

*A dissertation on*  
**Fruit Recognition and Quality Detection Based on  
Different Classifiers: A Case Study of Apple**

*submitted in partial fulfillment of the requirements  
for the award of degree of*

**Masters of Technology**  
**In**  
**Computer Science and Application**



*Submitted By*

**Varinderjit Kaur**

**Roll No. 601303028**

*Under the supervision of*

**Dr. Rajiv Kumar**

**Assistant Professor**

COMPUTER SCIENCE AND ENGINEERING DEPARTMENT

THAPAR UNIVERSITY

PATIALA – 147004

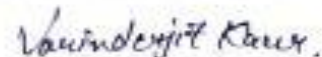
JULY 2015

## CERTIFICATE

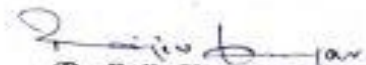
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I hereby certify that the work which is being presented in the dissertation entitled, "*Fruit Recognition and Quality Detection Based on Different Classifiers: A Case Study of Apple*", in partial fulfilment of the requirements for the award of degree of Master of Engineering in **Computer Science and Applications** submitted in **Computer Science and Engineering Department of Thapar University, Patiala**, is an authentic record of my own work carried out under the supervision of **Dr. Rajiv Kumar** and refers other researcher's work which are duly listed in the reference section.

The matter presented in the dissertation has not been submitted for award of any other degree of this or any other University.

  
(Varinderjit Kaur)

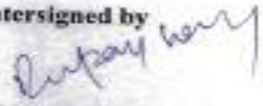
This is to certify that the above statement made by the candidate is correct and true to the best of my knowledge.

  
(Dr. Rajiv Kumar)

Assistant Professor

Computer Science and Engineering Department

Countersigned by

  
(Dr. Deepak Garg)

Head

Computer Science and Engineering Department

Thapar University

Patiala

  
(Dr. S. S. Bhatia)

Dean (Academic Affairs)

Thapar University

Patiala

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**VARINDERJIT KAUR**

**(601303028)**

## **ABSTRACT**

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The ability to identify the fruits based on quality in the food industry is very important now a days where every person has become health conscious. There are different types of apples available in the market. However, to identify best quality apples is cumbersome task. Therefore, the need arises to develop an algorithm that can detect the apples and classify it in order to increase its market value. Moreover, recognizing and classifying the both types of apples which are harvested and which are not harvested with same algorithm is not possible in one go. Therefore, the researchers proposed two different types of approaches for recognizing the apples in the images, one in which apples are harvested and other in which apples are not harvested. For the type of images in which apples are not harvested, one approach is used in which analysis is performed on the basis of color and shape. For the type of images, in which apples are not on the tree, another approach is used in which analysis is performed on the basis of edge and shape. After recognizing the apple in the respective image, quality is checked by different classifier (SVM and KNN). Proposed apple recognizing technique analyzes, identifies and classifies apple successfully up to 89.16% accuracy by SVM and up to 93.33% by KNN.

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# CHAPTER 1

## INTRODUCTION

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### 1.1 Overview

Image processing is an area that keeps on growing, with new applications being developed with every passing minute. It is a captivating area which has evolved with applications in various areas like entertainment industry, space program etc. The most concerning prospect of this data transition is its capability to transmit and acquire complex information that oversteps normal written text. Visual information sent in the way of images, has evolved as one of the major mode of communication in the 21<sup>st</sup> century. Description of image processing in detail is described as below.

### 1.2 Image Processing

It is a process of converting an image into the digital image to obtain the enhancement in image or to select some effective information from it. It uses any type of signal processing in which image is input and output of processing may result into an image or features of an image. It includes vast applications in various trades such as business, medical, industries etc.

Following are the main steps including in image processing:

- (a) Acquiring an image using scanner or by digital cameras.
- (b) Manipulation and analysis of the image is performed, which includes data compression and enhancement of image.
- (c) Obtained outcome of image processing can be an image or the details of the characteristics of image based upon the analysis of an input image.

### 1.3 Purpose of Image processing

Image processing can be used for different objectives. Broader division of purposes is shown below:

- (i) Image Recognition: Objects present in image is get qualified.
- (ii) Measurement of pattern: Different objects in an image are measured.
- (iii) Image sharpening and restoration: this is for the creation of better image.
- (iv) Image retrieval: Image of interest is explored.

### 1.4 Basics of Digital Image Processing

Basics of digital image processing are explained in the following section, which includes the basic representation of digital image.

#### 1.4.1 Representation of digital Image

Digital image is saved in the form of matrix and can be represented in two dimensional functions of space. Let  $f(x, y)$  be the function to represent an image. Input parameter of the function:  $x$  represents the row coordinates of image for each pixel and  $y$  represents the column coordinates of image for each pixel in the matrix of image. Value at each pixel represents the intensity value of that pixel. Representation of coordinates of digital image is shown in figure 1.1.

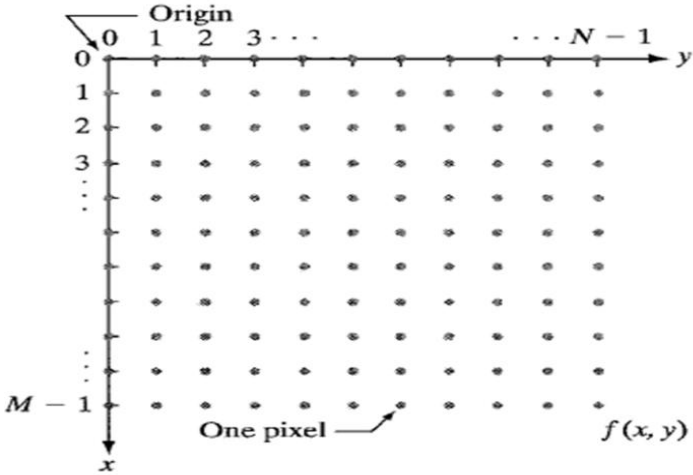


Figure 1.1: Showing coordinates of digital image.

As coordinates shown in figure 1.1 signifies that a digital image can be represented in the matrix form mathematically as shown in figure 1.2.

$$f(x,y) = \begin{bmatrix} f(0,1) & f(0,2) & \dots & f(0,N) \\ f(1,1) & f(1,2) & \dots & f(1,N) \\ \vdots & \vdots & \dots & \vdots \\ f(M,1) & f(M,2) & \dots & f(M,N) \end{bmatrix}$$

In mathematical representation of an image, there are M rows and N columns of matrix. That means represented image contains  $M \times N$  pixels, where M and N represents width and height of an image. In mathematically form of image,  $f(x, y)$  of matrix represents the pixel value of image.

## 1.5 Types of Digital Image

Digital image includes various types of images in order to perform the processing on images. Basic four types of images are mentioned in following sections:

### 1.5.1 Binary Image

In a binary image, each pixel assumes one of only two discrete values: 1 or 0. A binary image is stored as a logical array as shown in figure 1.2.

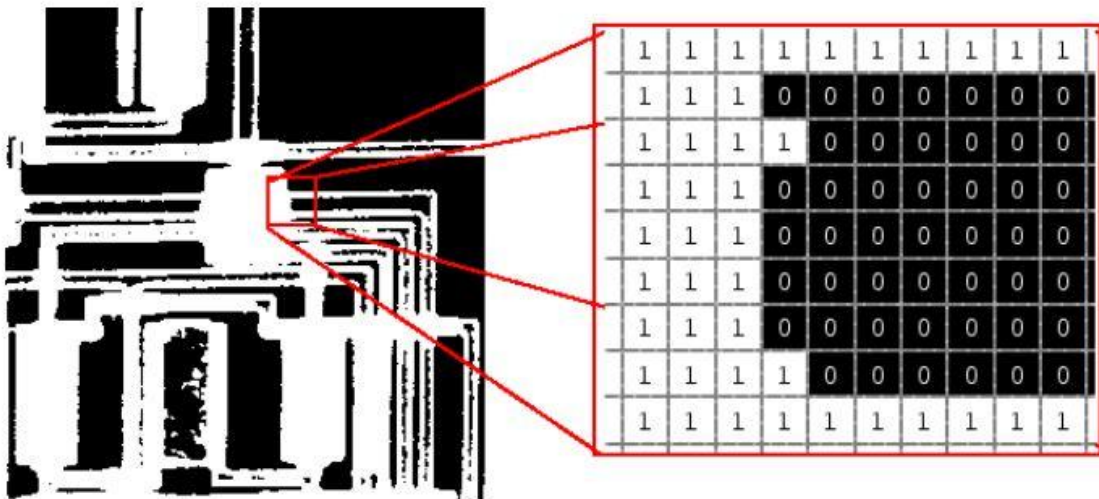


Figure 1.2: Binary Images with its pixel values.

### 1.5.2 Indexed Image

An indexed image (also called pseudocolor image) is that image which comprises of an array and a colormap matrix as shown in figure 1.3. Colormap is directly indexed by the pixel values of array. Traditionally colormap is represented by map.

Colormap matrix is consisted of array of dimension  $m \times 3$  where red, green and blue components are stored in each row of colormap. Direct mapping of pixel values to colormap is used by the indexed image. Color of each pixel is according to the stored value in colormap. Values of colormap can be arbitrary.

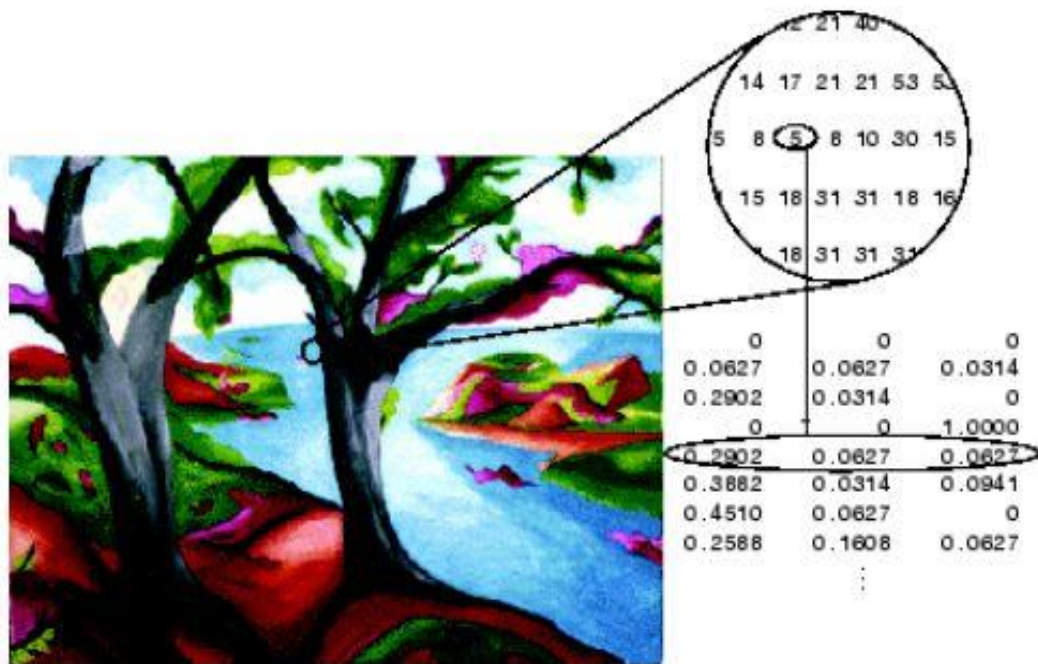


Figure 1.3: Indexed image with its pixel value mapped to colormap.

### 1.5.3 Grayscale Image

A grayscale image (also called intensity, or gray-level) is a single matrix whose each element represents the intensity of each pixel as shown in figure 1.4. Pixel value as 0 signifies black color, 1 signifies the white color and intermediate values are represented by the shades of gray.



Figure 1.4: Grayscale image.

### 1.5.4 Tricolor Image

A tricolor image (also called RGB image) is an image showing natural colors of an object in which each pixel is specified by three values, each for the red, blue, and green planes of the pixel's color. Colormap is not used in tricolor images. The combination of red, green and blue colors saved in each channel gives the color of corresponding pixel.

A pixel whose color planes values are (0,0,0) is displayed as black, and if a color planes values are (255,255,255) is displayed as white. Such as, the red, green, and blue color planes values of the pixel (20,15) are stored in RGB(20,15,1), RGB(20,15,2), and RGB(20,15,3), respectively.



Figure 1.5: Colored Image.

For the further explanation of three planes of RGB image. Figure 1.6 (a) shows a RGB image. Figure 1.3.1 shows the red plane of this image shown in figure 1.6 (b). Similarly figure 1.6 (c) and figure 1.6 (d) shows the green and blue planes of a RGB image respectively.

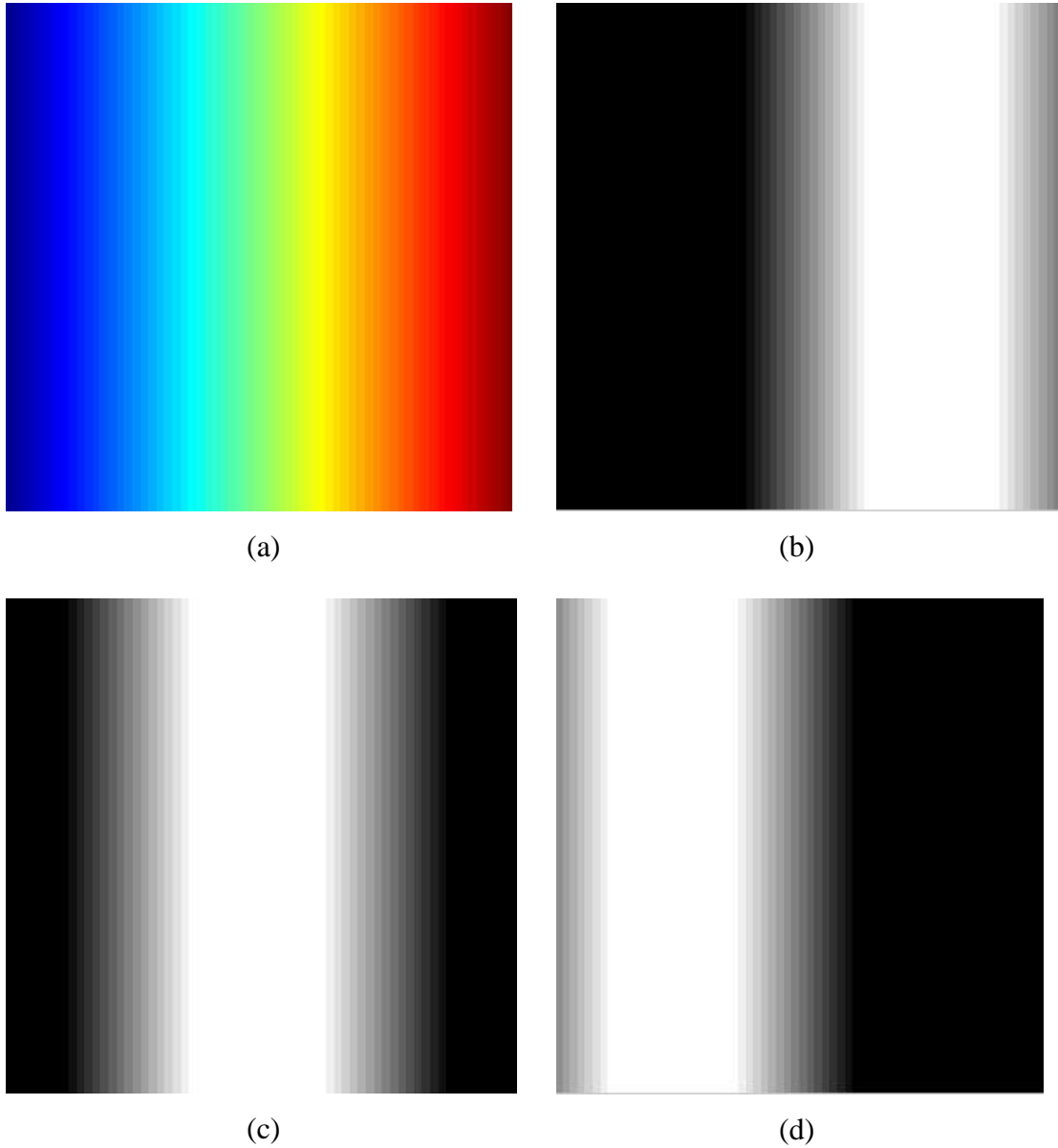


Figure 1.6: Color components of an RGB image. (a) Colored image. (b) Red plane of this colored image. (c) Green plane of this colored image. (d) Blue plane of this colored image.

## 1.6 Phases of Digital Image Processing

In processing the digital image, there are various phases which are to be followed in order to extract the required information from the digital image. Phases must be followed one after the other. Figure 1.7 shows the order of phases for processing of digital image.

The phases of digital image processing are:

- (a) Preprocessing: It includes the operations, which are to be performed before segmentation.
- (b) Segmentation: In this phase, object of interest is identified.
- (c) Feature Extraction: Features of segmented object are obtained in this phase.
- (d) Classification: Based upon extracted feature, classification is done.

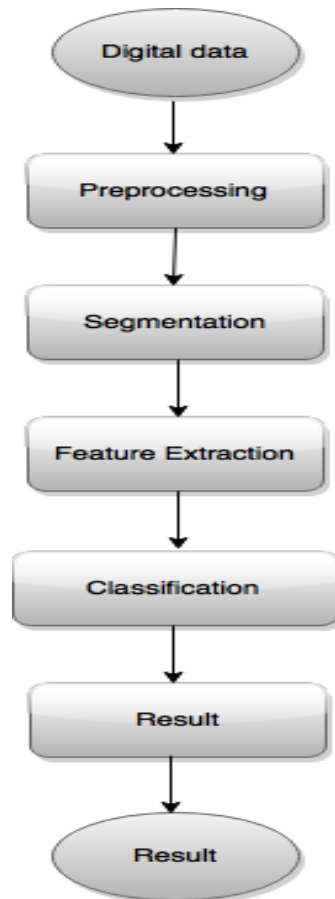


Figure 1.7: Phases of Digital Image Processing.

## 1.7 Preprocessing

The preprocessing phase is to improve the image data by enhancing the important image features which are necessary for further processing. This preprocessing will help to have better results of next phase.

### 1.7.1 Overview of Preprocessing Techniques

The preprocessing phase can be further subdivided into two main categories: Noise reduction or removal and compression of the image. Each of these sub phases have various techniques that are applied to prepare the image for subsequent phases. Each of these is described in detail below.

### 1.7.2 Noise Reduction

The main technique used for noise reduction:

(i) **Morphological Operations:** Morphological operations are used in digital image processing that can extract the components of an image. These operations are designed for connecting the broken lines and decompose the lines which are connected, contour smoothing and boundary extraction. So, we can say that morphological operations can be used for removal of noise. Further, these components can be used to describe the details of shape of region such as boundary, area etc. Two primitive and broadly utilized morphological operations are dilation and erosion. They are described in the accompanying sections to completely grasp the strategies examined in this study.

