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Defect Identification and Maturity Detection of Mango Fruits Using Image Analysis

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Abstract: The image processing and computer vision systems have been widely used for identification, classification, grading and quality evaluation in the agriculture area. Defect identification and maturity detection of mango fruits are challenging task for the computer vision to achieve near human levels of recognition. The proposed framework is useful in the supermarkets and can be utilized in computer vision for the automatic sorting of fruits from a set, consisting of different kind of fruits. The objective of this work is to develop an automated tool, which can be capable of identifying defect and detect maturity of mango fruits based on shape, size and color features by digital image analysis. MATLAB have been used as the programming tool for identification and classification of fruits using Image Processing toolbox. Proposed method can be used to detect the visible defects, stems, size and shape of mangos, and to grade the mango in high speed and precision.

Keywords: Defect Identification, Agriculture Image Processing, Image Moment, Mango Fruit, Maturity Detection

1. Introduction

Mango is one of the world's favorite tropical fruits with increasing production trends every year. Mango is the most important fruit of India and is known as king of fruit. The mango is cultivating in the largest area i.e. 4312 thousand hectares, and the production is around 15.03 million tons, contributing 40.48% of the total world production of mango. India exports mango to over 40 countries worldwide. Its physical appearance affects its value in the market, so, it is important to observe proper handling of fruits after harvesting. In general, the color of the fruit indicates its maturity and the presence of defects. In this work, an algorithm is proposed to automatically identify defect and maturity of mango fruit using image processing. This framework can be applied in various areas like manufacturing companies, where mango juices are produced and supermarket.

In recent years, many types of research have been done on fruit quality detection by using computer vision technology, and many significant results have been obtained. There are many research reports, but so far they are in the experimental stage, and the analysis method is far from practical application. Particularly in the defect identification and maturity detection, the current approach used to deal with very slow, cannot be used in actual online work. Therefore, it is of importance to study the defect detection method suitable for production.

The process of grading of mangoes relies on its physical characteristics. This process is presently done using manual labor and is substantially dependent on the human visual system. Fruit categorizations in agriculture have changed from traditional grading by humans to automatic classification over the past 20 years. Many companies are moving to automated classification in many crops such as grading on peaches and oranges [1]. The purpose of the study was to implement image-processing algorithms that can help in automating the process of mango defect and maturity detection.

Demand from the consumer for quality produces, the consistent behavior of machines in compare with humans, the insufficiency of labor and attempt to reduce labor costs are the primary motivations of proposed system. The primary objective of this work is to design an algorithm that can identify defect and maturity detection of mango fruits based on shape and size features by digital image analysis. In more detail, the research objectives are stated as follows. To develop an algorithm for image processing to identify defect and maturity detection of mango fruits, and test and verify the analysis of image processing with experimental results.

This proposed work is an attempt to implement an extensively designed project based on the topics covered. The project involves a proposed problems and solutions with MATLAB (Matrix Laboratory) programming. Section 1 includes a brief description plans, motivation, the necessity of defect identification and maturity detection of mango and purpose of this project. In Section 2, some related works are discussed. In Section 3, the problems are discussed which arise during mango image analysis. Section 4 explains the materials and methods involved in the completion of the proposed work. In Section 5, Experimental results of proposed work are discussed. In Section 6, conclusion and scope of future work are made. References are included in Section 7.

2. Related Work

The review of literature is accomplished very carefully and keenly towards the proper definition of the problem. Different methodologies are being investigated to propose and implement the present work. The reviewed literature has been classified into primary heads for the sake of the comprehensive analysis study such a classification shall help to study literature as per their context. Some of the most important implementation of image processing in agricultural products is:

(1) The image processing method for classification of orange by ripeness is developed. In this work, the proper degree of maturity is determined and based on that orange have been classified by histogram and morphological analysis. It uses standard CODEX benchmark, in that quality level of the commercial types of specified orange [2].

(2) A fusion approach is implemented for multiclass fruit and vegetable classification task in the distribution center and supermarket. A novel unified approach has been introduced, to combine many features and classifier. This method requires less training of data than another method that combines features individually and fed separately to classification algorithm [3].

(3) Using just one image feature to secure the class separability might not be sufficient, so it is necessary to extract and combine those features which are useful for the fruit and vegetable recognition problem. The result of the system depends upon the image segmentation method, so efficient image segmentation must be used. In the literature, available classifiers work on two classes only, but in the classification problem author considered more than two categories, so it is a major issue to use a binary classifier in a multiclass scenario [4].

(4) An image processing based hybrid algorithm has been implemented for automatic identification and classification of fruits. The hybrid method relies on the techniques of Fourier descriptors (FD), spatial domain analysis (SDA) and artificial neural network (ANN) [5].

(5) By performing digital image processing, defined as the acquisition and processing of visual information by computer, computer vision systems allow analyzing image data for specific applications to determine how images can be used to extract the required information. Among the most important features for accurate classification and sorting of products, it can be mentioned the shape. In this paper, for segmentation, a technique based on Hough Transform is used to detection of object shape [6].

