahalanobis distance, where a more detailed version of the edges is obtained. It is showing edges on the apple also, which is due to the difference in light reflectance from the apple's surface (because of its placement with respect to light source maybe) and is little extra detail which is not required at present.

Please see next page (below) for answers to the questions asked in the assignment.

4.1 Questions asked in the assignment

Q1. What are the advantages and disadvantages of each method investigated?
Ans. Advantages/disadvantages of the methods/techniques investigated are as follows:

- With a single channel we are able to detect the edges but the darker patches are not processed properly which reduces the size of the apple, as per the edges detected
- With 50 channels the darker patches become visible as more information gets added from various channels which deal with different regions of the electro-magnetic spectrum
- Though as seen in the case of mahalanobis distance too much detail gets added for edge detection after applying histogram equalization on it
- Blurring helps in smoothening out the edge pixel values to give a sharper boundary after thresholding is done. This helps when the gradient is calculated giving finer edges
- Histogram equalization is helpful in improving the contrast of the image and helps in detecting better and sharper edges

Q2. What is the primary limitation of analyzing hyper-spectral dataset and what is the potential solution(s) to minimize this limitation?
Ans. The primary limitation of analyzing hyper-spectral dataset is that there is too much information to process which increases the complexity of the task both in time and space. Hyperspectral image dataset would require a large space to store it. To process so many channels by adding all the information in a useful manner would require extensive compute thus increasing the time complexity of any algorithm being used for it.

Overcoming these limitations should not be difficult. With a little prior knowledge the amount of processing for the task can be handled or managed better. This way an intelligent approach on channel selection can be implemented for the analysis. For computation more sophisticated algorithms or hardware components can be built, which are able to manipulate the matrices faster and reduce time spent in waiting for the analysis to show results.

Q3. Are the techniques you developed transferable to other applications?
Ans. One of the main advantages of using hyperspectral images is that the analysis on them is easily transferable to other applications. With similar techniques edges can be detected for various purposes as mentioned in the introduction.

The only detail in the implementation that will change are the threshold values for the detection of edges which will differ with location, lighting conditions and the object which is being detected. Rest, the methodology and functions being used wouldn't change.