**Dilation:** The fundamental impact of the dilation on a binary image is to steadily broaden the limits of region of forefront pixels i.e. white pixels. Along this the area of forefront pixels expands in size while openings inside of those areas get to be littler.

**Erosion:** The fundamental impact of the erosion on a binary image is to disintegrate away the limits of areas of forefront pixels i.e. white pixels. In this way boundaries of closer view pixels condense in size and gaps inside of those regions get to be bigger.

### 1.7.3 Thresholding

One of the techniques used for image compression is thresholding. It is performed to reduce storage and increase the performance by converting grayscale images into binary images based on a threshold value: global or local.

The data which the image carries is not likely to have only two levels of intensities. It can have a range of intensities. This occurs both due to non-uniform printing and non-uniform illumination of the image. It results into intensity transitions at the edges.

The main objective of thresholding is to identify the pixels that belong to foreground region with a single intensity '1' and background region with a different intensity '0'. This separates the regions of an image corresponding to the objects of our interest. To differentiate the pixels we want to analyze from the remaining, a comparison of every pixel intensity value with respect to a *threshold value* is performed. Once we have separated the required pixels, we can assign them with a fixed value to identify them which means a value of either 0 (representing black) or 255 (representing white) or any other value according to our needs can be assigned.

#### (a) Global Thresholding

Global Thresholding selects an optimal or several optimal threshold values automatically in order to separate the objects of our interest in an image from the background based on their gray-level histogram distribution. It assigns a single unique threshold value to the whole image based on an estimation of the background intensity level from the intensity histogram of that image. If the pixel intensity values of the components can be distinguished easily from the background for the entire image then a global threshold value can be chosen appropriately. The concept of using a single or global value for thresholding is called as global thresholding.

The histogram for an image which has well-distinguished background and foreground intensities will have two distinct peaks. The intensity value is chosen at the valley between the two peaks that best separates the two peaks as it is the minimum between the two maxima.

The thresholding technique is demonstrated below in the figure 10 when global thresholding is applied. The low threshold gives an unclear image while the high threshold removes some of the important details from the image. Hence, the selection of good threshold is necessary for thresholding technique to achieve its objective.

### **(b) Local Thresholding**

It is noticed that due to noise and poor contrast, the images do not always have a well differentiated background and foreground. Therefore, a single value for thresholding these images is not a feasible approach. So we divide the image into several sub images and then threshold each of these sub image separately. Since each pixel defines its threshold value based on its placement in the image, we can also call this technique as adaptive thresholding.

The gray-level intensities are analyzed within the local windows across the entire image in order to determine the local thresholds. The local area information of the pixel determines the threshold value to be assigned to it. But the choice of the window size is a tricky problem. The window size should be choose in a manner that it is large enough to allow a satisfiable number of pixels from the background, in order to obtain a good estimate of the average values but not too large to pick over average non-uniform intensity of background.

## **1.8 Segmentation**

Segmentation is a process of dividing an image into various sections i.e. contiguous set of pixels. The objective of division is to change the representation of a picture into something that is more important and less demanding to analyze.

### **1.8.1 Overview of Segmentation Techniques**

Image segmentation is an area of research which requires a high degree of attention. There are a lot of different segmentation techniques that can be applied but there is no single technique which can be used for all types of images. Different techniques suit different types of images. The technique developed for a particular type of image might not be useful for the other types of images. Hence, there is lot of difficulty to develop a universal segmentation approach that can be used to segment all types of images. The

selection of a particular segmentation approach for a particular type of image is also not an easy task.

We can broadly classify image segmentation techniques into the following categories:-

Based on two aspects of images:

- **Detecting Discontinuities:** Partitioning an image on the basis of sudden changes in intensity i.e. edge detection.
- **Detecting Similarities:** Partitioning an image into different regions on the basis of similarity according to a predefined criterion i.e. thresholding, region growing, region splitting and merging.

### **1.8.2 Segmentation Based on Edge Detection**

Edge detection aims to identify all the points in an image document at which there is a sudden change in intensity or has discontinuity or when there is a jump in intensity from one pixel to the neighbouring pixel. It is of huge importance for image analysis. Edges define the image boundaries which are very helpful for segmentation. There are number of ways to accomplish edge detection; but they can be grouped into two main categories:

#### **(i) Gray Histogram Technique**

In this technique, histogram is calculated firstly on the basis of the color or intensity of the all pixels in the image, and then valleys and edges in image are found. Here, the segmentation is dependent on the threshold value that is chosen. The efficiency of this technique is more in comparison to other techniques. But the method cannot be used if the valleys and edges detected are large.

#### **(ii) Gradient Based Method**

Gradient based methods are best suited for images with sudden changes in intensity near edges and images having little noise. It is calculated as the first derivative [5] of the image. If the value of gradient magnitude is high, it indicated that there is rapid conversion between two regions. This identifies edge pixels which should be linked in order to form closed boundary of regions. Sobel, Canny, Prewitt and Robert operators are

some of the commonly used edge detection operators. The best out of these operators is Canny but it is more time consuming than Sobel.

### **1.8.3 Region Based Segmentation Methods**

Region based segmentation is applied to partition an image in regions which have some similarity based on some predefined criterion. Region splitting and merging, region growing, thresholding etc. are some of the techniques which belong to this category.

#### **(i) Thresholding Method**

Thresholding is applied to images when we need to speed up processing and reduce the requirements for storage. It is done by converting grayscale images into binary images based on a threshold value. These methods are based on image space segmentation of regions. The basic idea behind this method is based on the characteristics of an image.

Thresholding is applied to select a threshold value which divides the image into various classes and therefore separates the objects which belong to the background. If a single threshold value is picked for the entire image then we can say that any pixel intensity value which is greater than the threshold value belongs to the object and the pixel intensity values which are smaller than the threshold value belong to the background.

#### **(ii) Region Operating Methods**

Image segmentation segments an image into similar or homogenous regions. The method discussed above performed segmentation based on threshold values which were chosen based on the pixel information. Whereas region based methods obtain the complete required region directly. The only limitation of this method is that it is more time consuming.

**(a) Region Growing** In this method, pixels having similar properties are grouped together to form a region.

It is performed as follows:

- Find a seed pixel as an initial point for each of needed segmentation.
- Join together the similar or like properties of pixel (Based on a predetermined growing or similar formula to determine) with the seed pixel around the seed pixel domain into the domain of seed pixel.

- These new pixels act as a new seed pixel to continue the above process until no more pixels that satisfy the condition can be included.

**(b) Region Splitting and Merging** In this method, the image is subdivided into a set of arbitrary disjoint regions and then merge and/or split the region according to the given condition for segmentation. Region based segmentation is largely influenced by splitting. This splitting method can be represented in the form of quad trees in which every node has exactly four branches.

It is performed as follows:

- Split the region into the four disjoint branches.
- When no further splitting is possible, merge any region.
- Stop when no further merging is possible.

In this way, the segmentation can be done by splitting and merging technique. The limitation of this method is that it is complex and time-consuming method.

#### **1.8.4 Theory Based Segmentation**

This type of segmentation has a lot of segmentation techniques which are derived from various different fields and are quite imperative for segmentation. Some the algorithms based on this technique are wavelet based, fuzzy based, clustering based etc.

##### **(i) Clustering Techniques**

Grouping of similar images in a database is called as clustering. The basic idea behind this method is to increase the effectiveness of storage, quickly retrieval and to get desirable results. Various properties of an image like size, colour, texture etc. are considered while performing clustering.

**a) Fuzzy c means clustering** This method identifies the natural groups of data in order to form a large set of data which produces a brief representation of the systems behaviour. Fuzzy c-means is one of the data clustering methods in which datasets are grouped into “n” clusters where every data point from the dataset belongs to every cluster to a certain degree.

**b) K-Means Algorithm** This algorithm groups data vectors into a predefined number of clusters. The centroids of the predefined clusters are initialized randomly initially. The dimensions of the centroids are same as the dimensions of data vectors. Euclidian distance measure is used to determine the proximity of pixels and to assign them to clusters. Mean of each cluster is re-calculated after assigning all the pixels to respective clusters. This is repeated either until no changes are noticed for all cluster means or for a fixed number of iterations.

## 1.9 Feature Extraction

The feature can be described as a behavior of one or more estimations, where each of estimation determines some significant property of an object. Moreover, features characterized some significant aspects of an object. Researchers arrange the numerous features as follows:

- Ordinary features: These features include the features that are independent of application such as color, texture, and shape. According to the conceptual level, they can be further split into:
  - Pixel-level features: those features that can be measured at each pixel, e.g. color and location.
  - Local features: it includes the features that can be computed on the results of the division of image into three planes i.e. red, green and blue plane by image segmentation.
  - Global features: these features are determined over the whole image.
- Domain-specific features: it includes the features that are specific to a particular application such as human faces, fingerprints, and conceptual features. These features are often specific to a particular domain.

### 1.9.1 Overview of Feature Extraction Techniques

Feature extraction is an area of research which requires a high degree of attention. There are a lot of different feature extraction techniques that can be applied but there is no single technique which can be used for all types of images. Different techniques suit different types of images. The technique developed for a particular type of image might

not be useful for the other types of images. Therefore, various features that can be extracted are color, texture and shape features as given below:

### 1.9.2 Color features

One of the important features of image is color. Various color models or spaces are available for the extraction of color features from an image. Such models are RGB (red, green and blue), HIS (hue, saturation and intensity) etc. There are color moments for effective features extraction. The common moments are mean, standard deviation and skewness. Below listed are the formulas for the measurement of mean, standard deviation and skewness moment in equation 1, 2 and 3 respectively.

$$\mu_i = \frac{1}{N} \sum_{j=1}^N f_{ij} \quad (1)$$

$$\sigma_i = \left( \frac{1}{N} \sum_{j=1}^N (f_{ij} - \mu_i)^2 \right)^{\frac{1}{2}} \quad (2)$$

$$\gamma_i = \left( \frac{1}{N} \sum_{j=1}^N (f_{ij} - \mu_i)^3 \right)^{\frac{1}{3}} \quad (3)$$

where  $f_{ij}$  is the color value of the  $i^{\text{th}}$  color component of the  $j^{\text{th}}$  image pixel and  $N$  is the total number of pixels in the image.  $\mu_i$ ,  $\sigma_i$ ,  $\gamma_i$  ( $i=1,2,3$ ) denote the mean, standard deviation and skewness of each channel of an image respectively.

Color models that are used for the extraction of color are explained below:

#### (i) RGB Model

In RGB model, three channels of image contributes to create a RGB colored image. Where primary channels represent red, green and blue channel. To represent a particular color depends upon proportion of the combination of three primary channels. Figure 1.8 shows the Cartesian coordinates of three channels, in which three main axis of 3-D geometry represents the red channel as z-axis, green channel as x-axis and blue channel

as y-axis. By using this model color feature can be extracted for effective recognition of color [28]. Moreover, this model is mostly used for color monitors and video cameras.

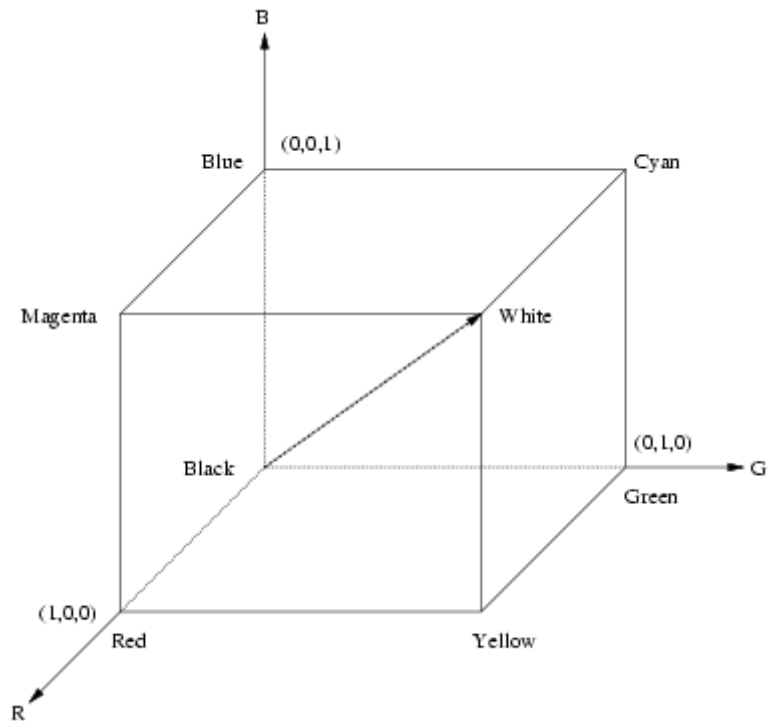


Figure 1.8: Coordinates of RGB color model.

**(ii) HSI Model**

In this model, color is specified by HSI i.e. hue, saturation and intensity. The entire space of colors is specified in figure 1.9. For an arbitrary color point, Hue is represented by the angle from the red axis and length of the vector is represented by the saturation. The intensity of all colors is given by position of plane on the vertical intensity axis [27].

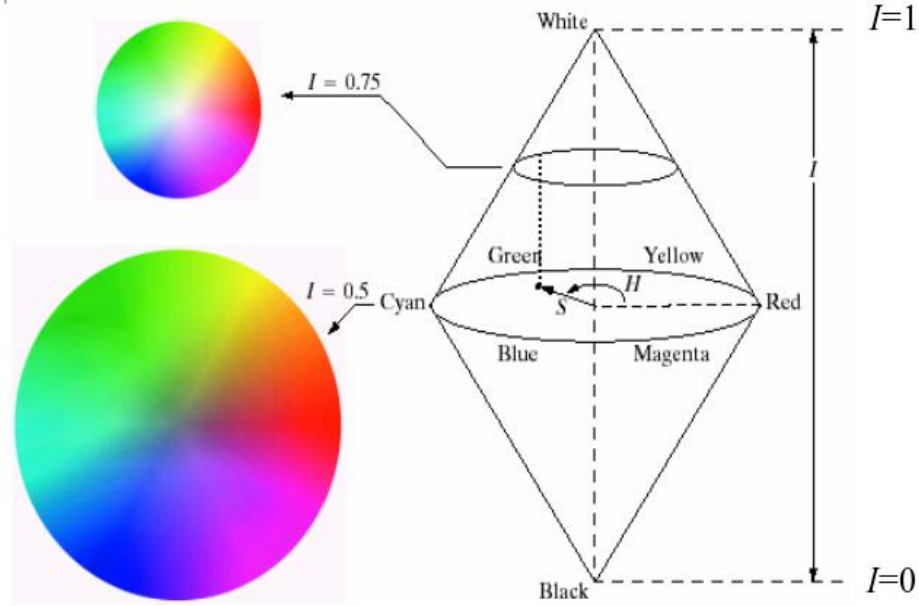


Figure 1.9: 3D circular HSI color planes.

Conversion of color from RGB to HSI : Given an image in RGB format. Hue of each RGB pixel is obtained by:

$$H = \begin{cases} \theta & \text{if } B \leq G \\ 360 - \theta & \text{if } B > G \end{cases}$$

$$\theta = \cos^{-1} \left\{ \frac{\frac{1}{2} [(R - G) + (R - B)]}{[(R - G)^2 + (R - B)(G - B)]^{1/2}} \right\}$$

$$S = 1 - \frac{3}{(R + G + B)} [\min(R, G, B)]$$

$$I = \frac{1}{3} (R + G + B)$$

### 1.9.3 Texture features

Image texture is used to recognize the texture of an image and it consists of metric which gives the information about spatial positioning of intensity in an image. It is used for the process of segmentation and classification an image [30]. Texture features of a

segmented image can be used for description and characteristics of segmented area. Mainly used techniques for the analysis of textural features are explained below:

**(i) Gray level cooccurrence matrices**

It is a statistical method for analyzing texture of an image by assuming that the spatial relationship of pixels is in the gray level cooccurrence matrices [29]. The GLCM functions characterize the texture of an image by calculating how often pairs of pixel with specific values and in a specified spatial relationship occur in an image, creating a GLCM, and then extracting statistical measures from this matrix. Mainly used statistics used are contrast, correlation, energy and homogeneity. Advantage of this approach is that it gives feature vector of small length. Disadvantage of this approach is that lot of computation is required because of calculations are in matrix form. Moreover, it is sensitive to the rotation and scaling.

**(ii) Local Binary Patterns**

This technique is used for texture feature analysis in which neighbor pixels of a center pixel are for measuring the threshold value for neighbor pixels based upon the center pixel. Advantage of this approach is that it is robust to changes caused in monotonic gray scale image like illumination changes. Moreover, it is easy for the computation. Disadvantage of this approach is that it is sensitive for noisy images.

**1.9.4 Shape features**

Shape is one of the most common object measurements for food quality evaluation. Compared with other features such as color and texture, shape is easier to measure using image processing techniques [23]. Frequently, the objects of one class can be distinguished from the others by their shapes, which are physical dimensional measurements that characterize the appearance of an object. Shape features can be measured independently and by combining size measurements [24]. But for the better results shape features can be collaborated with size feature to measure the object features in food product images. Features used to measure size of object are area, perimeter, length and width.

### **(i) Circular Hough Transform**

For detecting the circular shape, the edge extraction method gives a set of pixels which is employed to perform a specially designed Circular Hough Transform (CHT) [26]. The Hough Transform is a well-known method for extracting shape information from edge images. The circular version identifies the center and radius of probable arcs or circular edges. The use of the edge image as well as the direction of the gradient allows us to perform this transform more efficiently in time and more robustly against false detections. One of the major problems of this method is the selection of the threshold value to distinguish between a good candidate to be a circle center and an insufficiently voted candidate. We select the highest voted pixels until a 1% percentage of the total pixels are reached, and a later clustering technique groups the votes to highlight the stronger candidates whose votes could have been spread over a certain area due to the non-perfect spherical shape of the fruits. This spreading of the votes due to the imperfect shape of the fruits could cause a high density of pixels with medium votes but none of them with enough value to be considered a valid candidate after the thresholding. If a low enough threshold value is chosen, the medium voted pixels are considered.

This CHT not only manages a matrix of accumulators or matrix of votes, it also accumulates, for each pixel in the image, the average distance and reflectance of the surrounding pixels which vote for each pixel. This information allows a quick computation of the distance to the center of the fruit and an estimation of the reflectance of the surface of the object which will be used to calculate the ripeness.

## **1.10 Classification**

Classification is a process of classifying an image based upon the extracted features. Program that performs the classification is known as classifier. Typically, classification approach is implemented in two phases i.e. training phase and testing phase. In the training phase characteristics properties of images belongs to different category is separated into different classes for the generation of training set. In the further testing phase, an image is classified into a class on the basis of training set.

### **1.10.1 Overview of Classification Techniques**

Classification is an area of research which requires a high degree of attention. There are a lot of different classification techniques that can be applied. But different techniques suit different types of features. Different classifiers produce different results because of different techniques. Therefore, mainly two kinds of classifiers are available such as k-Nearest Neighbors (kNN) and Support vector machine as explained below.