(6) Machine vision has been introduced in a variety of industrial applications for fruit processing, allowing the automation of tasks performed so far by human operators. Such an important task is the detection of defects present on fruit peel which helps to grade or to classify fruit quality. In this paper, a hybrid algorithm, which is based on split and merger approach, is proposed for an image segmentation that can be used in fruit defect detection [7].

(7) Variable lighting condition, occlusions and clustering are some of the important issues needed to be addressed for accurate detection and localization of fruit in orchard environment. This paper summarizes various techniques and their advantages and disadvantages in detecting fruit in plant or tree canopies. The paper also summarizes the sensors and systems developed and used by researchers to localize fruit as well as the potential and limitations of those systems [8].

(8) Image processing is an efficient tool for analysis in various fields and applications in agriculture. Today's very advanced and automated industries used more accurate method for different inspection processes of agriculture object. This task is known as robotics task. In Indian agriculture industry, many kinds of activities are done like quality inspection, sorting, assembly, painting, packaging. Above mentioned activities are done manually. By using Digital Image processing tasks done conveniently and efficiently. Using Digital image processing many kinds of task fulfills like object Shape, size, color detection, texture extraction, firmness of purpose, aroma, maturity, etc. In this paper, various algorithms of shape detection are explained, and conclusions are provided for best algorithm even merits and demerits of each algorithm or method are described [9].

(9) Seasonal fruits, like mango, are harvested from gardens or farms in batches; the mangoes present in each batch are not uniformly matured, therefore, sorting of mangoes into different groups is necessary for transporting them to various locations. With this background, this paper proposes a machine-vision-based system for classification of mangoes by predicting maturity level and aimed to replace the manual sorting system. The prediction of maturity level has been performed from the video signal collected by the Charge Coupled Device (CCD)

camera placed on the top of the conveyor belt carrying mangoes. Extracted image frames from the video signal have been corrected and processed to extract various features, which were found to be more relevant for the prediction of maturity level [1].

(10) This paper focuses on the automatic detection of the pomegranate fruits in an orchard. The image is segmented based on the color feature using k-means clustering algorithm. The K-Means algorithm produces accurate segmentation results only when applied to images defined by similar regions on texture and color. Segmentation begins by clustering the pixels based on their color and spatial features. The clustered blocks are then merged to a particular number of regions. Thus it provides a solution for image retrieval. Thus this paper proposed the simulation results that have been attained using the algorithm [10].

The literature survey gives a keen insight into the various studies done in the field of defect identification and maturity detection of mango fruit. The study focused mainly on different methods and applications of Mango fruit defect identification and maturity detection system. A variety of methods has been suggested by the researchers to improve the performance of the scheme. This literature survey has provided useful insight into different techniques that can be utilized to plan design and development of the proposed method.

3. Problem Identification

To enhance the quality and quantity of the agriculture product, there is a need to adopt the new technology. Image processing approach is a non-invasive technique, which provides consistent, reasonably accurate, less time consuming and cost effective solution. A generalized block diagram of defect identification and maturity detection of mango fruits is shown in “Figure 1”.

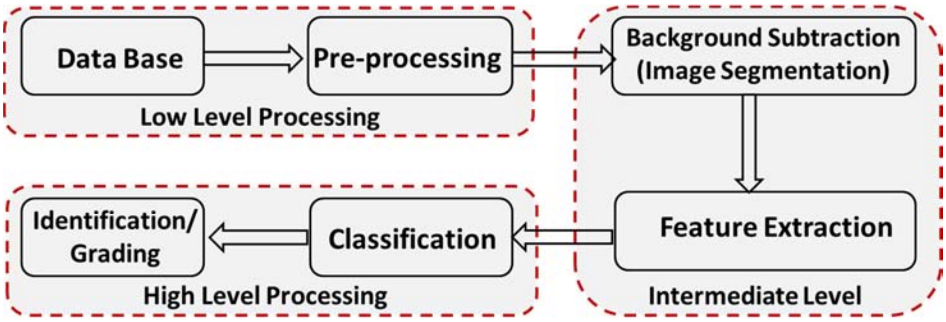


Figure 1. *A generalized block diagram of defect identification and maturity detection of mango fruits.*

Some important factors and issues, which are needed to be considered while development of defect identification and maturity detection of mango fruits using image analysis is listed below:

3.1. Background Subtraction

It is necessary to extract mango from the cluttered environment, so subtraction of background is essential for proper identification and classification of mango fruits. Background subtraction also reduces the scene complexities such as shading, light variation, background clutter. “Figure 2” shows due to the severe occlusion; it is impossible to detect the mangos even manually correctly.

Figure 2. *Variation of occlusion.*

3.2. Feature Extraction

Shape – Region and boundary are two types of shape description feature. Region-based features include grid-based and moment approaches, whereas finite element models, rectilinear shape, polygonal approximation and Fourier-based shape descriptors are boundary-based shape features.

Color - Color value and degree of color distribution are measured based on R, G, and B color component ratio. Example: Color may be different for example; Orange ranges from being green to yellow, to patchy and brown.

Size - Size may be large, medium or small. It is measured from the maximum length or area or calculated volume from several images.

3.3. Classifier

In classification process different feature such as geometric and, non-geometric features need to be classified. So, it is necessary to address the issue of proper selection of classifier.

