Automatic Fruit Defect Detection Using HSV and RGB Color Space Model

Mr.S V.Phakade, Miss. D'souza Flora, Miss. Halade Malashree, Miss. Joshi Rashmi

***Abstract*—This paper presents the development and application of image analysis and computer vision system in defect detection of fruit surface in the agricultural field. Computer vision is a rapid, consistent inspection technique, which has expanded to varied industries. Monitoring and detecting defect is becoming a very important issue in fruit management since ripeness is perceived by customers as main quality indicator. In this paper we present a method for automatic defect detection of various fruits based on image processing techniques. The method was implemented, and tested on sample of different fruit images. Segmentation is one of the basic techniques in computer vision. Color is often thought as a property of an individual object and the color of this object comes from the visible light that reflects off the object surface. In this experiment we have implemented a method to quantify the standard color of fruit in HSV(Hue, saturation and Value) color spaces in order to achieve fruit image segmentation.HSV system is suggested as the best color space for quantification in fruit defect detection. In this article we shall give the results of the experiments we have carried out. We have made a comparative study between HSV and RGB color space and the results so formed demonstrate the feasibility of our proposed method in color segmentation for various fruits.**

Index Terms—

Image Processing; Image Segmentation and Binarisation; Computer Vision, Quality Control, HSV and RGB Color Space

I. INTRODUCTION

Overseas commerce has increased drastically plenty fruits are exported to other nations. In India almost 30 percent of fruits are spoiled before sales. The main reason of lacking in international competition is the backward level of post-harvesting techniques used. The fruits are classified according to size, weight and blemishes on skin i.e defects. People are employed to sort the fruits. But the human visual inspection is tedious, time-consuming, laborious, non-consistent, and heavily dependent on the person's mood and easily changes based on physiological characteristics. During the last decades, developments in computer hardware and software have introduced objective methods for quality control in different industries[1].

Fruit quality detection is an important aspect of fruit commercialization, and the fruit appearance is an important index of detecting fruit quality. Here the classification is based on fruit surface defects. The unhealthy part of fruit surface can be called as defect, which is one of the important factor by which quality of fruit can be determined.

Digital images are one of the most key medium of conveying information. Extracting the information from images and understanding them such that the extracted information can be used for several tasks is an important characteristic. Machine vision consists of two main parts, including image capturing and image processing that result in a non-contact and non-destructive opportunity for quality measurement. Furthermore, color is an important feature for quality assessments, which is extensively used for grading agricultural products. Hence, it is important to detect the defects on the surface area of a particular fruit[2].

In this paper we have taken some fruits with defected surface and tested them by using HSV and RGB color thresholding algorithm.

- **Machine Vision:**

Nowadays, machine vision systems provide with a real time cost effective, consistent, high-speed and accurate quality assessment of products. Machine vision consists of two main parts

- Image capturing.
- image processing

The color correlates well with other physical, chemical and sensory properties and can be used to estimate ripeness, degree of defects, safety, storage time, nutritional value etc. Color machine vision and color image processing can result in color measurement, quality inspection and classification of food and agricultural products, and can yield significant savings in terms of labor costs together with an increase in product quality.

Machine vision systems and near infrared inspection systems have been introduced to many grading facilities with mechanisms for inspecting all sides of fruits and vegetables [12].Machine vision and image processing techniques have been found increasingly useful in the fruit industry, especially for applications in quality inspection and defect sorting applications. Research in this area indicates the feasibility of using machine vision systems to

Manuscript received May 12, 2014.

Mr.S.V.Phakade, Associate professor, Electronics and telecommunication , P.V.P.I.T, Budhgaon,, Sangli, India, Mobile No.7798025050, (e-mail: phakadesv@gmail.com).

Miss.Flora M. D'souza, , Electronics and telecommunication , P.V.P.I.T, Budhgaon, Sangli, India, Mobile No.7620369749, (e-mail: dsouzaflora.267@gmail.com).

Miss. Malashree T. Halade, Electronics and telecommunication , P.V.P.I.T, Budhgaon, Sangli, India, Mobile No.9175691904, (e-mail: malashreehalade@yahoo.com).

Miss. Rashmi S. Joshi, Electronics and telecommunication , P.V.P.I.T, Budhgaon, Sangli, India, Mobile No.7768047078, (e-mail: rashmijoshi488@yahoo.com).

improve product quality while freeing people from the traditional hand-sorting of agricultural materials.