### **1.10.2 k-Nearest Neighbors**

kNN is an approach for classifying an object. Distance metric is measured by kNN and classification is performed on the basis of distance. The data is assigned to a category on the basis of its closest k neighbors. In this, Euclidean distance is used for measuring the distance between features of test image and features of training data.

Simple implementation of this classifier is one of its advantages. Moreover, there is no need to have only linearly separable classes. But this classifier has also some disadvantages like it is sensitive to irrelevant data. Moreover, due to calculation of distance for known instances, procedure of testing becomes time consuming.

### **1.10.3 Support Vector Machine**

Support Vector Machine (SVM) is a classifier that was introduced for classifying problems with only 2-classes, but for problem having multi-classes SVM was extended using the existing one against all strategies. SVM can also be used for the purpose of making decisions. It has two stages where first stage is off-line, where training is provided for pixel sets. Along with this, decision function is also computed. But second stage is the on-line, where decisions are made with help of decision function, already computed in the off line stage, for every new incoming. Other one uses Multi-class SVM (MSVM) as a group of binary SVM (SVMs) for the purpose of training and categorization.

Advantage of this classifier is that it gives suitable results for high dimensional data. Moreover, it is enough robust even if training set contains some noise. Disadvantage of this classifier is that it gives efficient results only with the large training samples. But with the increase in training samples, process of learning becomes time consuming.

## **1.11 Motivation Behind This Work**

Fruits are necessary for human bodies as they have many vitamins and nutrients. They are the major source of anti-oxidants. The availability of fruits is limited during certain seasons. Fruits are used both in fresh and processed forms. Therefore, it is very essential to identify the good quality fruits for the purpose of its usage that is for its directly consumption as well as for various necessities in industries. However, identifying quality of fruits manually is the main obstacle because it takes a lot of time and labor.

The fresh fruit markets are responsible for determining quality of fruits using certain rules because they are the only link between producers and consumers. Specifically, quality of the fruit apple depends on its color, shape and skin defects. A very common proverb “An apple a day, keeps a doctor away”. Though fresh fruit market providers with the help of experts grade quality categories of apple according to their color, shape and defects but this quality criteria is not yet efficient and consequently remains a manual operation, repetitive, expensive, unreliable and costly affair due to the distant locations of their availability. Therefore, automatic detection of quality of fruits is of great significance which can automatically detect the quality of fruits.

To the best of our knowledge, no technique is available for the assessing the quality of types of apples, one which are harvested and one which are not harvested. But the search of techniques in determining the quality of fruits continues in the empirical front. Surely we live in a society that makes a lot of demand on us, but quality determination are never meant to be easy. It takes a lot of effort, hard work and time to get the good quality fruits. Therefore, it is our responsibility to search and provide economic and efficient techniques for quality determination of fruits to help producers and consumers to improve the health of human beings. All these factors motivated the experimenters to endeavor this study. The present study focuses on recognizing and classifying the both types of apples which are harvested and which are not harvested with different algorithms.

## **1.12 Objectives of Thesis**

Objective behind this thesis was as mentioned below:

- Different approaches are required for recognition and classifications of apples for both types of apples, which are harvested as well as which are not harvested.
- A segmentation technique is required to segment the apple from an image of apples that are present on the tree and are not harvested so that segmented apple can undergoes for the classification.
- An efficient approach is required to segment and classify the apple from the images of apple that has been harvested.
- Rate of accuracy of classification can be maximize on the basis of efficient and accurate segmentation technique, thus emphasis on segmentation technique is required.
- During the phase of recognition of apples, there is a need to select a single apple among recognized overlapped apples.
- Different classifiers may produce different results, thus require an analysis of results produced by different classifiers.

## **1.13 Organization of Thesis**

The thesis is organized in a sequential way starting with introduction to image processing followed by the emphasis on digital image processing and its phases. Chapter 2, this chapter includes the description of the literatures that reveals various developments in process of recognition and classification of object, and different techniques used to recognize various fruits so far. In chapter 3 details about the problem definition is given. In chapter 4 a new approach for recognition and classification of apples which are harvested and which are not harvested is implemented. In chapter 5 discussions on results of this study is given with the snapshots of the outcomes. In chapter 6 authors have concluded with a summary of this work and discussed on future scope of research.

## CHAPTER 2

### LITERATURE SURVEY

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The inexplicable research work done in recognition or segmentation of objects for further classification has been done. For efficient and accurate identification of fruit, features extracted from the segmented image considered to be an essential part. In order to understand the current state of art in this area, a survey of work done related to recognition and classification of fruit has been presented in this chapter.

Aleixos et al. [2002] designed and implement a multispectral camera to capture visible and near infrared images. The main focus is on size, color and presence of defects on citrus fruits. The given experiment is able to inspect the lemons, mandarins and oranges. The study presents a parallel system for estimating size as well as inspecting its surface for diseases. Proposed system is capable of classifying mandarins and lemon correctly with the precession of 93% [1].

Kleynen et al. [2003] described the best filters for detecting broad range of wavelength for detecting defects on fruit based upon quadratic discriminant analysis. Multi spectral vision system is used for this work. NIR spectrometer is used for reflectance spectra of damaged and sound surface. Defects considered are scald, visible flesh damage, bruises, frost damage etc. For differentiating bruise surface from healthier one is performed by the use of combination of four filters. Thus the proposed method was able to select the wavelength band to sort the jonagold apples [2].

Leemans and Destain [2004] have presented a grading method for jonagold apples only. Technique used in this approach is k-means clustering which clusters the objects and clusters undergoes for classification. Results of the classification probabilities of objects were analyzed and jonagold is graded on the basis of these results. There are various steps that performed for grading the jonagold apples. First image acquisition is performed and then segmentation of image is done to locate the fruit in the image. Finally find the possibility of defects for the grading purposes. The correct rate of classification for jonagold apple is 73% [3].

Brewer et al. [2006] have developed the analyzer for tomato fruit and other species of plant. So that to analyze the shape and size of tomato and other species of plant. While other species of plant may include banana, pepper, grape, strawberry and chili pepper. Different colors are used for determining the boundaries of fruit accurately. The researcher can implement recognize the shape variation of tomato and depict the 2-D shape of fruit. It provides the analysis of morphology of fruit and gives descriptors. For achieving the objective of measurement of shape of fruits, the controlled vocabulary and mathematical descriptors are combined. Where controlled vocabulary defines bounds for species of fruits shape and mathematical descriptor can measure the fruit feature with a single formula for each feature. Such features are shape of fruit, index of fruit shape, fruit shape triangle, eccentricity of fruit shape, circular, rectangular and ellipsoid. Fruit size includes height, width, area, mass and perimeter of fruit [4].

Roushdy [2006] described a subjective investigation of edge recognition strategies are described. Experimental results demonstrate that Boie-Cox, Shen- Castan and Canny operators are superior to Laplacian of Gaussian (LOG), while LOG is superior to Prewitt furthermore, Sobel if there is need to deal with noisy image. This is because Gaussian edge recognizers are symmetric on the edge and noise can minimize by image smoothing. Subjective and objective techniques are utilized to compare the diverse edge operators. The morphological filter is more vital as an introductory process in the edge location for noisy image and utilized opening-closing operation as preprocessing to filter noise. Additionally, smooth the image by first closing and then dilation to improve the image before the edge operators' influence [5].

Sanchis et al. [2008] proposed an approach for correction of light in adverse effect of spherical objects in the images. This study deals with the specific case of citrus fruits. As spherical object is darken near the peripheral area than the central area, which makes it difficult to analyze. The approach considers the surface of fruit as lambertian ellipsoidal surface. Therefore, author requires calculating the amount of radiation that must reach camera and maintain the uniformity in the intensity of light that is captured by the camera. An approach is tested using hyper spectral computer vision system. In

experiments performed standard deviation is reduced that increases the rate of classification for given approach [6].

Blasco et al. [2009] proposed an algorithm for fruit sorting including mandarins and oranges. It also presents system in which recognition and classification of skin defects of citrus fruit is performed. Techniques used for overall distinguish of defect are near infrared reflectance (NIR) and ultraviolet induced fluorescence (UVFL). With the use of morphological operations, a fruit sorting algorithm is proposed. A fruit sorting algorithm is developed by the contribution of NIR and UVFL. The success rate of classification is 86% [7].

Bashish et al. [2010] have proposed the process for detection and classification of plant leaf diseases. HSI color space is used which gives good results because it is light invariant. Image processing techniques used are k-means for the segmentation of image for disease part. By then segmented image has classified using the supervised neural network which is based on statistical classification. Results indicate that statistical classification successfully classifies the plant stem diseases with precession of 93% [8].

Liming and Yancho [2010] have graded the strawberry based on image processing techniques. Features used for grading are shape, size and color. Where shape feature has found by drawing lines and by k-means clustering. Color features has extracted by well known color method for a channel. Size feature uses the largest diameter approach. Above three extracted features contribute to grade the strawberry with color precession of 88.8% and shape precession of 90% [9].

Uemura et al. [2011] have presented an edge detection approach. Edge detection is the basic and important step for efficient image segmentation. Author has used the boundary code technique for detailed edge detection. Further image segmentation is performed using obtained edges. Boundary code technique is compared with sobel filter and laplace of Gaussian methods of edge detection. Experimental results show that boundary code technique is better than the well known existing techniques [10].

Costa et al. [2011] have reviewed the main techniques of shape analysis on food products. As the appearance of product affect the market intensely. Patter recognition

technique has collaborated with shape analyzes for better results. Appearance is examined by criteria such as shape, size, color, freshness and visually absence of defects, where shape plays an important role among all. Thus, relationship of shape with product characterization, product sorting has inspected. Author has proposed the shape analyzing method that could be useful for industrial purposes as well as for scientific purposes [11].

Ohali [2011] have described the classification of date on the basis of various features. Classification is performed in 3 grades i.e. grade 1, grade 2 and grade 3. Technique used for classification is back propagation neural network. Features considered are flabbiness, size and shape. Date quality can inspect by flabbiness. Color intensity has used for the calculation of flabbiness. Size features are extracted from the area enclosed by date. Shape feature has extracted from the edge based detection method. Its accuracy is 80% [12].

Haidar et al. [2012] have performed the classification of date fruit. Three kinds of features extracted from the image of date fruit are color, shape and texture features. Color feature is extracted by the mean and standard deviation values of the three main planes of colored image i.e. red, green and blue plane. Shape features are extracted from number of pixels enclosed in the area covered by date. Entropy and gray level dependency matrix is used for the extraction of textural features. Classification is performed by multiple classifiers. Top accuracy achieved is 89% [13].

Pathare et al. [2013] gave a review on measurement and analysis of color for the quality of fruits. The importance of color for quality characteristics is discussed. As it impacts purchaser's decision and inclinations. Color of food is checked by physical changes which happen amid growth, maturation, post harvest and handling after that. Color estimation of food items can be used as measure of other quality traits, for example, flavor and contents of product as it is more straightforward, quicker. Review describes the various techniques of color analysis. As authors have analyzed that CIELAB has become the most suitable and efficient color model for the analysis and measurement of the colors. As color is the best measurement criterion for analyzing the food product and its maturity level. Moreover, handling of fruit in post harvesting situation can also be estimated [14].

Jhuria et al. [2013] have considered two types of grapes disease. Feature vector selected are color, texture and shape. HSV histogram value has used for extraction of color features. Shape detection of diseases is determined by using morphology. For visual pattern of skin of fruit, wavelet transform is used for obtaining textural features. Results shows that color and morphology is preferable than texture features [15].

Mohanaiah et al. [2013] represent a method for extracting visual content of images for indexing. There are general features of image like color, shape and size. But here author has described the statistical texture feature for evaluation of image. The described four statistical features are correlation, entropy, angular moment and inverse difference moment. These features are also useful for motion evaluation of videos and real time pattern recognition applications. The results present that texture features have high accuracy rate and requires less time for computation. Thus mentioned method can be used for the application of pattern recognition in real time [16].

Fleyeh et al. [2013] have proposed a new approach to recognize the traffic signs. The techniques used are segmentation based upon color using binary classifier, circular hough transform. The binary classifier has trained to segment the traffic signs images according to required color. Voting mechanism has used for the property curves. Firstly, SVM classifier has trained for property curves of each category then it is used the prediction of category of testing curve. Circular hough transform has used for detecting the probable circles in the traffic signs image. Experiment has performed under different lighting conditions i.e. sunny, cloudy and fog and shows that the proposed method has high accuracy on the basis of color segmentation and recognition of traffic signs [17].

Rashmi et al. [2013] have study and compared various edge detection techniques. Such methods for edge detection are robert, canny, sobel and prewitt operators. Experiments show that canny edge detector gives the better results than all the rest of edge detectors based upon the facts such as for noisy images, provides sharp edges, having less likeliness for recognizing false edges. Moreover, canny algorithm founds in many applications such as image for brain MRI, real time facial recognition, automatic face detection and tracking. Even in the medical field also canny is used for analyzing x-rays, ultrasound etc [18].

Beaulieu and Megherbi [2014] proposed a performance criterion metrics results for 2-sample t-test to choose features pixels and reorganize them to enhance the recognition results. The intent of work is to analyze the criteria of selecting relevant feature pixels for maximizing the recognition rate. Authors have also introduced the performance criteria to estimate robustness for the methods of classification. The proposed approach focuses on the recognition and classification of object within the image. Therefore, analysis on selecting the relevant features has performed to decrease the dimensions of data. Results show that on the basis of 2-sample t-test, reordering and selection of pixels is done in the raw image [19].

From this immense study of literature survey it is found that a wide range of algorithms were given by numerous researchers to segment an image by means of various techniques. But there are implementation gaps and none of the algorithm produces satisfactorily results for detecting a fruit and then performs quality identification by classifying a fruit. Subsequently, it is required to fill these gaps. Therefore, a work has been proposed where an efficient algorithm was developed and implemented that can recognize a fruit and do the quality identification of a fruit.

## CHAPTER 3

### PROBLEM STATEMENT

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Quality has turned into the vital viewpoint for customer. Though consumers get access of apples in market but it takes a long time to identify a good quality apple. Thus a fast and efficient method required for classification of apples. But before classification, there is need for segmentation of images to extract features of a particular apple. Therefore, these features can pass to classifier for classification. Various works have been done in these problems. An attempt to describe the problem of segmentation for classification and the gaps in its implementation by existing algorithms has been made in this chapter.

#### 3.1 Problem Definition

Quality has become the very important aspect for consumer to differentiate the products of same category. Nowadays consumer's view point for quality checking is important. Especially, in case of food industry, dealers take care of fruits as these products are directly fed from farm to customer through many stages such as packing, transportation etc. Possibility of food products getting spoiled is likely to happen because fruit harvesting, packing and supplying of fruits so that different dealers can provide fruits to consumers. This whole process takes a long time. Hence, there is a need for fast and efficient algorithm for quality identification. For essence of fruit commerce, manufacturers have to produce the cost effective refined products. Traditionally, quality is investigated manually, which is boring and time consuming activity. A larger number of workers are required in this process but there is labor shortage problem. Moreover long shifts are required with limited workers. Working conditions are hard. Most important thing is limitation of time for products freshness. These problems lead to develop an efficient algorithm for recognition and quality identification of fruits encompassing image processing techniques. It may affect the quality of product. Since it will enhance the speed and decrease the manual errors. An algorithm will take an image of fruit then extract the fruit from that image using image processing techniques such as segmentation is required. Further, set of procedure has to follow for quality identification of a fruit, which will notify the quality as good or bad to the user. In developing the

algorithm, various challenges will be faced are differentiating fruit from leaves and branches in an image. Also, different algorithms are required for images of fruits before harvesting and images of fruits after harvesting. A classifier is also required for the classification of a fruit. In case of many fruits in an image, classification should be on each fruit and result should be separately reported.

### **3.2 Gap Analysis and Justifications**

Earlier work has shown that there is not any algorithm for the problem of recognition of fruits that are not harvested and checks its quality in terms of good or bad. In existing work, most of the work is done in jonagold apples and they focused only on the recognition of one type of images, either on the image in which apples are harvested or on image in which apples are not harvested. Apples before harvesting are not classified on tree itself. Moreover, during recognition, recognized overlapped fruits problem is not resolved so far into selection of one fruit. This leads to minimization of rate of recognition that will affect the efficiency of the whole system. Therefore, efficiency and accuracy of the existing work for recognition and classification can be improved. Consequently, the gaps can be summarized as

- Quality identification of extracted apples from the images of apple that are not harvested is not performed.
- Recognized overlapped fruits are not resolved so far into a selection of a single fruit.
- Recognition and classification of apples from images in which apples are harvested and in which apples are not harvested, is not performed in any algorithm.

To address the above gaps, objectives of this thesis would be come out as given below:

- Rate of accuracy of classification can be maximize on the basis of efficient and accurate segmentation technique, thus emphasis on segmentation technique is required.
- Different approaches are required for recognition and classifications of apples for both types of apples, which are harvested as well as which are not harvested.

- A segmentation technique is required for the segmentation of apple from an image of apples that are present on the tree and are not harvested so that segmented apple can undergoes for the classification.
- An efficient approach is required to segment and classify the apple from the images of apple that has been harvested.
- During the phase of recognition of apples, there is a need to select a single apple among recognized overlapped apples.
- Different classifiers may produce different results, thus require an analysis of results produced by different classifiers.

The next chapter describes the proposed solution divided into four sections where section 4.1 describing preprocessing techniques applied to the image, section 4.2 detailing the segmentation to obtain an apple enclosed in a boundary, section 4.3 provides details on feature extraction of the enclosed apple, section 4.4 have description of classification of an apple into great and bruise depending upon the features.

## CHAPTER 4

### PROBLEM SOLUTION

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Now a day's people are becoming health conscious. Fruit market provides a number of fruits and vegetables. Within each type of fruits there are various different varieties. Similarly there are different types of apples available in the market. However, to identify best quality apples is a cumbersome task. Therefore, the need arises to develop an algorithm that can detect the apples and classify it in order to increase its market value. The proposed solution to recognize and classify an apple is described in four sections given below.

#### 4.1 Preprocessing

The preprocessing phase is improving the image data by enhancing the important image features which are necessary for further processing. This preprocessing will improve the results of segmentation of image.

##### 4.1.1 Grayscale conversion

A colored image is converted to the grayscale or intensity image. It is done by a weighted sum of R, G and B component of a true color image.

Using:  $G_{val} = 0.299 * R + 0.587 * G + 0.114 * B$

Where,  $G_{val}$  is the new pixel value.

R, G and B are red, green and blue component of original pixel respectively.

##### 4.1.2 Morphological operations

Morphological operations used in digital image processing that can extract the components of an image. Further, these components can be used to describe the details of shape of region such as boundary, area etc. Two primitive and broadly utilized morphological operations are dilation and erosion. They are described in the accompanying sections to completely grasp the strategies examined in this study.