4. Materials and Methods

The Proposed algorithm for defect identification and maturity detection of mango fruits using image analysis is shown in "Figure 3". Theoretically, proposed algorithm involves three types of processing i.e. low level, intermediate and high-level processing. In low-level processing, input image/dataset is pre-processed. Pre-processing includes RGB to gray conversion, image binarization, and image filtering. Intermediate level processing involves background subtraction, feature extraction, and filtering. Identification of defected region and detection of the maturity level of mango fruit has been performed in high-level processing.

4.1. Database

Database of 100 calibrated images of mangoes 'Kent' (50 mangos photographed by both sides) is obtained from the web [11]. These samples are mangos cv. 'Kent' in different maturity stages. The image acquisition system was composed of a digital camera (EOS 550D, Canon Inc.) used to acquire high-quality images with a size of 1200 x 800 pixels and a resolution of 0.03 mm/pixel. Images of fruit were stored in JPG format due to internet limitations.

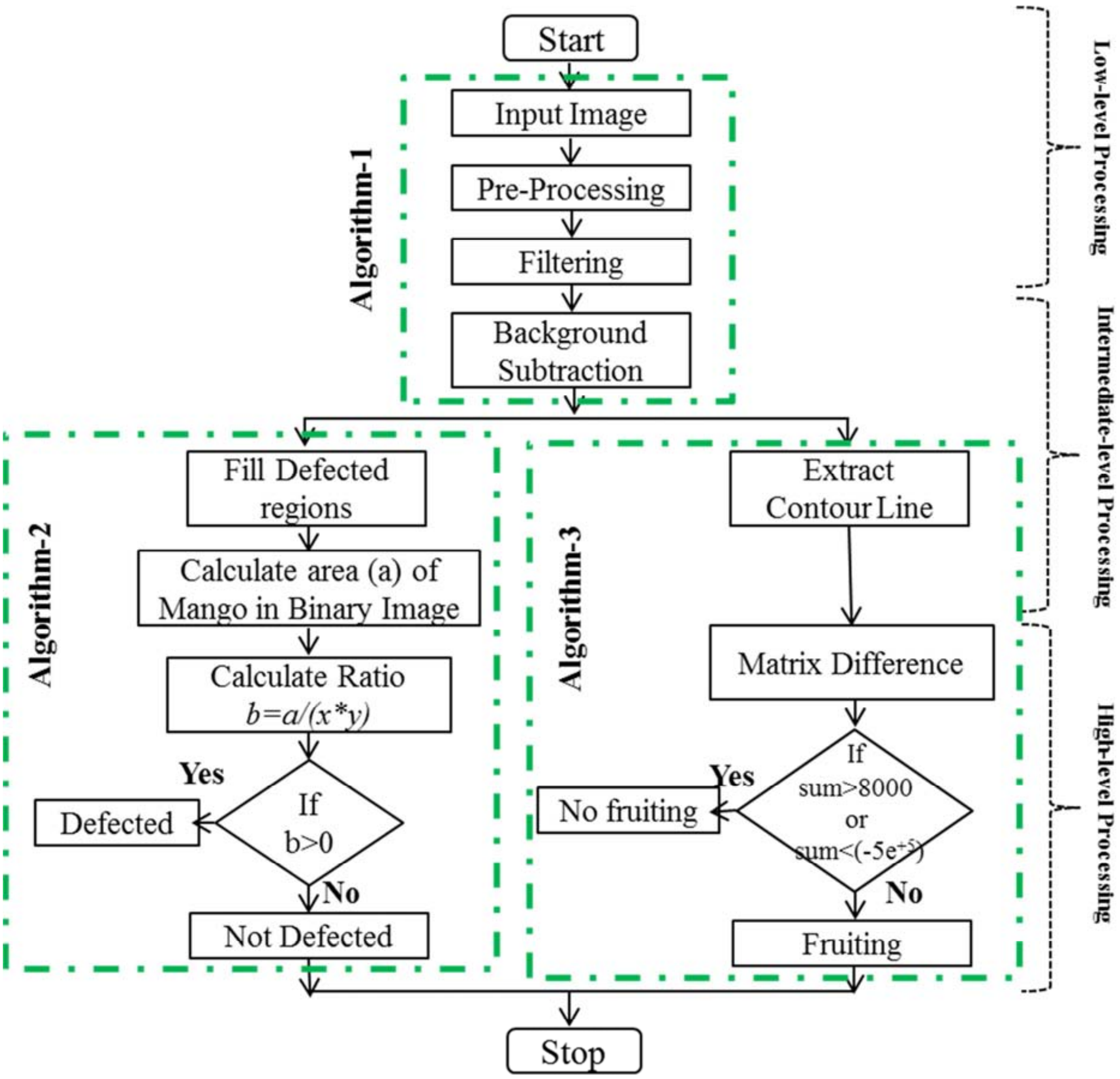


Figure 3. *Automatic Defect Identification and Maturity Detection for Mango Fruit.*

The images were taken by placing each sample inside an inspection chamber in which contained the camera and the lighting system. The vision system used to acquire the images is shown in “Figure 4”. The camera was placed at a distance of 20 cm from the samples. Illumination was achieved using four lamps that contained two fluorescent tubes. The angle between the axis of the lens and the sources of illumination was of approximately 45 degrees with the diffuse reflection responsible for the color occurs at 45 degrees of the incident light.