The use of machine vision for the inspection of fruits and vegetables has increased during recent years. Nevertheless, the market constantly requires higher quality products and consequently, additional features have been developed to enhance machine vision inspection systems (e.g. to locate stems, to determine the main and secondary color of the skin,to detect blemishes). The specific objectives are to quantify the following attributes for inspection of fruits:

1. Color.
2. Texture (homogeneity or non-homogeneity),
3. Size (projected area),
4. External blemishes (detect defects).
5. Evaluate the accuracy of the techniques by comparison with manual inspection.

The objective of the present study is to apply computer vision methods for defect detection and grading of some single-color fruits.

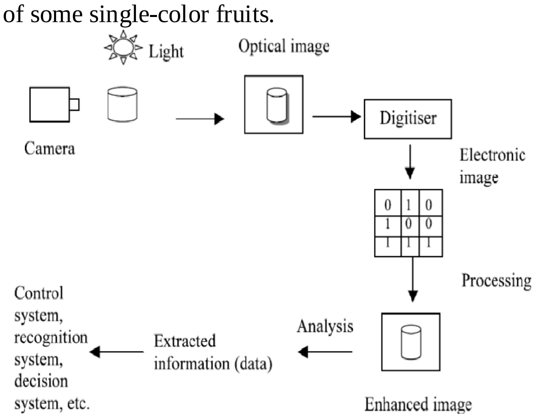
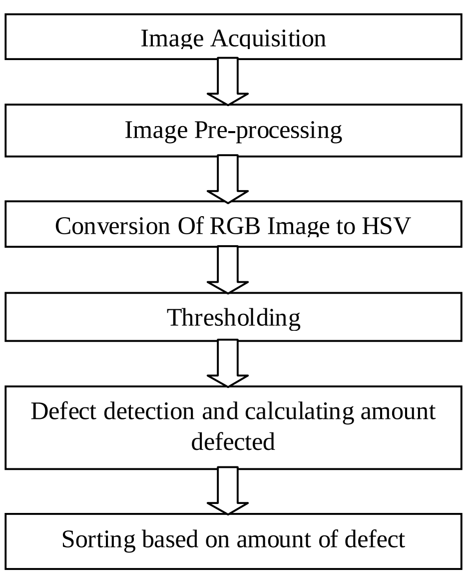


Fig 1: Principle of computer vision system.

II. PROPOSED METHOD



i. Image Acquisition

Lighting:

A good illumination system should provide uniform radiation across the scene, avoiding the presence of shine or shadows, and as far as possible must be spectrally uniform and stable over time. If the scene is not lit properly, it will increase the uncertainty and classification error, leading to the need for a pre-processing of the images, thus increasing the time required to analyze each image.

The arrangement of the light sources significantly affect the images acquired, due to the fact that some areas may receive more light than others, changing the total amount of radiation reflected from the objects in these areas. An uneven illumination can be corrected by calibrating the image using a white board of known reflectance (reference white), but this correction consumes some of the computational resources. Moreover, it is very important to consider the geometry of the inspected object. For example, directing the illumination at an angle of 45° with respect to the vertical is effective when a plane object is being illuminated, in order to avoid direct reflections on the camera.

A polarizer filter and the use of cross polarizer can prevent glare and reflection on the object. Fluorescent tubes are valid for applications where visible light is important (for example, sorting by color),but produce little radiation in the infrared region[13].

Lighting condition preferred is as below:

1. Samples are illuminated using two parallel lamps (two tubes in each lamp 18W).
2. Color temperatures 6500K. (D65, standard light source.).
3. Color rendering index (Ra) close to 95%.
4. Both lamps 35cm above the samples at 45degree to the sample.

ii. Image preprocessing techniques:

There are three aspects that determine color, namely the

- Type of emission source that irradiates an object.
- The physical properties of the object itself (which reflects the radiation consequently detected by the sensor).
- The in-between medium (e.g., air or water).

In general, a computer vision system captures the color of each pixel within the image of the object using three color sensors (or one sensor with three alternating filters) per pixel .The RGB model is the most often used color model, in which each sensor captures the intensity of the light in the red (R), green (G) or blue (B) spectrum, respectively. However, the RGB model is device-dependent.The differences between colors in the RGB space do not correspond to color differences as perceived by humans.