Dilation: The fundamental impact of the dilation on a binary image is to steadily broaden the limits of region of forefront pixels i.e. white pixels. Along this the area of forefront pixels expands in size while openings inside of those areas get to be littler.

Erosion: The fundamental impact of the erosion on a binary image is to disintegrate away the limits of areas of forefront pixels i.e. white pixels. In this way boundaries of closer view pixels condense in size and gaps inside of those regions get to be bigger.

## **4.2 Segmentation**

Segmentation is a process of dividing an image into various sections i.e. contiguous set of pixels. The objective of division is to change the representation of a picture into something that is more important and less demanding to analyze. In a proposed algorithm, a segmentation of a fruit is done by two different approaches depending upon the type of image given for segmentation to obtain an apple enclosed in a boundary. Researchers have considered two types of images of apples i.e. images of apples before harvesting and images of apples after harvesting.

For the type of images of apples which are not harvested yet i.e. apples present on the tree as shown in figure 4.1. Segmentation of image is done on the basis of color and shape analysis. For color analysis, RGB color model is used as explained in chapter 1. By then particular extent of characteristics is picked for each plane of RGB color model to detect red shades. For shape analysis, Circular hough transform is used to detect the circular objects as explained in chapter 1. An algorithm of this approach is mentioned in module i.e. Rec\_before\_harvesting.



Figure 4.1: Image of apple before harvesting.

The procedure given below is for the images that consist of apples which are harvested as shown in figure 4.2. Segmentation for this type of image is performed on the basis of edge detection. Moreover, morphological dilation, erosion is used for the recognition. For edge detection canny algorithm is used [18]. Detected edges are broadened in size to cover the object. Remaining holes of object are filled. Finally to make an object look natural, morphological erode operation is used twice for smoothening of the borders of object. Stated approach is mentioned in module i.e. Rec\_after\_harvesting.



Figure 4.2: Image of apple after harvesting.

### **4.3 Feature Extraction**

The feature can be described as a behavior of one or more estimations, where each of estimation determines some significant property of an object. Thus features can be used in order to categorize an object by its characteristics. To get these characteristics of an object, feature extraction is required. These days various techniques deal with feature extraction in image processing as mentioned in chapter 1. Texture features are the most significant probing with the end goal of pattern recognition in digital images. Thus, in this study texture features are extracted from the image for categorization of an apple into two different classes i.e. an apple of good quality or an apple of bad quality. The main characteristic of a texture is basic pattern recurrence that can contribute to categorization. Grey-Level Co-occurrence Matrices (GLCMs) approach is used for analysis of texture based features [20]. Features computed are Contrast, Correlation, Autocorrelation, Cluster Prominence, Dissimilarity, Energy, Entropy, Homogeneity, Sum of square, Sum average, Sum variance, Sum entropy, Difference in variance, etc.

## 4.4 Classification

Classification is a process of classifying an image based upon the extracted features. Program that performs the classification is known as classifier. Typically, classification approach is implemented in two phases i.e. training phase and testing phase. In the training phase characteristics properties of images belongs to different category is separated into different classes for the generation of training set. In the further testing phase, an image is classified into a class on the basis of training set. Now a days various kinds of classifiers are available as explained in chapter 1. Two classifiers: SVM and kNN is used in this study to classify an apple into good or bad quality apple. As among many classifiers SVM and kNN gives the better results [21]. Thus results obtained by these two classifiers will be compared. A training set of 120 real world images have taken for training data. Training data is composed of features extracted from 120 images using GLCM. By then features of images are hand labeled into two classes: good and bad to train classifier. Mechanism of classifier is also described in figure 4.3. Thus SVM and kNN classifier have used with a particular final objective is to classify a testing image of apple into good or bad quality of apple.

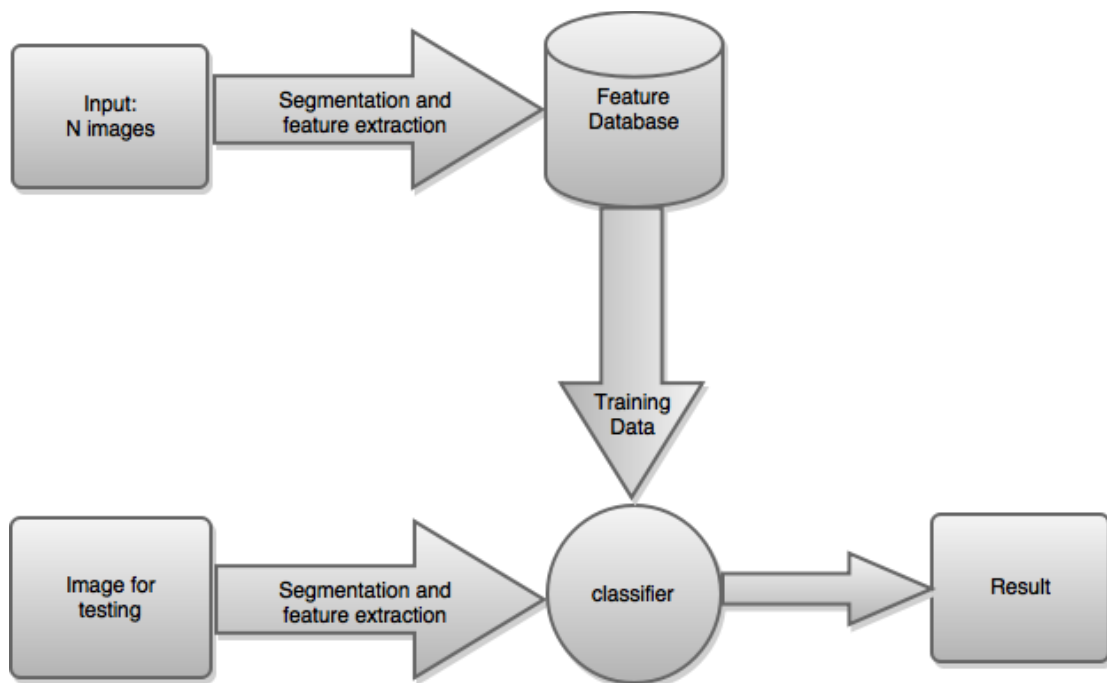


Figure 4.3: Mechanism of classifier.

## Module of Training of classifier

**Step 1:** Get a training set S1 of 'n' images.

**Step 2:** Extract the feature set (say F1) of all the members of S1 and save them.

/\* F1 includes the Contrast, Correlation, Autocorrelation, Cluster Prominence, Dissimilarity, Energy, Entropy, Homogeneity, Sum of square, Sum average, Sum variance, Sum entropy, Difference in variance, etc. These features are extracted using GLCM (Gray Level Coocurrence Matrix) [20]. \*/

**Step 3:** Group the images into two classes  $C_1$  and  $C_2$ . Train the classifier using extracted features in F1 and with their class to which each image belongs.

/\*  $C_1$  is apples having good quality and  $C_2$  is apples having bad quality. \*/

The above algorithm can be used for training a set of images to fall into their respective classes based upon the features of images of apples. This module is called by Quality\_identification module to test the image.

Ensuing is the proposed algorithm in which different modules (Rec\_before\_harvesting, Rec\_after\_harvesting, Selecting\_specific\_apple and Quality\_identification) are used to recognize and classify an apple.

=====

### Main Program: Proposed Algorithm

=====

1. Get an image and store it in *Img1*.
2. Check the type of image and store it in *image\_type*.
3. If *image\_type* = 1.

/\* the image consist of apples that are not harvested and are still present on the tree. \*/

*Img2* = Rec\_before\_harvesting (*Img1*).

Else

/\* the image consist of apples that are harvested. \*/

Img2 = Rec\_after\_harvesting (Img1).

End-if.

4. Img3 = Selecting\_specific\_apple (Img2).

5. Result = Quality\_identification (Img3).

6. If Result = 1.

Display “Apple has good quality”.

Else

Display “Apple has bad quality”.

End-if.

7. Exit.

=====

The proposed algorithm checks the type of an image, whether an image consist of apples which are harvested or are not harvested. Type of image is checked on the basis of number of green pixels in the image. After identifying the type of image, different modules are applied according to kind of that image. The module Rec\_before\_harvest is used for the type of images consists of apples which are not harvested. The module Rec\_after\_harvest is used for the type of images consists of apples which are harvested. Further, depending upon the input given by user an apple is selected. The selected apple then undergoes for quality identification and result is saved. If the outcome is 1 then apple belongs to the good quality else it is of bad quality.

**Modules used in main program are explained in the following sections:**

**Module 1: Rec\_before\_harvesting (Input Image: Img1).**

/\* the complete image is taken as input parameter and output gives the detected apples in an image. \*/

**Step 1:** Display the image Img1.

**Step 2:** Circular objects of particular range of radius values are detected.

$$x = a + r * \cos\Theta$$

$$y = b + r * \sin\Theta$$

/\* where (x,y) is point on the boundary of circle.

(a,b) is the centre of circle.

r is the radius of circle. \*/

/\* It gives a false detection due to the presence of leaves and other things. Therefore the following steps are taken for removing unwanted things in order to get the right detection of the apples.\*/

**Step 3:** Color components are separated in Red, green and blue plane. Then particular range of values for each component is selected.

/\* Here, I1 is 3-D matrix, row is number of rows of image and col is number of columns of image. \*/

For i = 1 to row

For j = 1 to col

$$\text{redComp}(i,j) = \text{Img1}(i,j,1)$$

$$\text{blueComp}(i,j) = \text{Img1}(i,j,2)$$

$$\text{greenComp}(i,j) = \text{Img1}(i,j,3)$$

```

        End-for
    End-for

    /* Here,

        rlt is lowest threshold value of red, rht is highest threshold value of red.

        glt is lowest threshold value of green, ght is highest threshold value of green.

        blt is lowest threshold value of blue, bht is highest threshold value of blue. */

    For i = 1 to row
        For j = 1 to col
            If ((redComp(i,j) >= rlt) && (redComp(i,j)<=rht))
                redC(i,j) = 1
            Else
                redC(i,j) = 0
            End-if
        End-for
    End-for

```

In same way greenC and blueC can be assigned for green and blue components.

**Step 4:** Combine these components to create a color filter and created a mask.

```

    For i = 1 to row
        For j = 1 to col
            If( (redC(i,j)==1) & (greenC(i,j)==1) & (blueC(i,j)==1))
                redFilter(i,j) = 1
            End-if
        End-for
    End-for

```

Else

$\text{redFilter}(i,j) = 0$

End-if

End-for

End-for

**Step 5:** Noise is removed by filling up the small holes and mask is applied on original image.

For  $i = 1$  to row

For  $j = 1$  to col

$\text{imageR}(i,j) = \text{redFilter}(i,j) * \text{redComp}(i,j).$

$\text{imageG}(i,j) = \text{redFilter}(i,j) * \text{greenComp}(i,j).$

$\text{imageB}(i,j) = \text{redFilter}(i,j) * \text{blueComp}(i,j).$

End-for

End-for

For  $i = 1$  to row

For  $j = 1$  to col

$\text{imageRGB}(i,j,1) = \text{imageR}(i,j)$

$\text{imageRGB}(i,j,2) = \text{imageG}(i,j)$

$\text{imageRGB}(i,j,3) = \text{imageB}(i,j)$

End-for

End-for

**Step 6:** /\* Overlapping detected fruit objects are removed.

len is number of rows of array of centers of selected circles. i.e. centerc(len,2).

radii is the array of radius of selected circles. i.e. radii(len)

tol is tolerance for an overlap. i.e. number of pixels. \*/

For i = 1 to len

s = i + 1

For j = s to len

x1 = centerc(i,1)

y1 = centerc(i,2)

x2 = centerc(j,1)

y2 = centerc(j,2)

dis =  $\sqrt{(x1 - x2)^2 + (y1 - y2)^2}$

k = radii(i) + radii(j) - tol

If (dis < k & radii(j) > 0)

    If (radii(i) > radii(j))

        centerc(j,1) = 0

        centerc(j,2) = 0

        radii(j) = 0

    Else

        centerc(i,1) = 0

        centerc(i,2) = 0

radii(i) = 0

End-if

End-if

End-for

End-for

**Step 7:** After removing the overlapping apples. Display an image of detected apple fruits and return the image.

In this module, the complete image is taken as input parameter and output gives the detected apples in an image. Recognition of apple is performed on basis of color and shape. A colored image *Img1* is taken and its three color components are disengaged i.e. red, green and blue components. At this point specific scope of qualities for every component is chosen. Then a single mask is created fulfilling all characteristics. Mask is applied to original image to get the red colored objects only. By then probable circular objects are detected by utilizing circular hough transform. Recognized overlapped apples are removed by considering single apple among them. Finally, obtained an apple enclosed in a boundary from images of apple fruits before harvesting and image is returned.

## **Module 2: Rec\_after\_harvesting (Input Image: I1)**

/\* the complete image is taken as input parameter and output gives the detected apples in an image. \*/

**Step 1:** Display an image *I1*.

**Step 2:** Convert *I1* to intensity image.

**Step 3:** Find edges of apple using edge detection algorithm canny and store it in *b\_w*.

**Step 4:** Apply morphological dilation operation.

**Step 5:** Fill the interior holes of a *b\_w* image.

**Step 6:** Apply morphological erode operation twice.

**Step 7:** Apply Circular Hough Transform and store information about the circular object in M1.

**Step 8:** Return M1.

In above algorithm, edge based detection is done on black and white image. Canny algorithm is used for detection of edges of objects. Detected edges are broadening in size of an image utilizing morphological dilation operation. By then remaining interior holes are filled by 4-connected background neighbors. Now, to make the segmented object look natural, smoothen the object by morphological erode operation twice. As of now, Circular objects are detected using circular hough transform [26].

### **Module 3: Selecting\_specific\_apple (Matrix: M1, Input image: I1)**

/\* Input parameter is I1 and M1 as matrix of information of circles. Output will be single selected apple. \*/

**Step 1:** Display the image I1.

**Step 2:** Display “Click on the apple, which is to be classified.”

**Step 3:** Determine the apple to which the coordinates chosen by user ( $x_1, y_1$ ) belong to.

$$\text{Using: } (x - a)^2 + (y - b)^2 - r^2 < 0$$

/\*  $r_1$  as radius, ( $cx_1, cy_1$ ) as center of circle and len is the length of matrix. \*/

For  $i = 1$  to len

$$cx_1 = M1(i,1)$$

$$cy_1 = M1(i,2)$$

$$r_1 = M1(i,3)$$

/\* Calculate \*/

```
var1 = (x1 - cx1) * (x1 - cx1) + (y1 - cy1) * (y1 - cy1) - r1 * r1;
```

```
If var1 < 0.
```

```
    /* It means (x1, y1) belongs to the current circle. */
```

```
    Break;
```

```
End if.
```

```
End for.
```

**Step 4:** Extract the selected apple in *Img2*.

**Step 5:** Return *Img2*.

This module prompts a dialog box message to user for selecting an apple for further classification. Consequently researchers have discovered the directions of point where user has clicked to recognize a solitary apple. Extract that selected apple as an image from whole image and return the image. Extracted image will be the testing image for classifier.

#### **Module 4: Quality\_identification (Sample image: T1, Feature set: F1)**

**Step 1:** Extract the features of T1 in F2.

**Step 2:** Compare F2 with F1.

**Step 3:** A class which has the maximum features matching with T1 is assigned to it.

**Step 4:** Return class.

This algorithm takes a test image T1 as an input and its features are extracted as mentioned above in section 4.3. The extracted features are then compared with the stored features of the training set. The class with which the maximum features of the test image match is then assigned to it. Return type is of numeric type i.e. 1 for good quality class and 2 for bad quality. This defines the quality of an apple as a great or bruise.

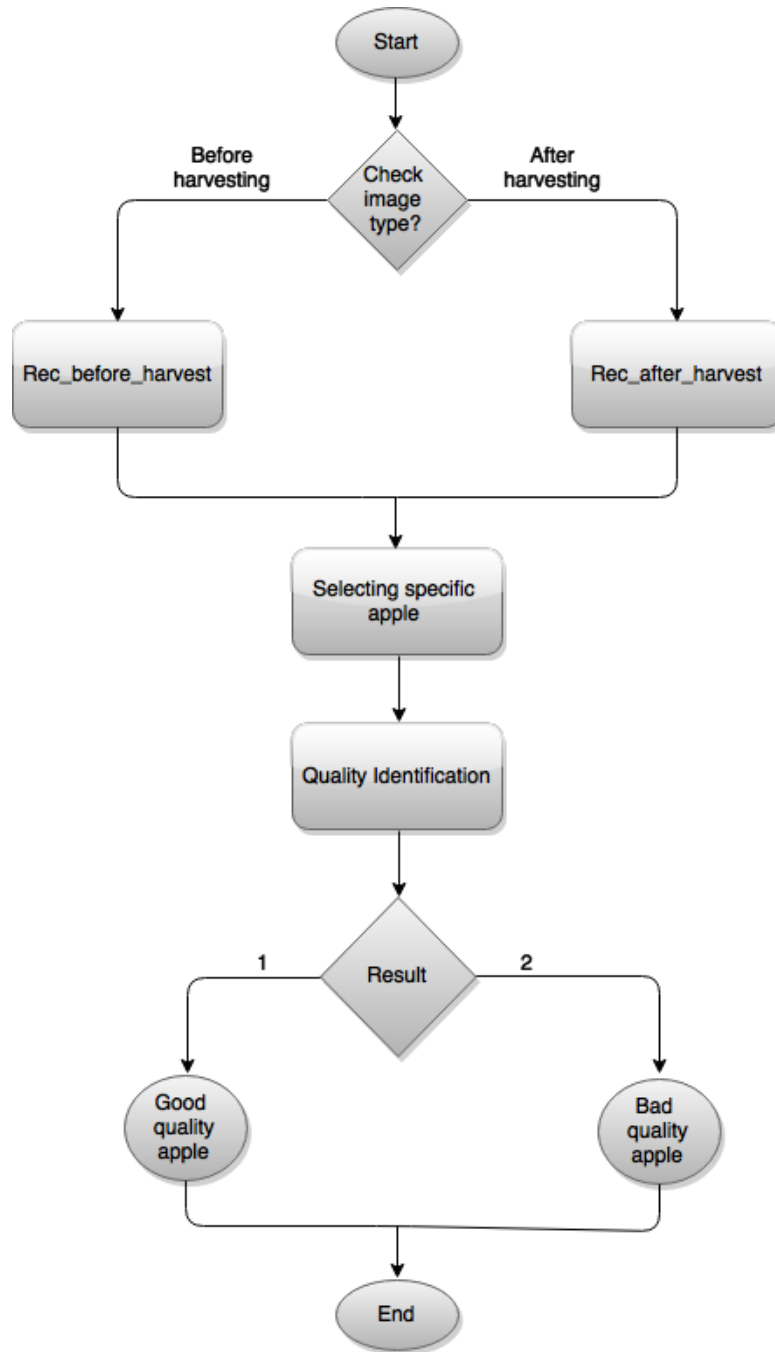


Figure 4.4: Flowchart of outlining research.