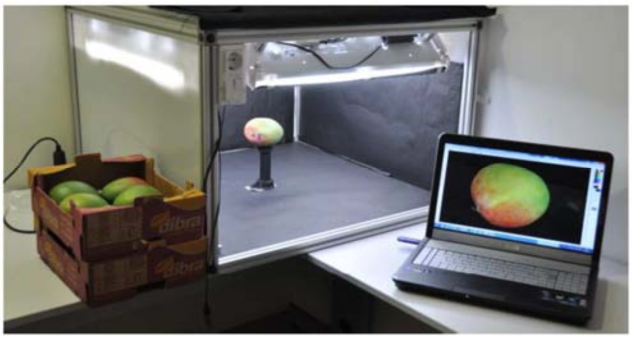


Figure 4. *The setup used to capture the images.*

However, the samples have a curved shape that can still produce bright spots affecting the color measurements. To minimize the impact of these specular reflections cross polarization was used by placing polarizing filters in front of the lamps and the camera lenses. The fluorescent tubes were powered using high-frequency electronic ballast to avoid the flickering effect of the other current and produce a more stable light. Two images of each mango were taken (A and B) from both sides. The settings of the camera used for the acquisition are summarized in “Table 1”.

Table 1. *Camera Settings and Parameters.*

X-Resolution	72 inch
Y-Resolution	72 inch
Exposure time [s]	¼
F-Number	22.0
ISO speed ratings	800
Shutter speed [s]	¼
Aperture	F22.6
Flash	No flash
Focal length [mm]	35
Color space	SRGB
Compression setting	Fine
White balance	Cloudy

4.2. Proposed Methodology

In general, the implementation of defect identification and maturity detection of mango fruits comprises the following three consecutive algorithms. Algorithm-1 is developed for pre-processing of the database. In which, a color image is converted into a grayscale and binary image, and also filtering is performed to remove background and foreground noise from the database.

```
Algorithm 1: Low-Level Processing
Start
Step 1: Read each image into the MATLAB from the particular folder of mango dataset.
Step 2: Convert the original image into greyscale image and binary image.
Step 3: Filter the image using a median filter.
Step 4: Remove or subtract the background from pre-processed image.
Step 5: Filter the image using a median filter.
Stop.
```

```
Algorithm 2: Defect Identification
Start
Step 1: Calculate area of mango image.
Step 2: Calculate quality ratio b=a/(x*y).
Step 3: Apply condition
        if (b> 0)
                Mango is defected.
        else
                Mango is not defected.
        end
Step 4: Finally, displaying various results.
Stop.
```

Algorithm-2 is proposed for identification of defects by calculation quality ratio *b=a/(x*y)*, where *b* is the area of defected region and *(x*y)* pixel value. The maturity of the harvested mango is detected by Algorithm-3, in which, based on the value of matrix difference maturity of mango is detected.

```
Algorithm 3: Maturity Detection of Harvested Mangoes
Start
Step 1: Calculate contour information.
Step 2: Calculate matrix difference.
Step 3: Apply condition
        if (sum> 8000 || sum <(-5.0000e+005)
                Not Mature.
        else
                Mature.
        end
Step 4: Finally, displaying various results.
Stop.
```

4.2.1. Pre-processing

Initially, raw RGB mango image is converted to grey-scale by grey-scale image processing. The original RGB image is shown in “Figure 5(a)” and converted grey-scale image is shown in “Figure 5(b)”.

4.2.2. Background Subtraction

The preliminary background subtraction serves two purposes. The first purpose is to remove most of the background pixels for determination of the coarse mango regions. The second purpose is to determine whether mango pixels as a whole are darker than the background.

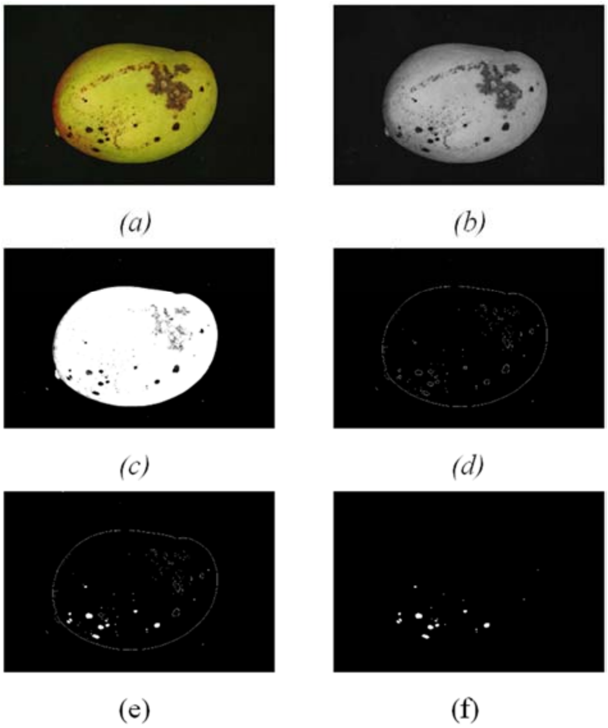


Figure 5. *(a) Original Image (b) Grey-scale Image (c) Binary Image (d) Edge Detection (e) Contour Filling (f) Filtered Image.*

After pre-processing, the grey-scale image is converted to a binary image by with the 0.15 threshold value is shown in "Figure 5(c)". So that the mango area is black, the rest of the region is white. Finally, figure reversal is applied, so that black and white color area reversed when the mango area is white, which improves the performance of the classifier.