All the above algorithms have been implemented in MATLAB and their results and analysis are discussed in the next chapter.

#### 5.1 Results of Proposed Algorithm

The proposed algorithm in chapter 4 is implemented in MATLAB R2013a version and an interactive GUI is built using the same. The algorithm was applied to a test set of 120 images where 60 images belong to each category i.e. apples of good quality and apples of bad quality.

First, a screen will be shown to user for selecting an image among images of apples before harvesting or images of apple after harvesting. According to selected option, the segmentation of apple will be done. Then user will ask to select an apple for further classification. Selected apple will be extracted and assumes as test image.

As of now, test image obtained from the above proposed algorithm is passed for quality identification. Where the features of the images in the training set has extracted using GLCM and stored into a matrix after labeling each one of them into any of the two classes: good and bad. This training is done by various classifiers such as SVM and kNN. Then, the features of image belonging to test set are compared with the stored feature matrix of the images in training set and labeled as one of the two classes by the respective classifiers.

None of the algorithms as discussed in chapter 2 can classify an apple before harvesting. But the proposed algorithm is able to select a particular apple from an image and then further classify it as good or bad. In the proposed algorithm one image is taken of apples before harvesting then after segmentation one apple is selected among all selected apples. As of now classification of selected apple is completed. Classification is done by two classifiers i.e. SVM and kNN. Then accuracy is calculated by using equation (1).

**RESULTS:** The ensuing results present the snapshots of running program in sequential order.

The results of proposed algorithm are presented in two sections. Section 1 includes the results for the images of apples which are not harvested. Section 2 includes the results for the images of apples that are harvested.

**Section 1: Results for images of apples which are not harvested.**

Figure 5.1 shows the original image, which is passed and read by the main program in `Img1`.

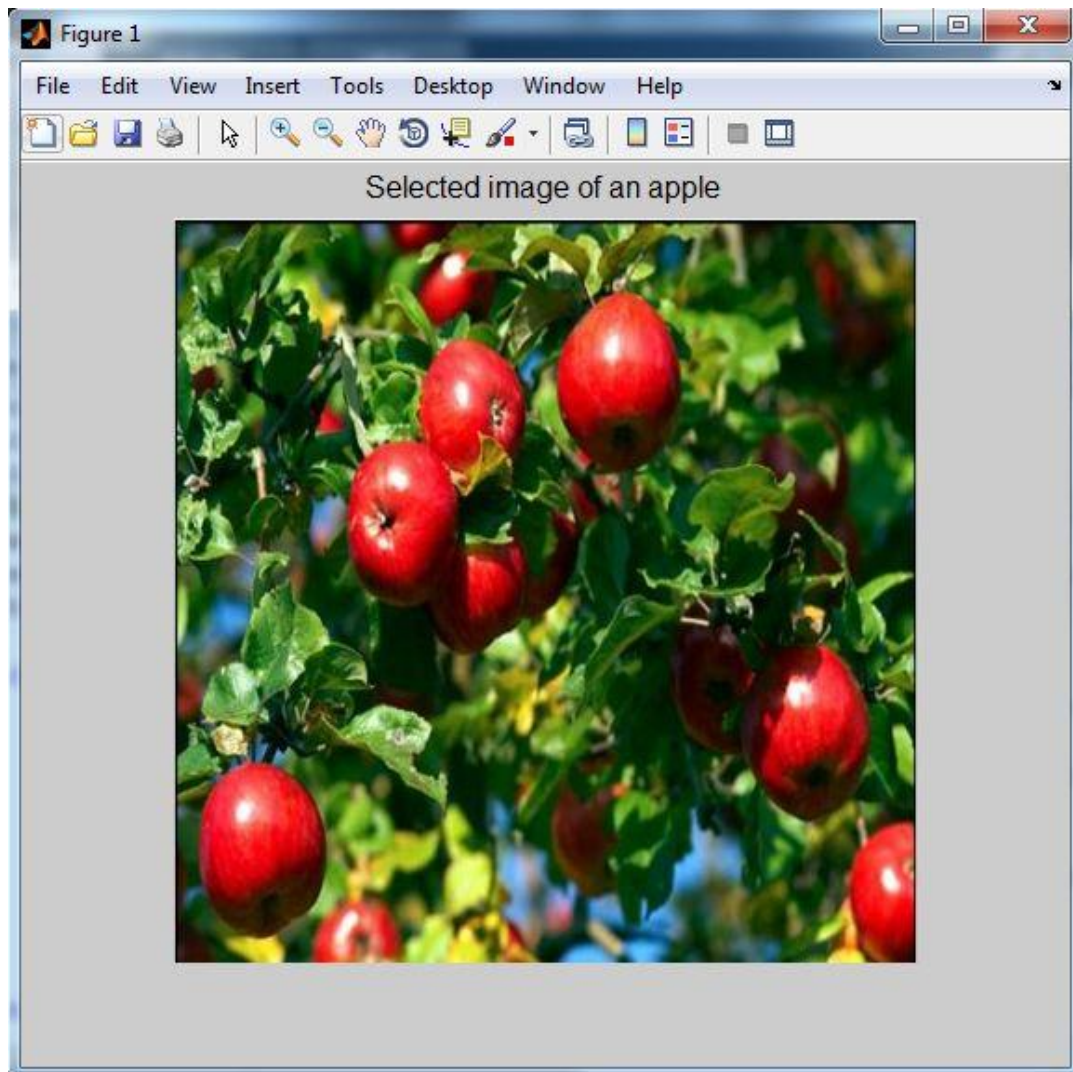


Figure 5.1: Original image.

Then image type is checked on the basis of the number of green pixels present in the image. As green pixels are present in enough number therefore image is considered as the image of apples that are not harvested.

According to the proposed algorithm, for the type of images of apples which are not harvested, module 1 i.e. Rec\_before\_harvest is called with input parameter as Img1. This module has various operations.

First operation of module 1 is to detect the circular objects in an image. Then display the detected circle on the Img1 as shown in figure 5.2.

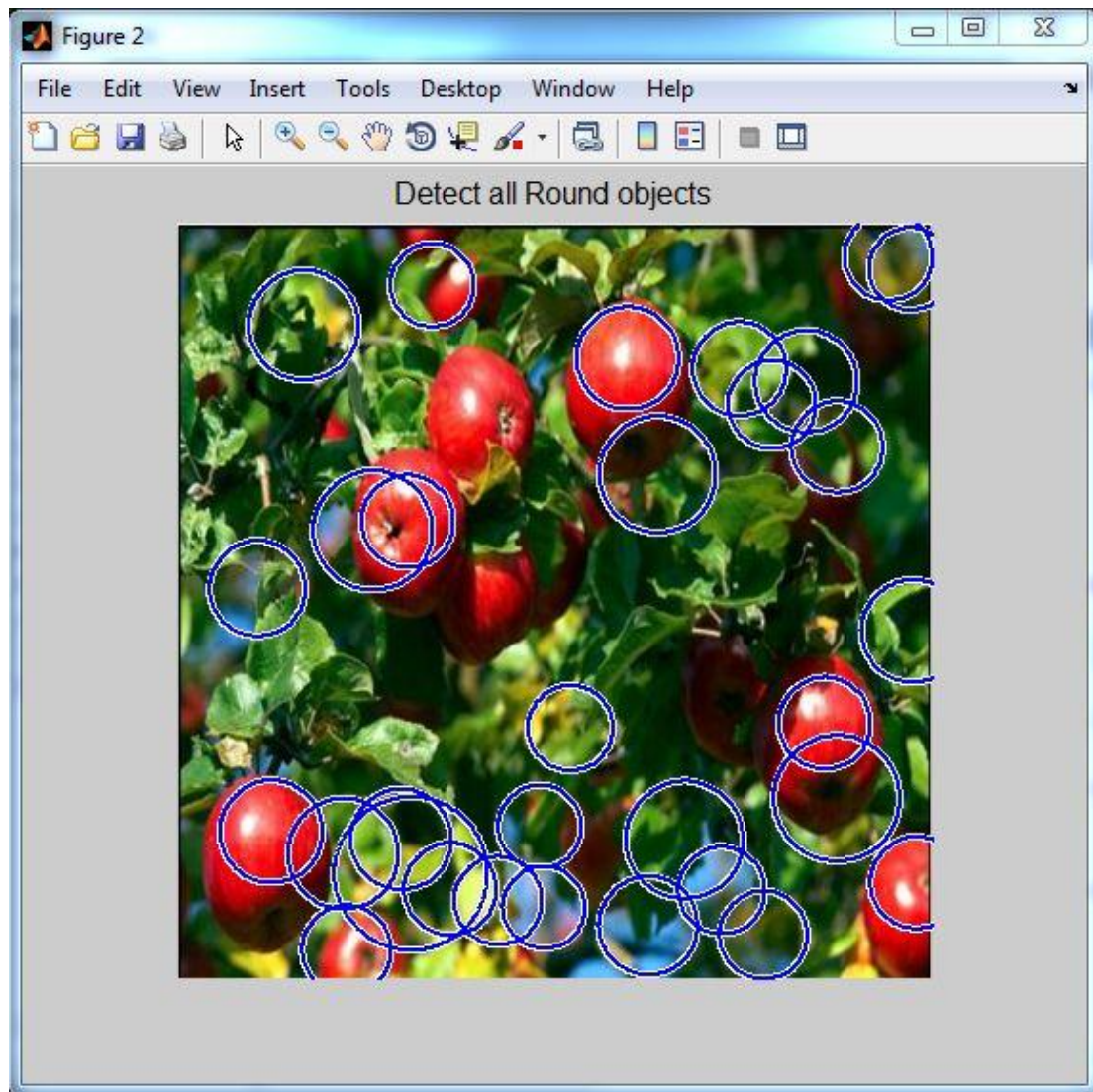
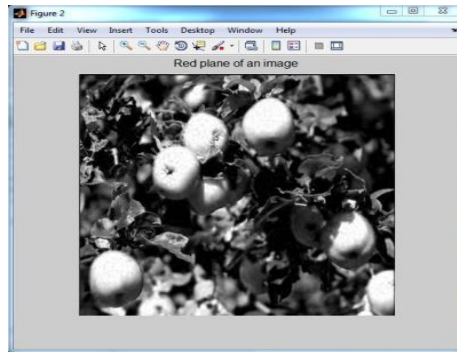


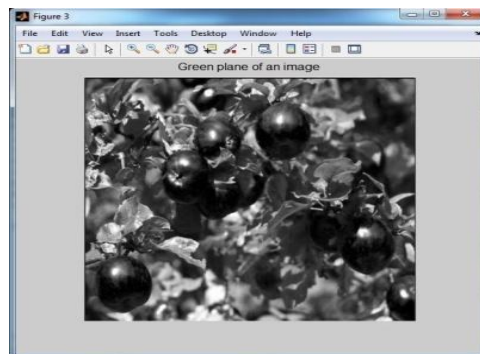
Figure 5.2: Image displaying the detected circular objects.

It can be seen easily that detection of circular objects in *Img1* directly gives false detections due to presence of leaves and other things. Therefore, following approach is required to get the right detection of apples.

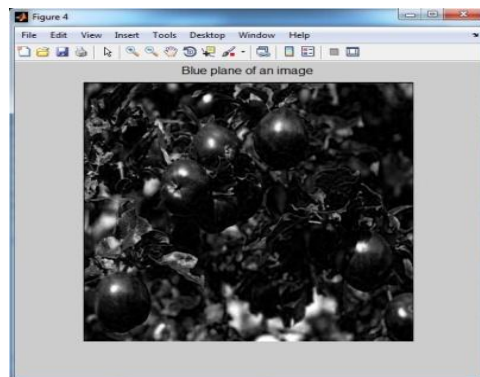
Second operation of module 1 is to separate the three planes of RGB colored image into red, green and blue plane respectively as shown in figure 5.3 (a), 5.3 (b) and 5.3(c).



(a)



(b)



(c)

Figure 5.3: Separation of three planes of an RGB colored image. (a) Red plane of an image. (b) Green plane of an image. (c) Blue plane of an image.

Third operation includes the selection of particular range of color shades of each plane. Then selected shades are combined to reflect the shades of three planes in one image, which will be called as mask for selecting the ripen apples. Created mask is shown in figure 5.4.

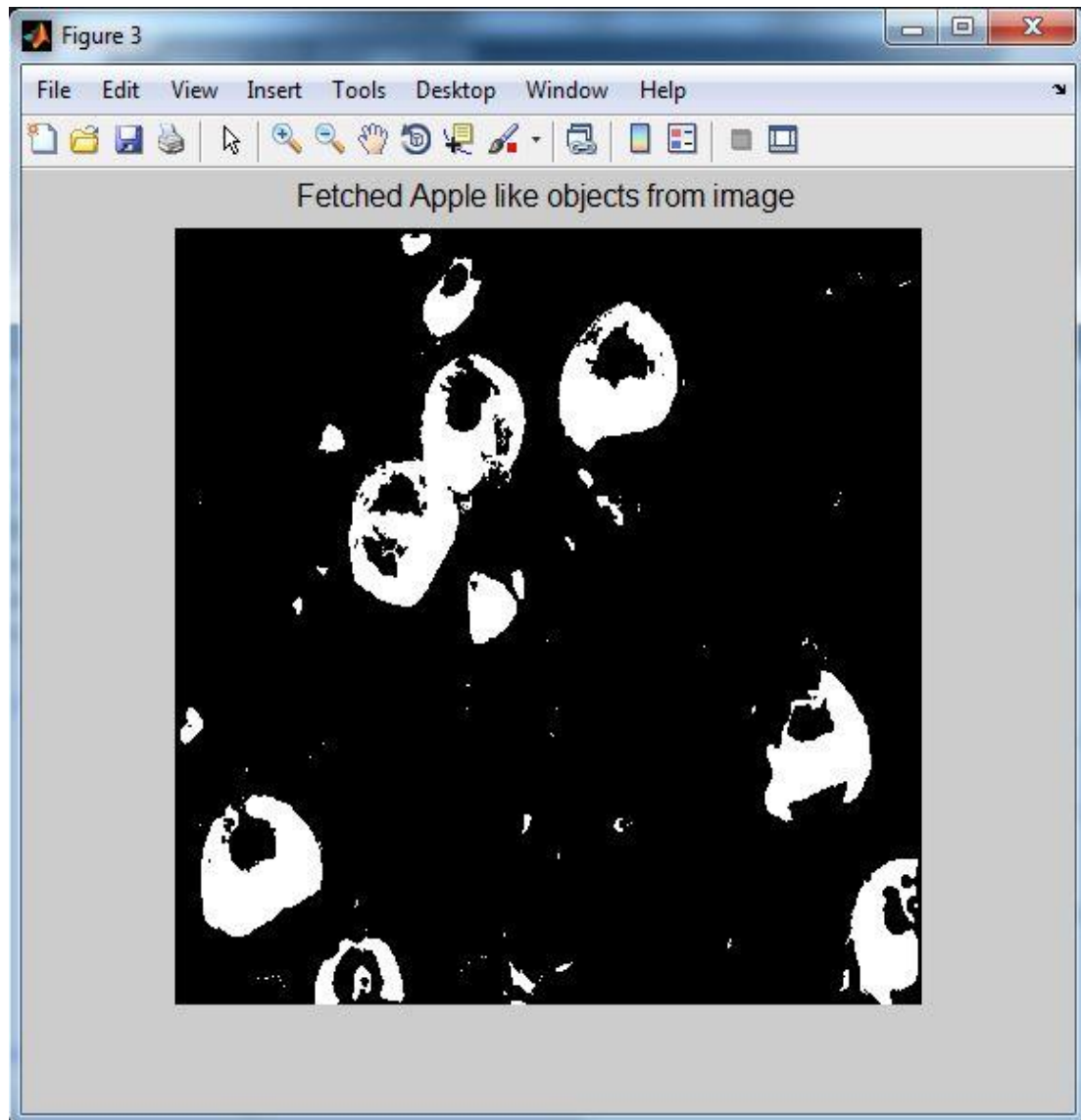


Figure 5.4: Image showing mask for ripen apples.

In the fourth operation, created mask is applied on the original image *Img1* to detect the ripen apples only as shown in figure 5.5.

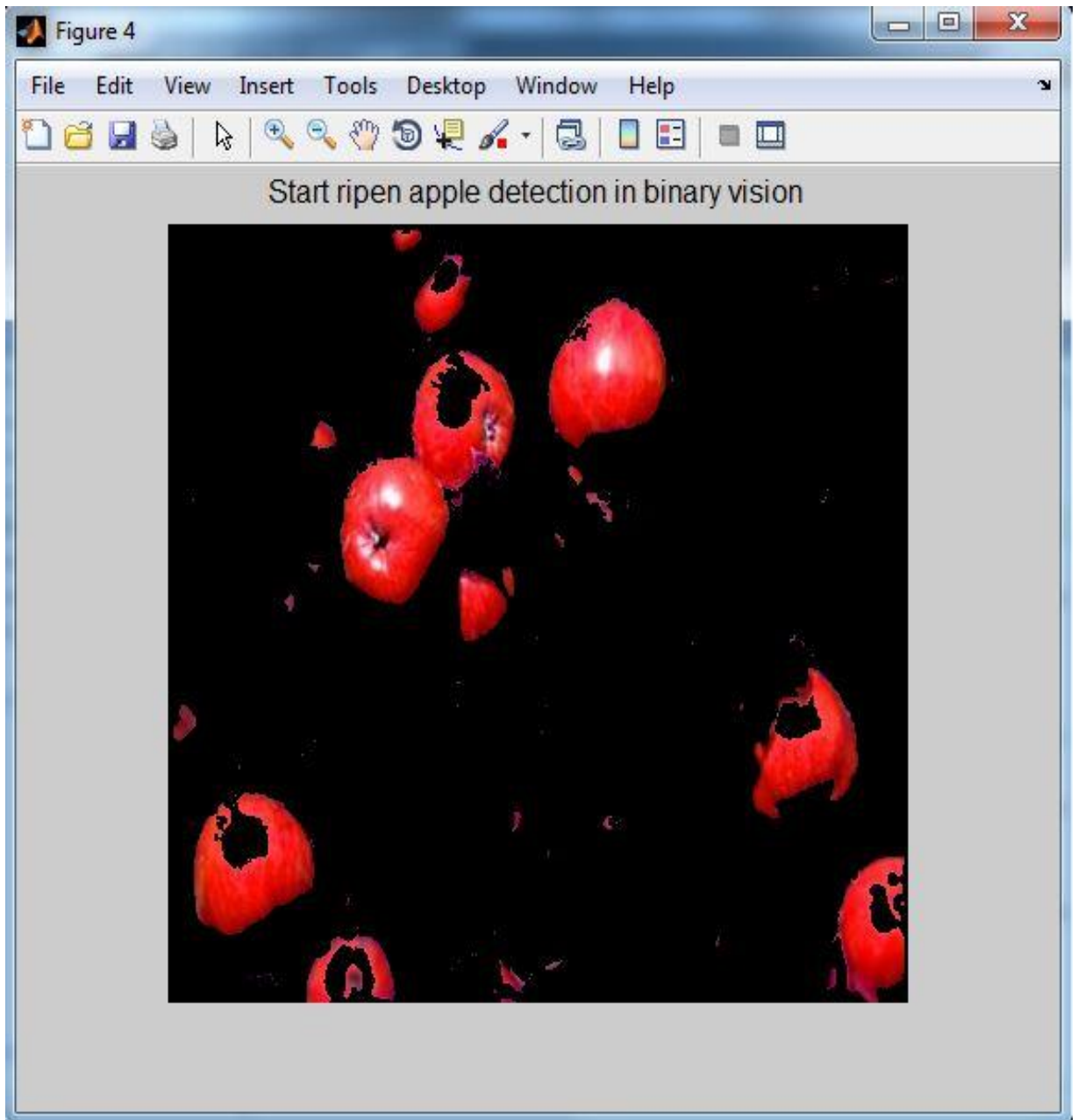


Figure 5.5: Showing the detection of ripens apples in an image.

In figure 5.5, ripen apples are identified. However, noise is also present in terms of small unwanted red marks. Therefore, in next operation, these types of noises are removed by applying the strategy of removing small objects. An image after removal of noise is shown in figure 5.6.

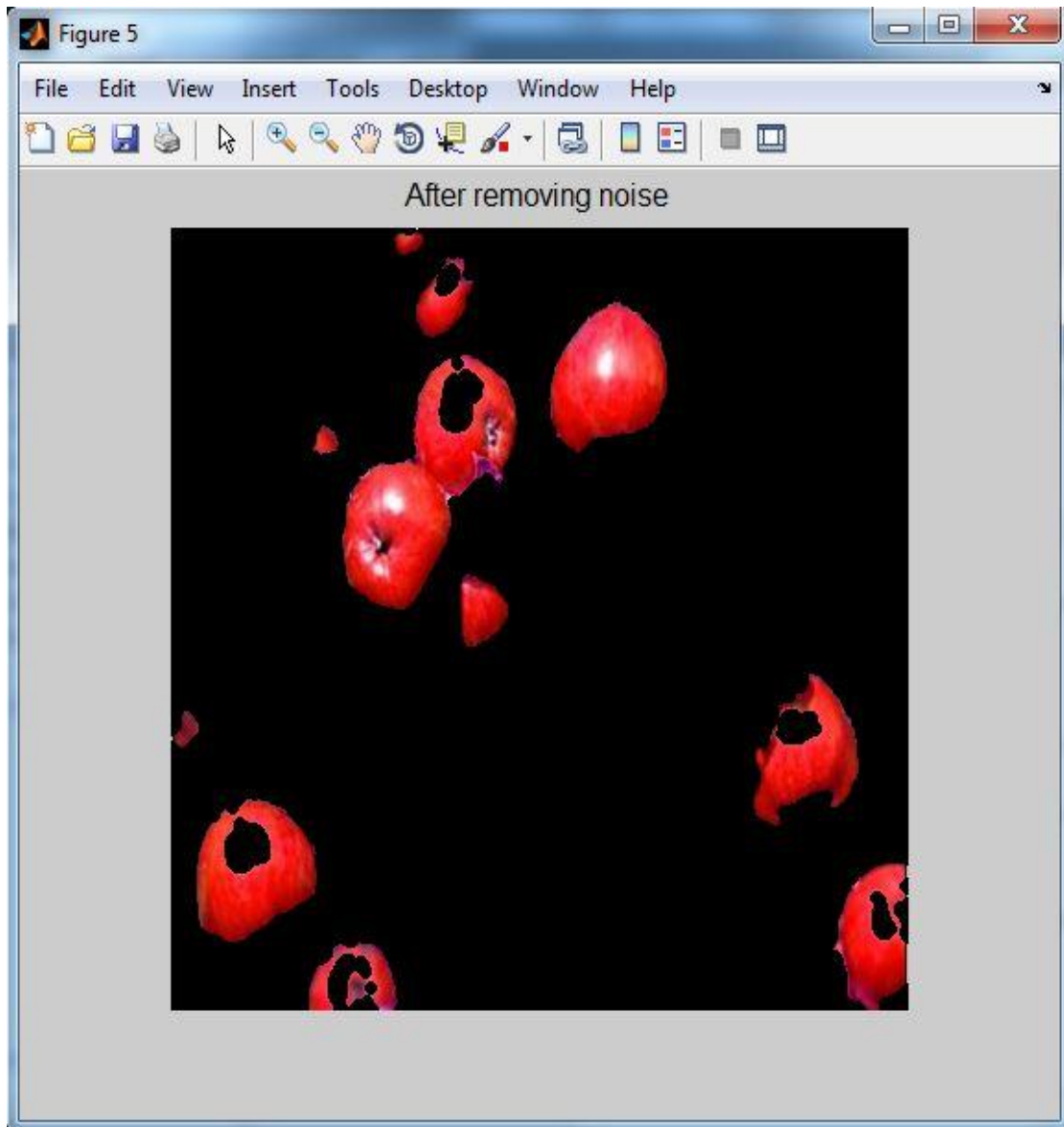


Figure 5.6: Image after noise removal.

The final operation of module 1 is detection of apples in an image in which only ripen apples are shown without any noise. Finally, the detected apples are clearly visible in the original image Img1 (see figure 5.7).

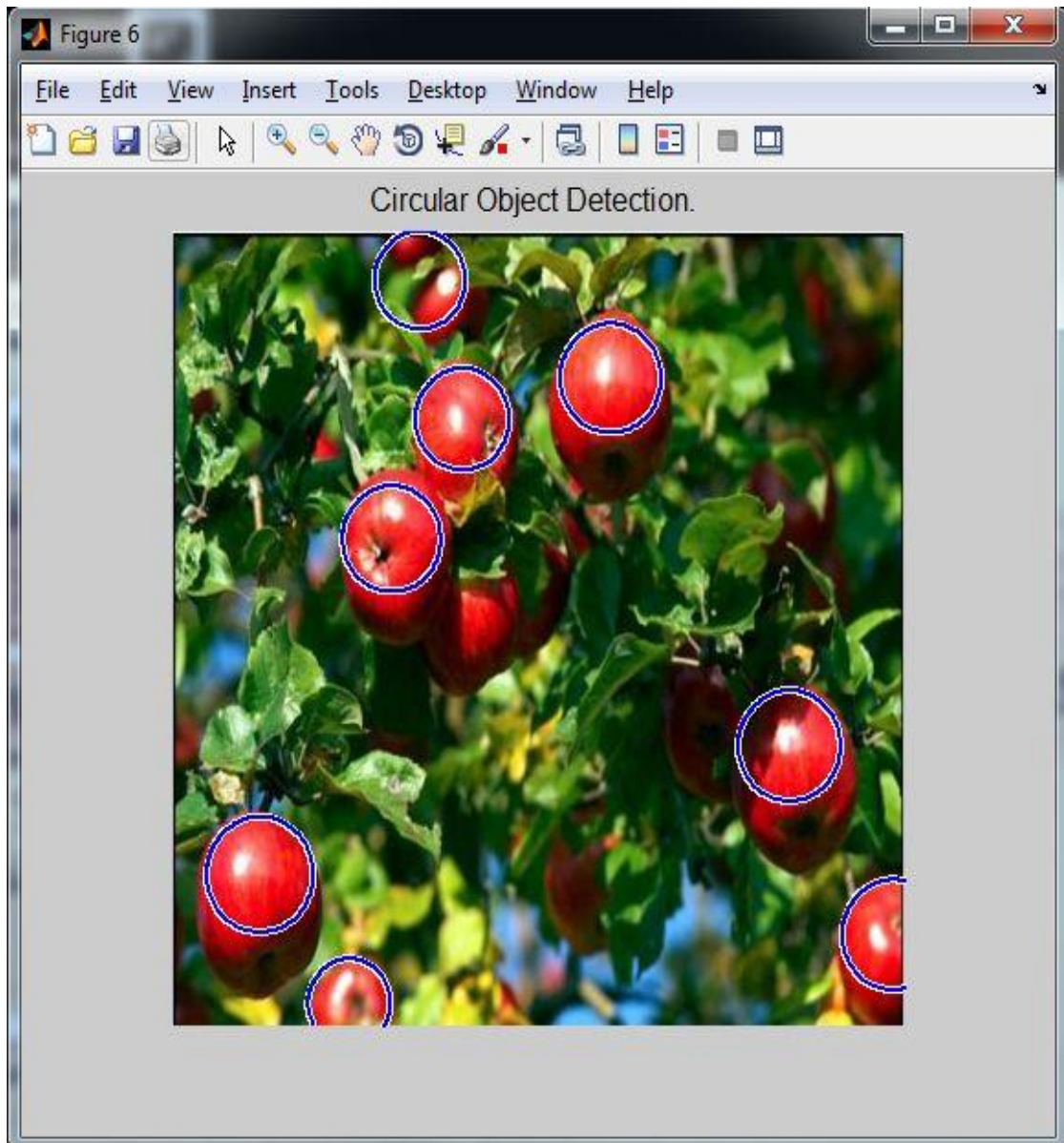


Figure 5.7: Detected apples are shown with probable boundary.

Module 1 will return an image with detected apples to the main program as shown in figure 5.7. Thereafter, the user will select single apple for further classification by randomly clicking any apple among the detected apples as shown in figure 5.8.

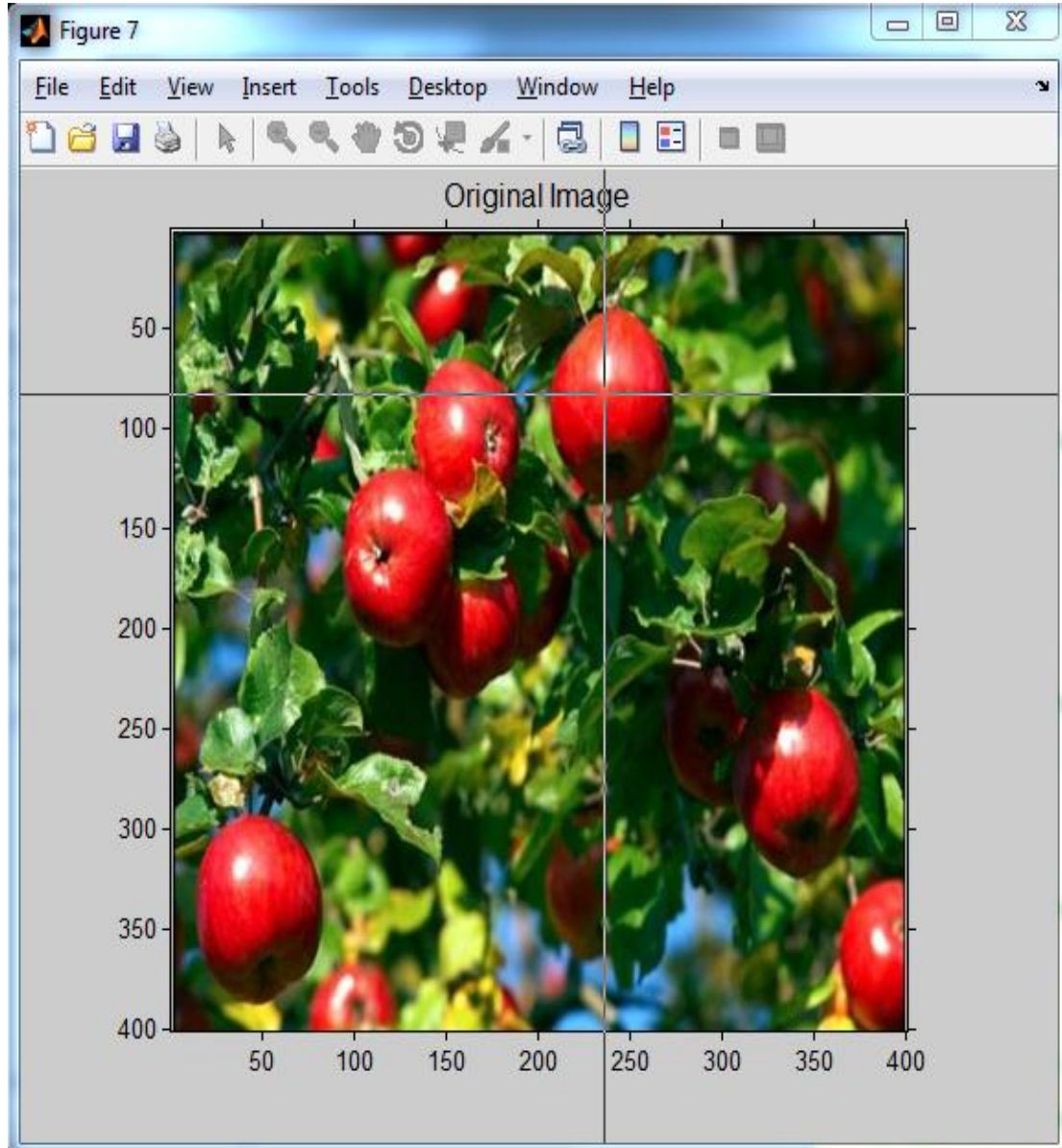


Figure 5.8: Image for selecting single apple.

Figure 5.8 shows an image in which user wishes to select the apple for further classification in order to check its quality. The selected apple is cropped and shown in figure 5.9.



Figure 5.9: cropped image of selected apple.

Finally, the cropped image of selected apple will undergo for quality identification. As discussed in the main program that the cropped image will be passed as input parameter (say `Img_c`) in the `quality_identification` module. Output parameter of `quality_identification` module will give an integer value. The integer value 1 signifies that apple is of good quality otherwise it is of bad quality.



Figure 5.10: Selected apple is categorized into good quality.

Figure 5.10 shows the final result of the identification and classification of the apples which are not harvested and which shows the apple is of good quality.

## **Section 2: Results for images of apples which are harvested.**

Figure 5.1 shows the original image *Img1*, which is passed and read by the main program.

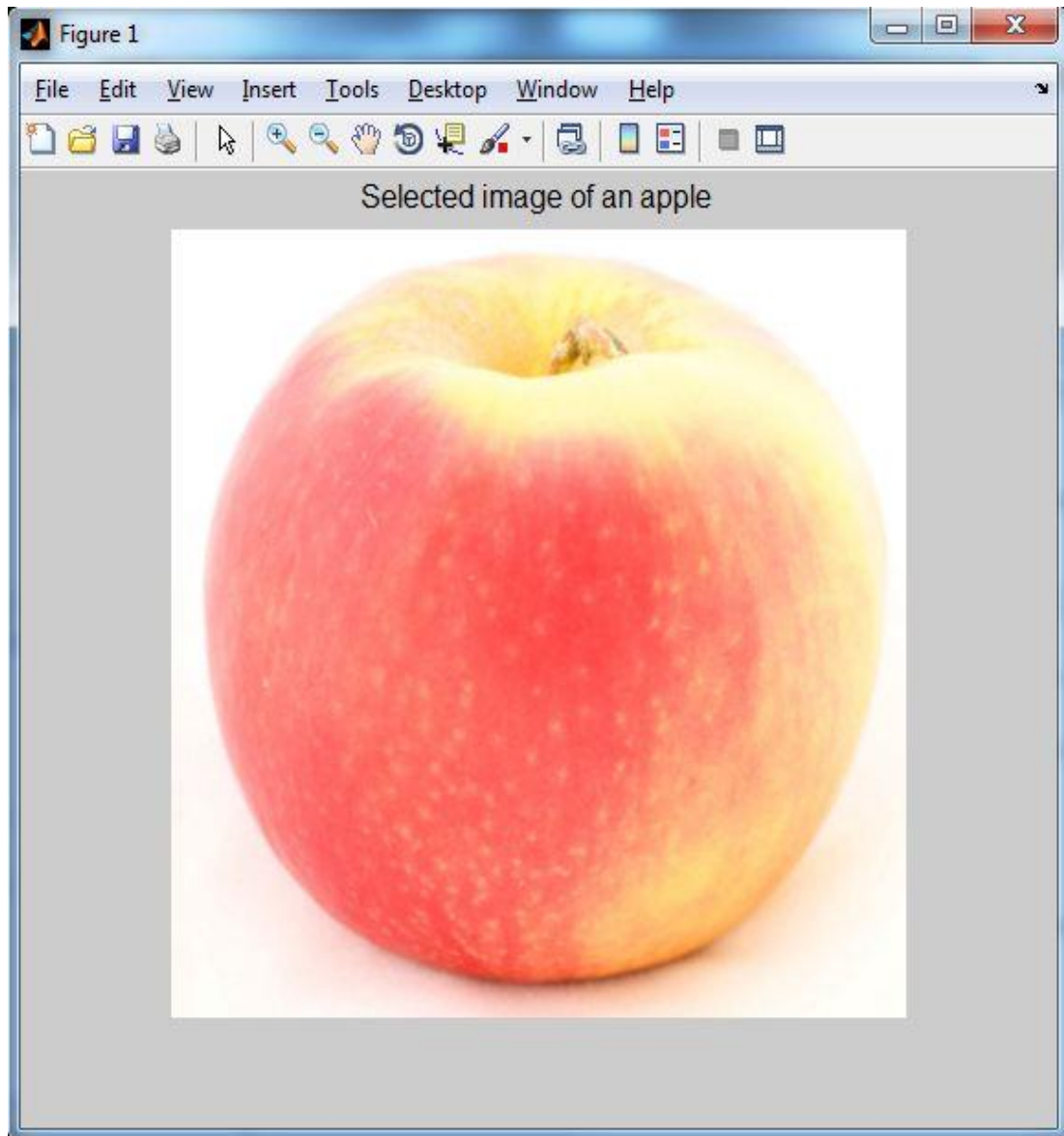


Figure 5.11: Original Image.

Then `Img1` is checked on the basis of the number of green pixels present in the image. As green pixels are not present in enough number therefore, image is considered as the image of apples that are harvested.

According to the proposed algorithm, for the above mentioned image in which apples are harvested, module 2 i.e. `Rec_after_harvest` is applied with the input parameter `Img1`. This module 2 also has various operations as in module 1.

First operation of module 2 is to convert a colored image into gray-scale image as shown in figure 5.12.