4.2.3. Feature Extraction

Recently, image moments are widely used, because moments are the most popular descriptor among all descriptor. The moment can be easily computed from a binary or a segmented image. Mainly, there is two type of image features are used in different application, local and global features. In this paper, moment based global features are adopted to enhance the robustness of framework [12].

Let $f(x,y) \geq 0$ be a real bounded function of a compact region R. The $(i+j)$ order moment of $f(x,y)$ are given as

$$m_{ij} = \iint_R x^i y^j f(x,y)\,dxdy \quad (1)$$

where the order of the moment is $(i+j)$. If $(i=j=0)$, then it is called zeroth order moment of $f(x,y)$ which is the number of pixel in the region and also represent an area of the region.

$$m_{00} = \iint_R f(x,y)\,dxdy \quad (2)$$

First order moment is m_{01} or m_{10} of $f(x,y)$. The central moment μ_{ij} is computed with respect to the object centroid (x_g, y_g).

$$m_{01} = \iint_R x f(x,y)\,dxdy; m_{10} = \iint_R y f(x,y)\,dxdy \quad (3)$$

$$\mu_{ij} = \iint_R (x-x_g)^i (y-y_g)^j f(x,y)\,dx\,dy \quad (4)$$

$$x_g = (m_{10}/m_{00}); y_g = (m_{01}/m_{00}) \quad (5)$$

Finally, zeroth order moment is used to calculate the area of defected region. Using the ratio of the total to the pixel value *(x*y)* of the whole image, multiplying the area of the image, gives the area of the mango about the image, and this area is utilized for screening.

4.2.4. Defect Identification

The defected mango is identified by extracting the contour of damaged part. Then damaged part has been filled to find its area in the image as the basis for discrimination. Mango is identified into two classes based on features. In the first class, flawless mangos and in second class defected mangoes are classified. Detection of defected mango has been performed based on surface defect (such as scars, dark spots, etc.). Then the intensity value of the grayscale image is adjusted. Followed by the median filter is used to filter the image. Then, edge detection is performed to create a boundary of contours on filtered mango image. Edge detected image is shown in "Figure 5(d)". Then, contour (defective part) is filled with the white pixel is shown in "Figure 5(e)". Followed by filtering, this is shown in "Figure 5(f)". The noise filter for defects in the number of pixels *a*, the total number of pixels in the picture *(x*y)* then the ratio of *b* is the basis for judgment, the program set *b = 0*.

4.2.5. Maturity Detection

Fruit maturity is typically based on time since fruit set and a subjective assessment of skin roughness, fruit firmness, glossiness, shoulder 'fullness,' peel and flesh color. Based on shoulder 'fullness' parameters, there are two different stages of assessing the maturity of mango fruit, viz., "Figure 6(a)" shows the fruit shoulders are in line with stem i.e. mango is mature, and "Figure 6(b)" The shoulders outgrow the stem-end i.e. mango is immature.

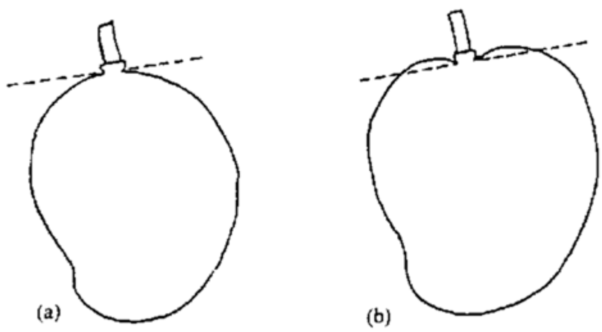


Figure 6. *Maturity Detection.*

The detection of mango stems, mainly by mango's contour line matrix to achieve differential. Using the image processing technology, mango extracts the contour line information from the intensity image, and then difference and the approximate derivative are determined from contour information, then the difference values are summed, and a sum value is obtained. This value is the basis for us to determine whether the mature. When it is mature, then the sum will be 0 to -5×10^5 (estimated value), and immature of the sum value is positive.

5. Result and Discussion

The proposed work is an extension of the recently published article [13]. The proposed algorithm is an attempt to make a simple and efficient tool for defect identification and maturity detection of mango fruits using image processing. In this section, the result at various stages of the algorithm is shown and discussed. Experiments were carried out with a set of 28 Mangos. A preliminary result is shown in "Figure 7" and "Figure 8". These shows the better results are obtainable using proposed algorithm.