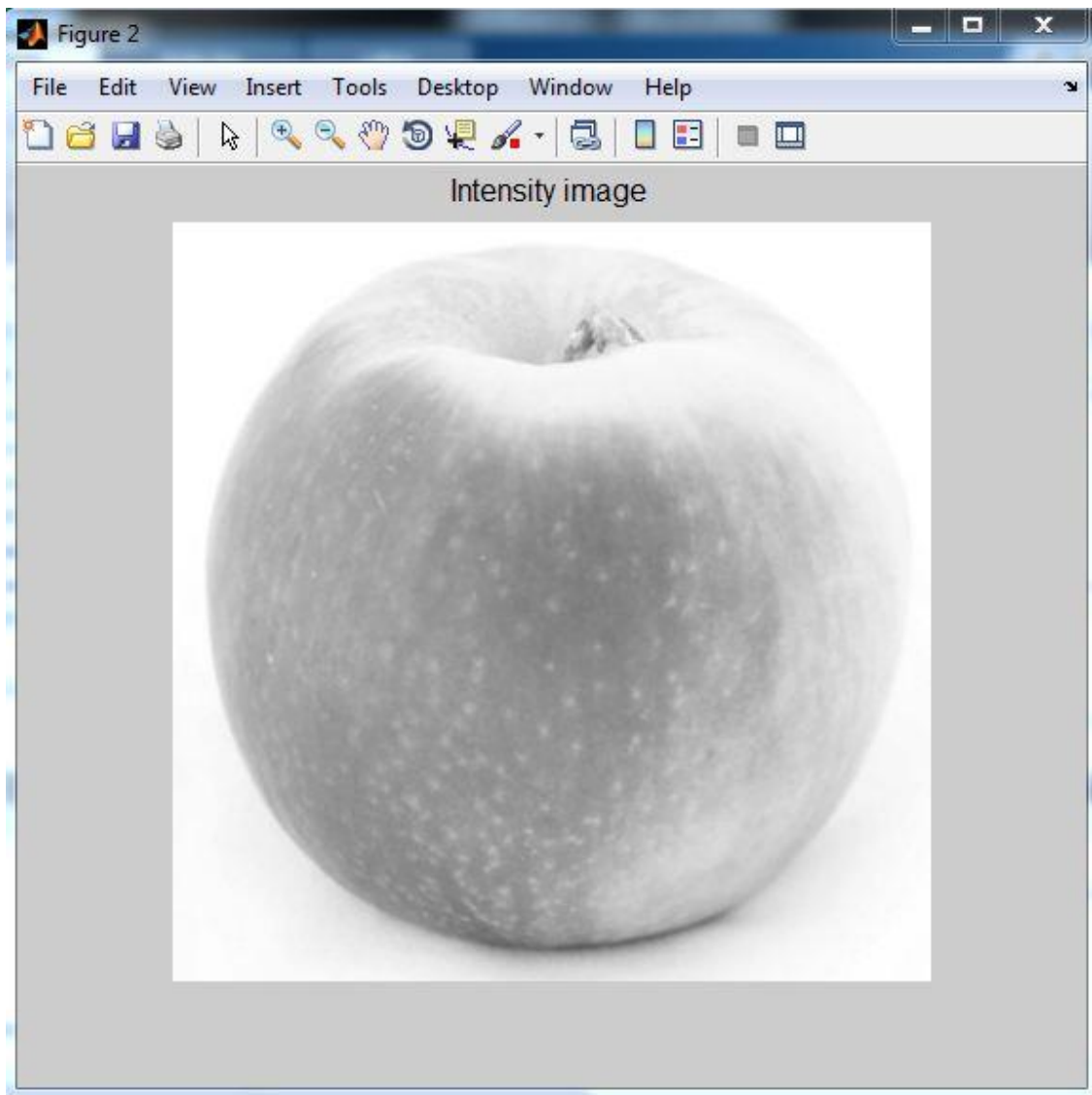


Figure 5.12: Gray scale image.

Second operation of module 2 returns the output as binary image by detecting the edges on the gray scale image.

Figure 5.13 shows the detected edges as white color and background as black color.

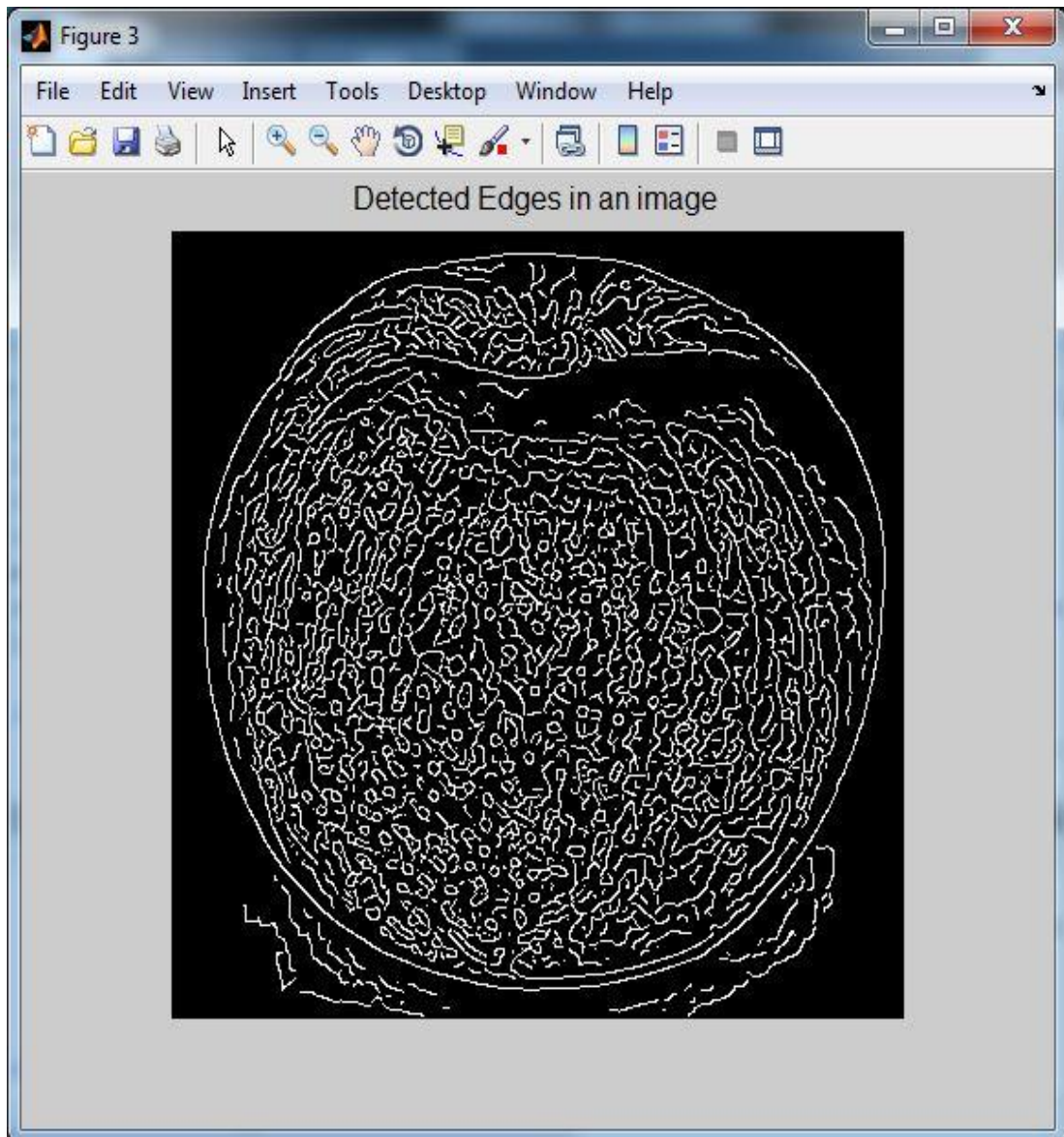


Figure 5.13: Image of detected edges.

After the detection of edges in an image, the third operation of module 2 will widen the edges to cover the maximum area of object as shown in figure 5.14.

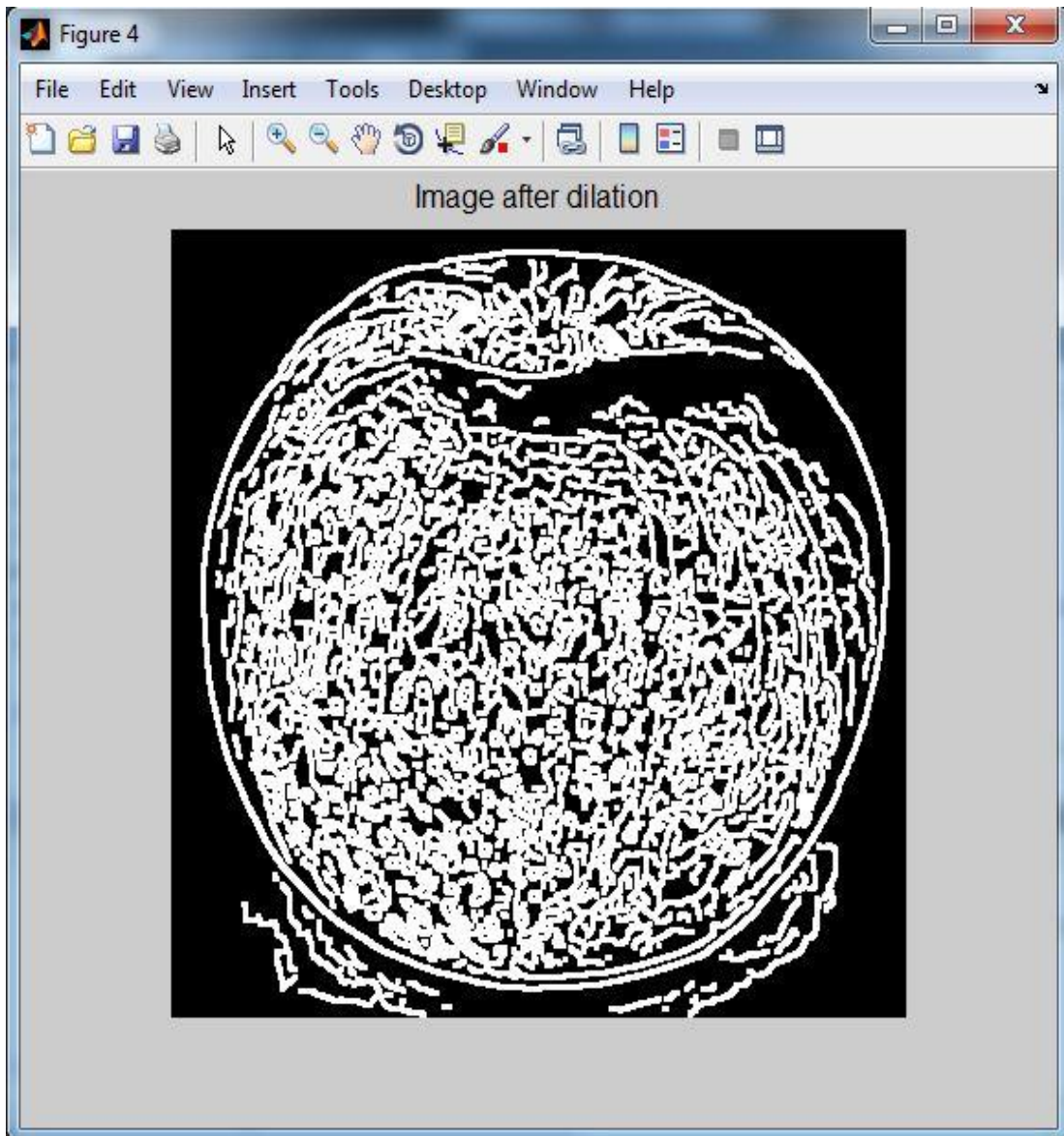


Figure 5.14: Image after the widened edges.

Fourth operation of module 2 converts the tiny black hole within the edges into white color as shown in figure 5.15.

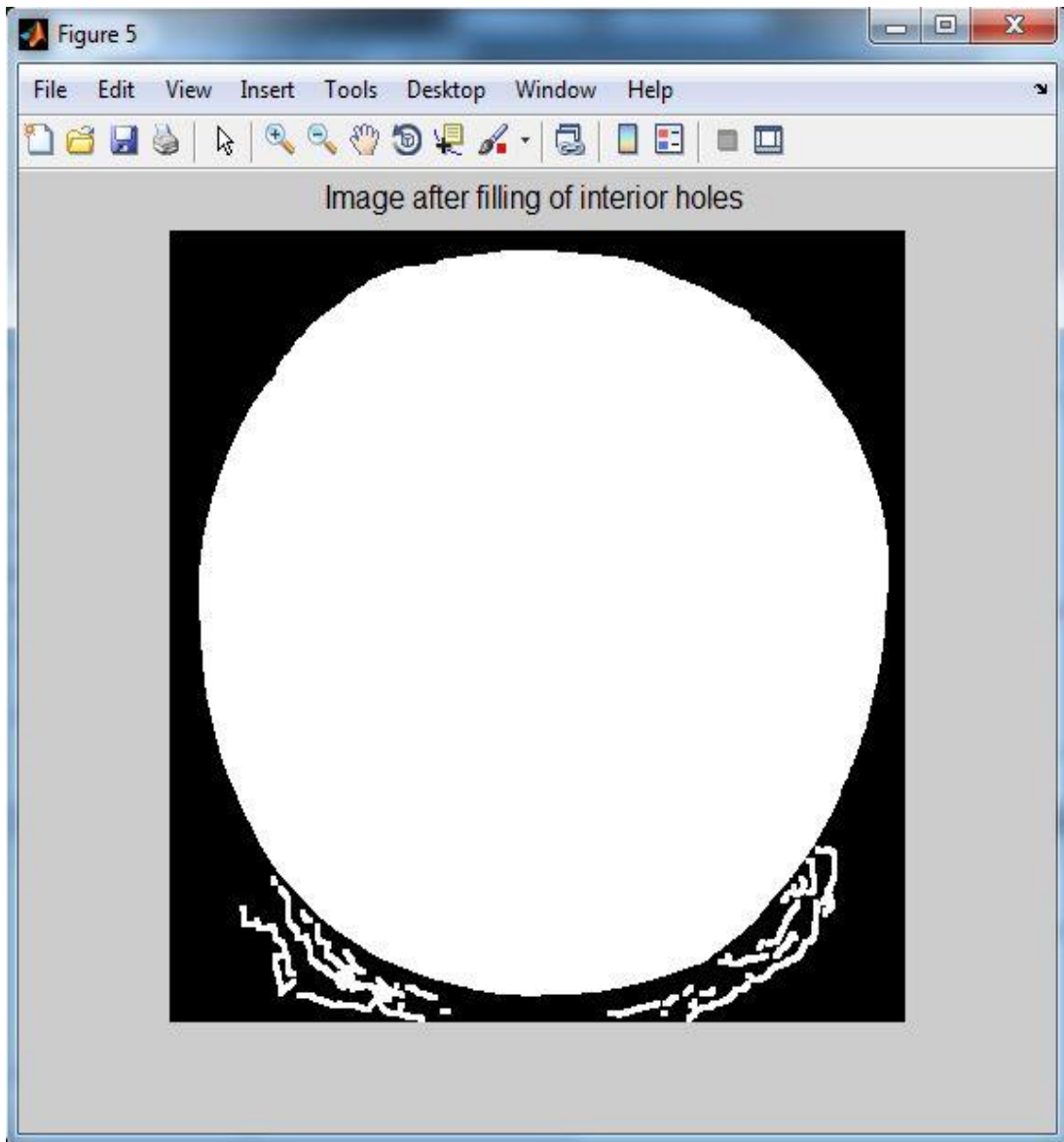


Figure 5.15: Image after filled interior holes.

Finally, fifth operation will give smoothened segmented object in binary form by applying the strategy of removing small objects (see figure 5.16).

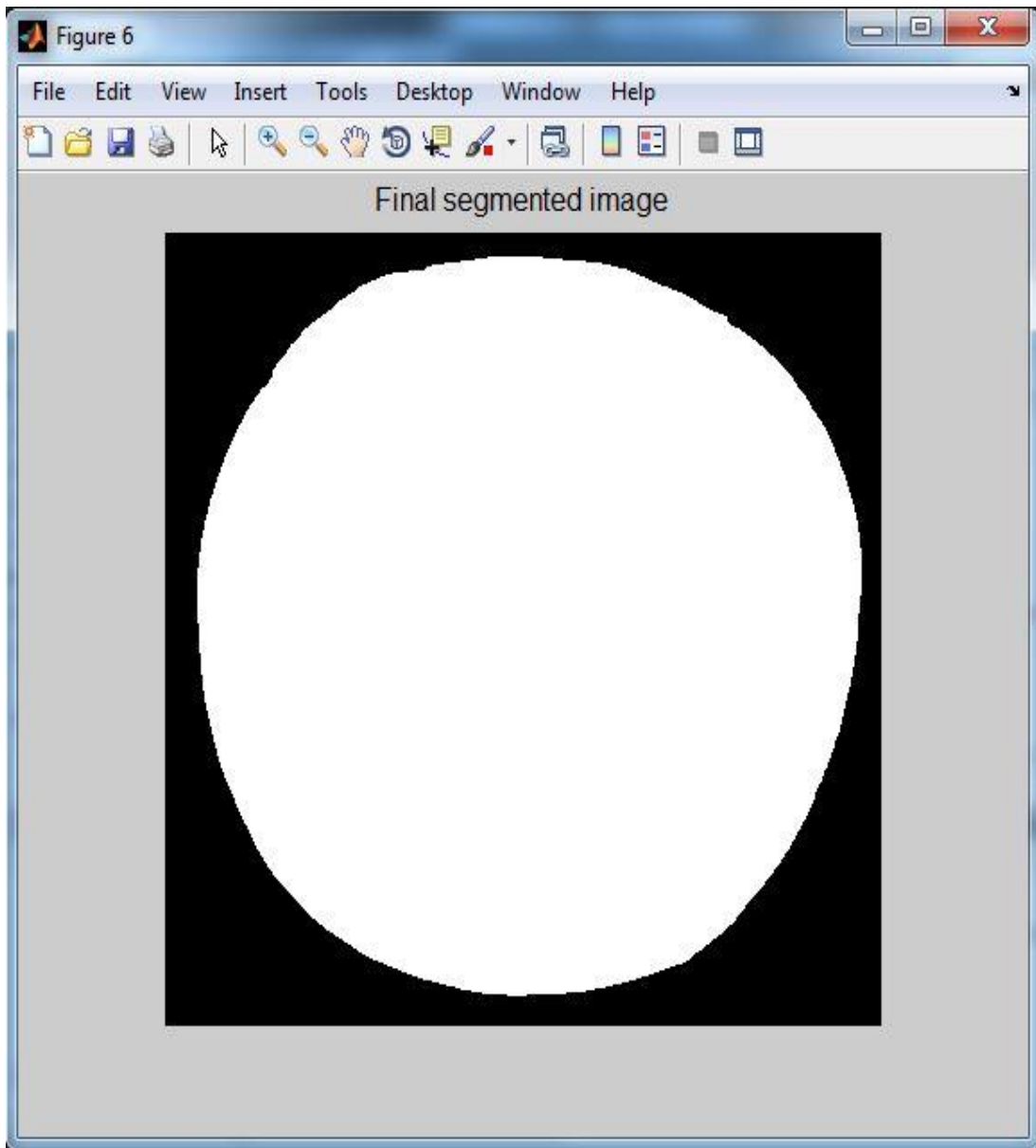


Figure 5.16: Segmented binary image.