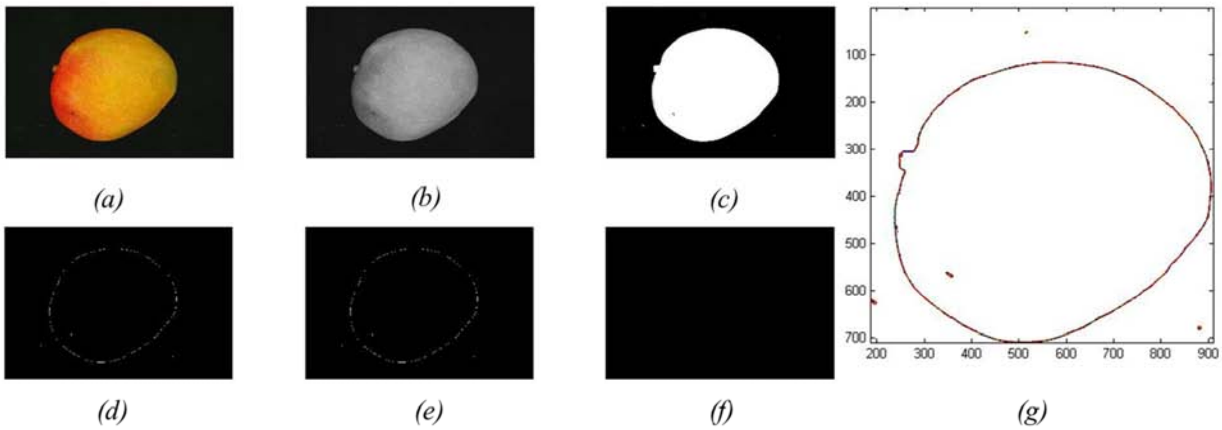


Figure 7. *No Defect and Mature Mango Result (a) Original Image (b) Grey-scale Image (c) Binary Image (d) Edge Detection (e) Contour Filling (f) Filtered Image (g) Contour Outline.*

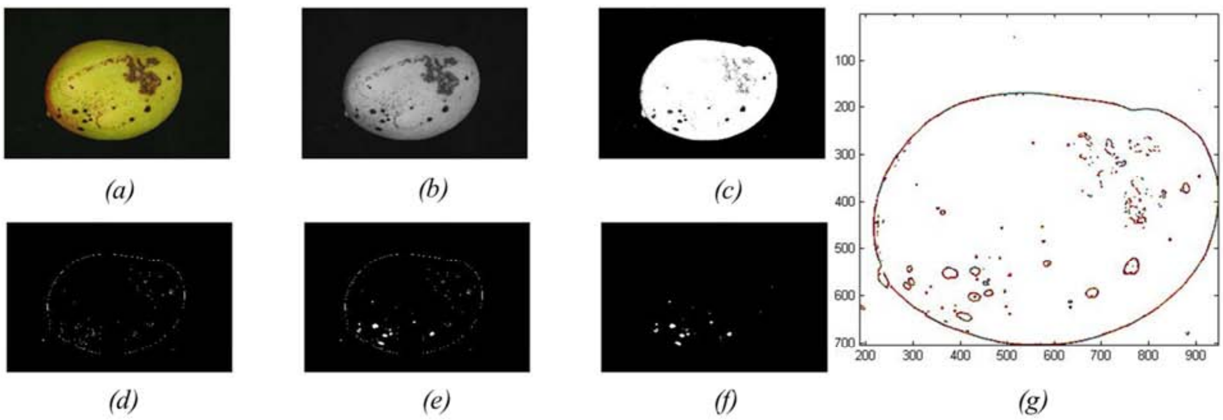
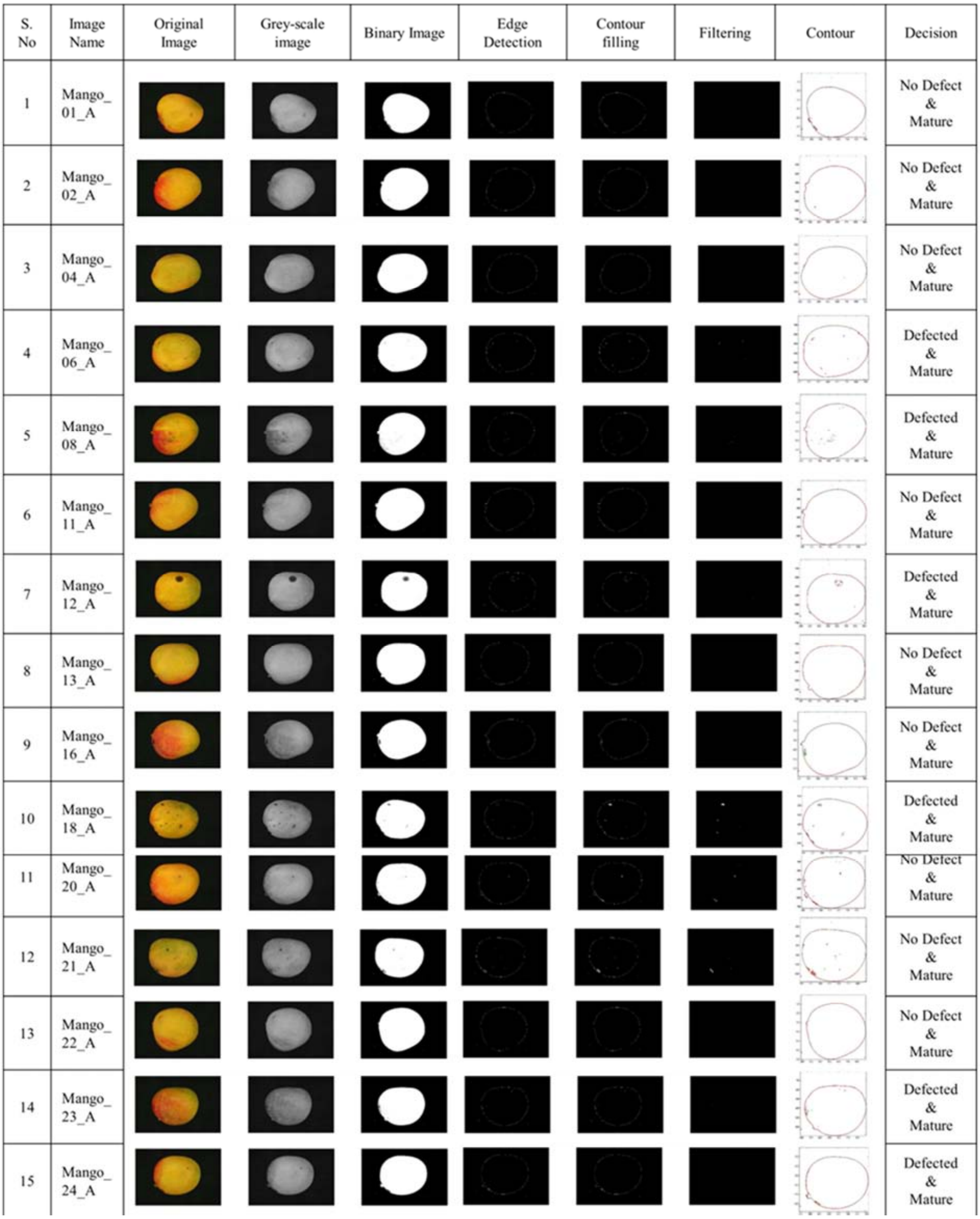