In next operation, the smoothed segmented binary image is applied on the original image *Img1* which gives the outcome as detected apple (see figure 5.17).

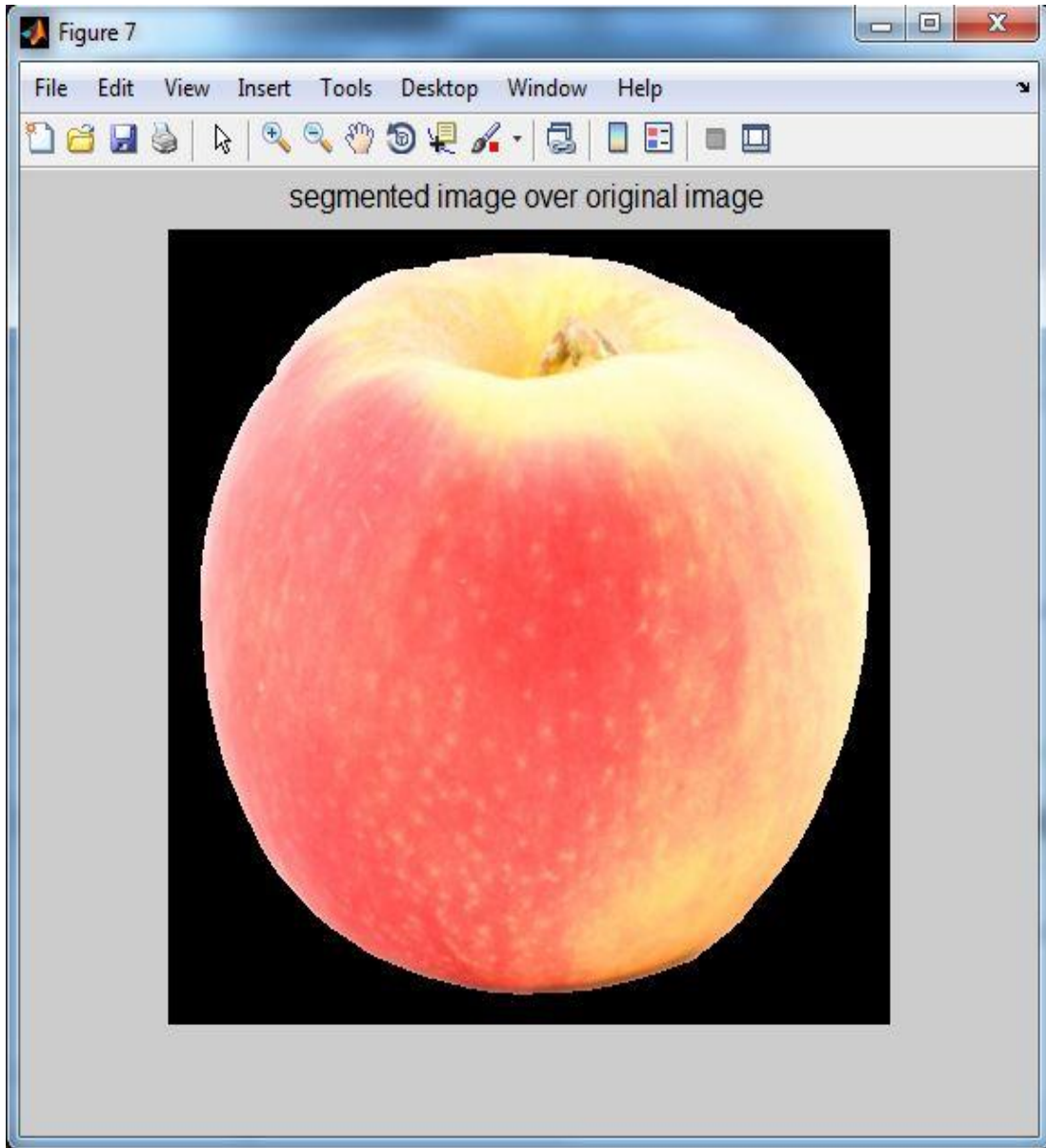


Figure 5.17: Segmented image of apple.

Circular object detected in a figure 5.17 by this operation is displayed in original image *Img1* (see figure 5.18).

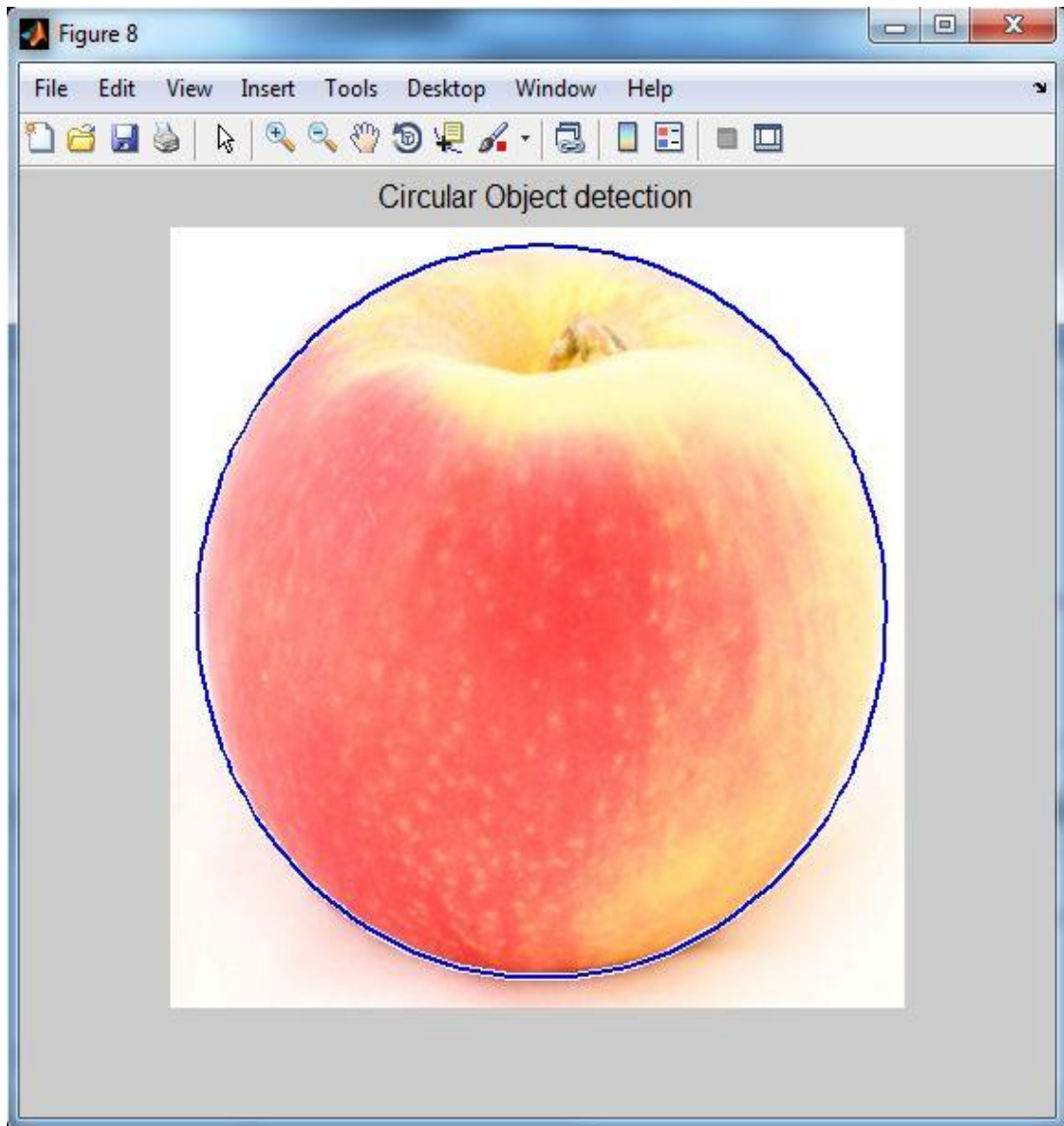


Figure 5.18: Image showing detected circular object.

Module 2 returns an image of apple encircled in a boundary to the main program as shown in figure 5.18. Thereafter, the user will select an apple for further classification by randomly clicking on the detected apple as shown in figure 5.19.

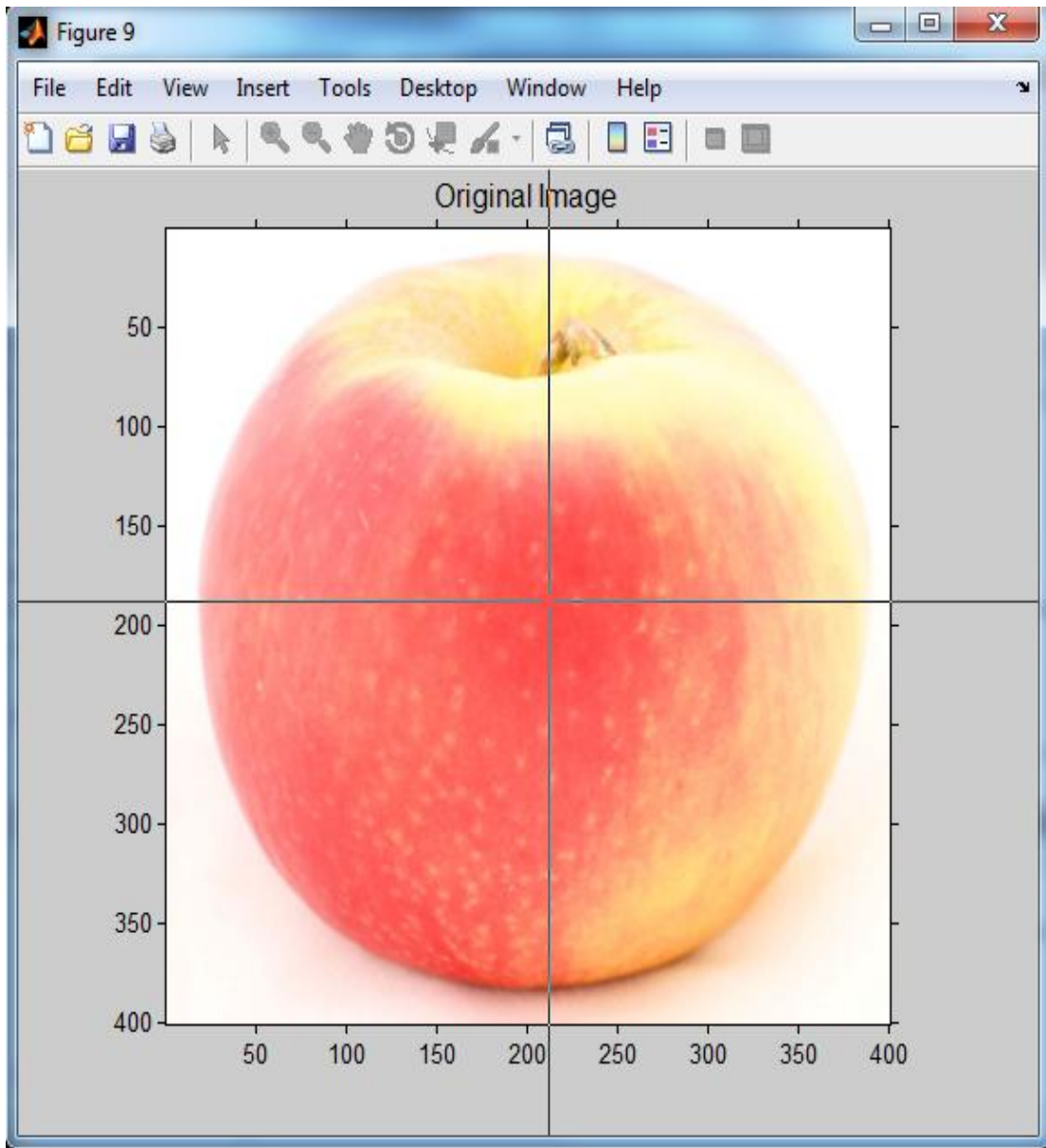


Figure 5.19: Image for selecting an apple.

As discussed in the main program, the image of selected apple is passed as input parameter (say `Img_s`) in the `quality_identification` module. Output parameter of `quality_identification` module gives an integer value. The integer value 1 signifies that apple is of good quality otherwise it is of bad quality.

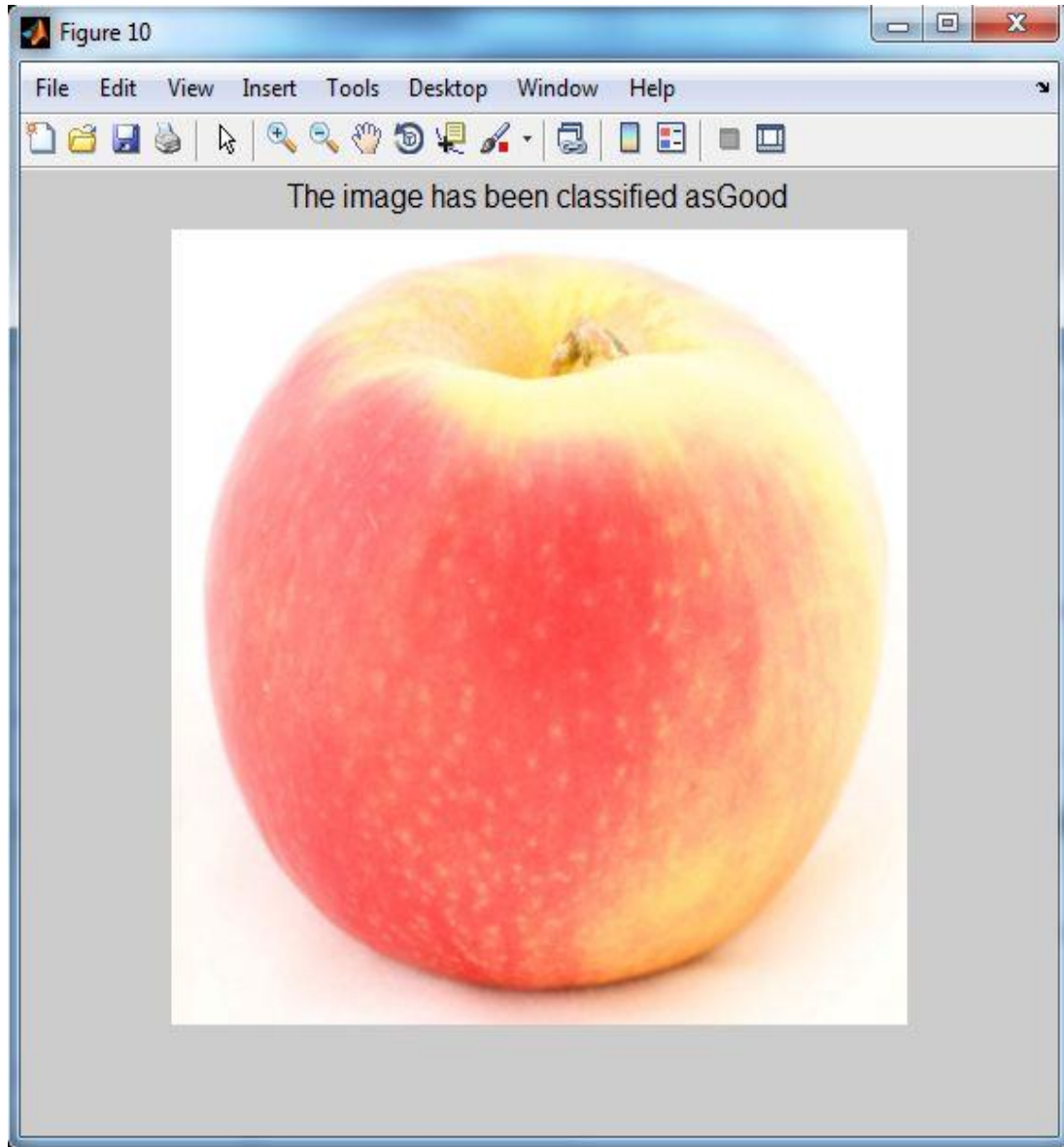


Figure 5.20: Image showing result of classification.

Figure 5.20 shows the final result of the identification and classification of the apple which is harvested and which shows the apple is of good quality.

The concluded results of experiment conducted on various images of apples as shown above. Table 5.1 shows of classification by various classifiers.

Formula used for calculating the accuracy is given below:

$$Accuracy (\%) = \frac{\text{Total number of images correctly classified}}{\text{Total number of images used for testing}} \times 100 \quad (1)$$

**Table 1: Classification results given by different classifiers.**

Class	Available	Correctly Classified	
		SVM	kNN
<b>Good</b>	60	51	56
<b>Bad</b>	60	56	56
Total	120	108	112
Accuracy		89.16%	93.33 %



Figure 5.21: Rate of classification accuracy by different classifiers.

In this work, 120 apples, 60 good apples and 60 bad apples were selected for testing set. 89.16 % and 93.33 % accuracy of classification has been achieved by SVM and kNN respectively using the proposed method. Thus according to the results obtained, authors have concluded that kNN classifier has better results of classification of apple than SVM classifier.

# CONCLUSION AND FUTURE SCOPE

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### 6.1 Conclusion

Surface defects are the most essential trait of fruits, which not only affect their market value, but also purchasers' inclination to their inward quality also to some extent. Therefore, it is very essential and important to get a fruit without defects otherwise it becomes cumbersome task at post harvesting stage. Inadequate manual investigation will require a lot of labor and time. In the present work, quality identification of fruit is done by using proposed algorithm for segmentation of fruit. Total 120 sample images of apples, where 60 images of each type (good and bad quality) are taken for testing the proposed algorithm. Different segmentation methods are used for images of apples that are harvested and images of apples that are not harvested. For the images of apples that are harvested, segmentation of apple is done on the basis of edge and shape. For the image of apples that are not harvested, the segmentation of apple is done based upon its color and shape. After the segmentation, single apple is selected by user. Further feature are extracted of selected apple by utilizing GLCM approach. Different classifiers in the present study have been used to classification of an apple into good or bad quality. After this results of different classifiers are compared. Results demonstrate that 89.16% accuracy of classification has achieved by using SVM classifier. However, kNN classifier shows more preferable result over SVM with accuracy of 93.33 %.

### 6.2 Future Scope

Detected fruits from image of apples that are not harvested can be utilized for harvesting of fruit by a robot. This will speed up the harvesting and will save time. Proposed approach can be improved and enhanced in functionality and flexibility to recognize more efficiently for widely use. Further enhancement can be done by considering the combination of size, color and texture features. Present work can be implemented to identify quality of other fruits.

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## **VIDEO PRESENTATION**

The implemented work can be understood with help of the video presentation that has been presented on [www.youtube.com](http://www.youtube.com). The URL has also been provided here.

<http://youtu.be/EdmbodvPmi8>