Figure 8. *Defected and Immature Mango Result (a) Original Image (b) Grey-scale Image (c) Binary Image (d) Edge Detection (e) Contour Filling (f) Filtered Image (g) Contour Outline.*

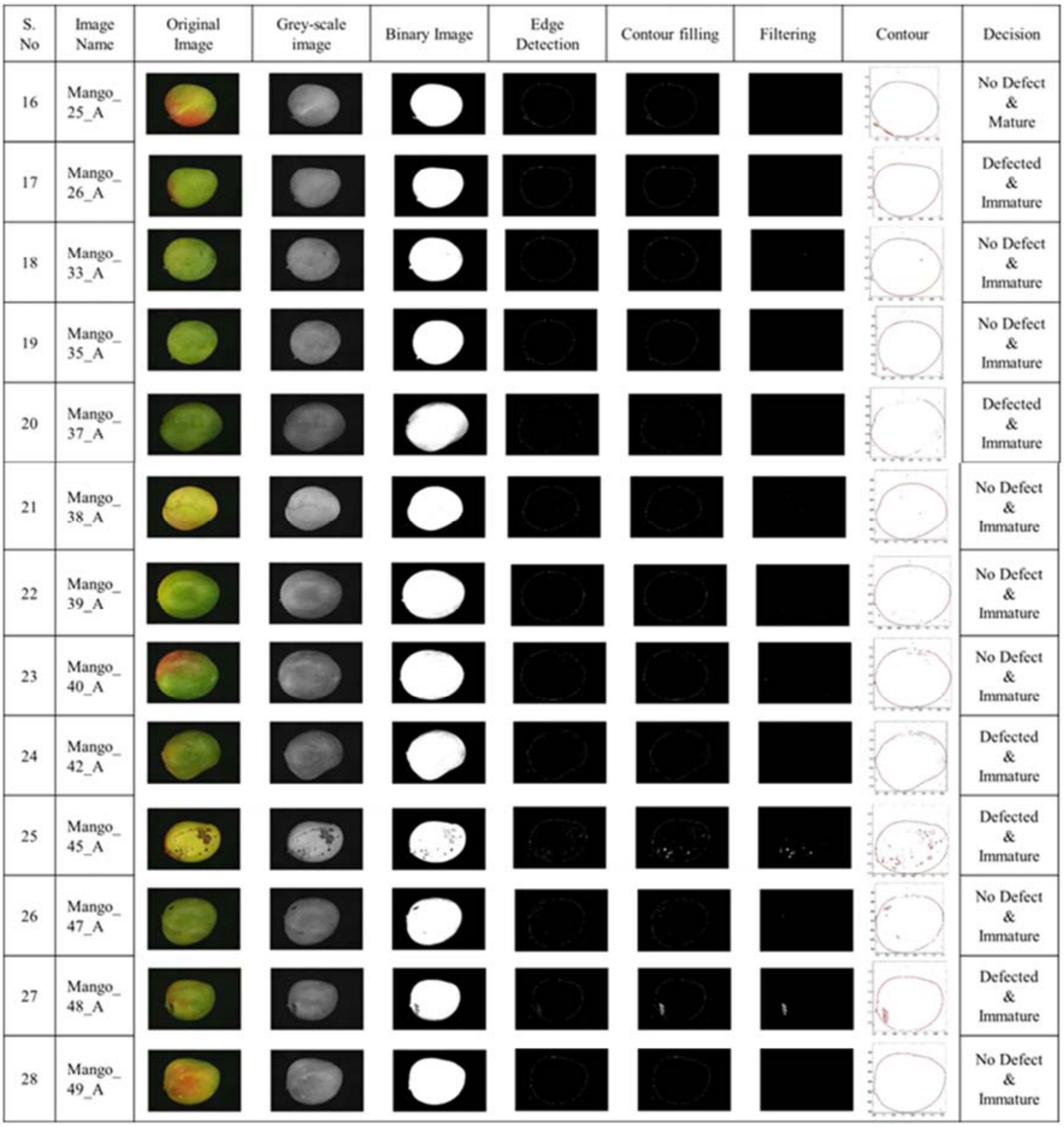
The proposed algorithm is tested using 28 mango images. "Figure 9" and "Figure 10" shows the results at various stages of an algorithm for 28 mango images. Among 28 mango images, 14 mangos are defected and 14 are not defected.

"Figure 11" shows that plot of defect identification of Mango based on quality ratio b=a/(x*y) value. It is observed from the "Figure 9" and "Figure 10" proposed algorithm efficiently and accurately determines the quality of mango.



S. No	Image Name	Original Image	Grey-scale image	Binary Image	Edge Detection	Contour filling	Filtering	Contour	Decision
1	Mango_ 01_A								No Defect & Mature
2	Mango_ 02_A								No Defect & Mature
3	Mango_ 04_A								No Defect & Mature
4	Mango_ 06_A								Defected & Mature
5	Mango_ 08_A								Defected & Mature
6	Mango_ 11_A								No Defect & Mature
7	Mango_ 12_A								Defected & Mature
8	Mango_ 13_A								No Defect & Mature
9	Mango_ 16_A								No Defect & Mature
10	Mango_ 18_A								Defected & Mature
11	Mango_ 20_A								No Defect & Mature
12	Mango_ 21_A								No Defect & Mature
13	Mango_ 22_A								No Defect & Mature
14	Mango_ 23_A								Defected & Mature
15	Mango_ 24_A								Defected & Mature

Figure 9. *Results of 1- 15 dataset (out of 28).*



S. No	Image Name	Original Image	Grey-scale image	Binary Image	Edge Detection	Contour filling	Filtering	Contour	Decision
16	Mango_25_A								No Defect & Mature
17	Mango_26_A								Defected & Immature
18	Mango_33_A								No Defect & Immature
19	Mango_35_A								No Defect & Immature
20	Mango_37_A								Defected & Immature
21	Mango_38_A								No Defect & Immature
22	Mango_39_A								No Defect & Immature
23	Mango_40_A								No Defect & Immature
24	Mango_42_A								Defected & Immature
25	Mango_45_A								Defected & Immature
26	Mango_47_A								No Defect & Immature
27	Mango_48_A								Defected & Immature
28	Mango_49_A								No Defect & Immature

Figure 10. *Results of 16-28 dataset (out of 28).*

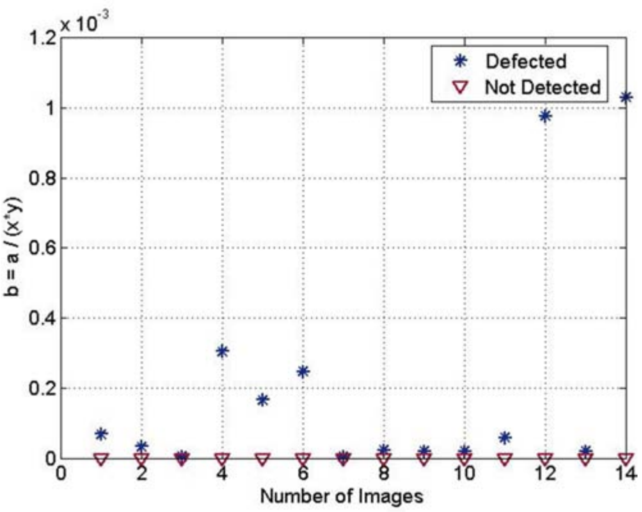


Figure 11. *Classification of Mango based on quality ratio b=a/(x*y) Value.*

6. Conclusion and Future Scope

Due to the growing demand of quality mango fruit, an automatic and reliable defect identification and maturity detection mechanism to handle the bulk of data are implemented. Algorithms were developed to identify defect and maturity the mango fruit, based on single view fruit images and the mango fruits were categorized into two classes based on the quality ratio. If the value of the quality ratio is greater than the set threshold value, the fruit is rotten. On the contrary, if the value of the quality ratio is less than the set threshold value, the fruit is good. Hence using proposed algorithm, one can able to sort the mango fruits based on quality which is essential for value addition of fruits. In future, color, perimeter, roundness, and percent defect feature can be utilized to enhance the accuracy of the algorithm. The roundness and percent defect were used to identify whether the mango's quality was export, local or reject. An optimal and adaptive threshold method can be used for segmentation of mango from the background.

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