Preprocessing of an image can include thresholdng, cropping, gradient analysis, and many more algorithms. All of the processes permanently change the pixel values inside an image so that it can be analyzed by a computer.

1. RGB image is first converted in Gray scale

2. Noise removal: Noise is the incorrect representation of a pixel inside an image. It is best observed in variations in the color of a uniformly colored surface. Since the noise is not the same in every image, when averaged the noise will blend into its surroundings, making the resulting image much clearer. But we preferred median filter. The gray image is given as input to median filter of order [7 7]. Median filter provides noise reduction and considerably less blurring then linear smoothing filter of same size.

Calculation of total area of fruit:

Original RGB image is spitted into three color bands i.e. red band, blue band and green band. Then convert each color band into corresponding binary image with proper thresholding. The images so obtained are filled using '*imfill*' routine of image processing toolbox, of Matlab .User has to make decision to select among the three filled images of corresponding color band to get the total area of the fruit. When the user selects the total area of fruit, then the ratio of black and white pixels is calculated using '*bwarea*' routine of image processing toolbox, of Matlab.

Fig 2: fruit

Fig 3: Total area

The total area of this fruit in fig 2. is obtained by filling red channel image.Thus for different fruits we get total area of fruit by filling any one of the 3 channel image.

II.1 RGB color space

There are several ways to specify colors. The most common of these is the RGB color model. The RGB model defines a color by giving the intensity level of red, green and blue light that mix together to create a pixel on the display. With most of today's displays, the intensity of each color can vary from 0 to 255, which gives 16,777,216 different colors. (Older displays with less memory might only allow 256 colors, and really ancient displays might have only 16).

The RGB color model is an additive color model in which red, green, and blue light are added together in various ways to reproduce a broad array of colors. The name of the model comes from the initials of the three additive primary colors, red, green, and blue. Before the electronic age, the RGB color model already had a solid theory behind it, based in human perception of colors.[11]MATLAB uses a numerical array with three columns to represent color values of image. Each image is composed of an array of M*N pixels (contraction of "picture element") with M rows and N columns of pixels. Each pixel contains a certain value for red, green and blue. Varying these values for red, green, blue (RGB) user can get almost any color.

Here are some example colors and their red, green and blue intensity values. As shown in table 1.

Table:1

Color	Red	Green	Blue
Red	1	0	0
Green	0	1	0
Blue	0	0	1
Yellow	1	1	0
Cyan	0	1	1
Magenta	1	0	1
White	1	1	1
Black	0	0	0

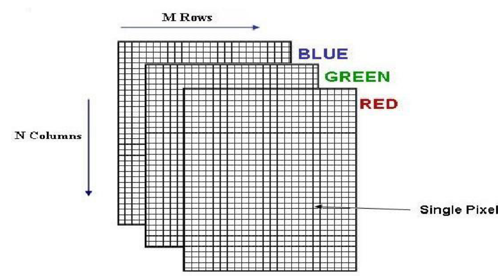


Fig 4: Image stored in matlab

II.2 HSV color space

- The ***hue*** (H) of a color refers to which pure color it resembles. All tints, tones and shades of red have the same hue. Hues are described by a number that specifies the position of the corresponding pure color on the color wheel, as a fraction between 0 and 1. Value 0 refers to red; 1/6 is yellow; 1/3 is green; and so forth around the color wheel.
- The ***saturation*** (S) of a color describes how white the color is. A pure red is fully saturated, with a saturation of 1; tints of red have saturations less than 1; and white has a saturation of 0.
- The ***value*** (V) of a color, also called its *lightness*, describes how dark the color is. A value of 0 is black, with increasing lightness moving away from black.

II.3 RGB to HSV conversion:

HSV (Hue, Saturation and Value) defines a type of color space. It is similar to the modern RGB and CMYK models. The HSV color space has three components: hue, saturation and value. Brightness is sometimes substituted for 'Value' and then it is known as HSB. HSV is also known as the hex-cone color model.
The HSV color model can be considered as a different view of the RGB cube. Hence the values of HSV can be

considered as a transformation from RGB using geometric methods. The diagonal of the RGB cube from black (the origin) to white corresponds to the *V* axis of the hexagon in the HSV model. For any set of RGB values, *V* is equal to the maximum value in this set. The HSV point corresponding to the set of RGB values lies on the hexagonal cross section at value *V*. The parameter *S* is then determined as the relative distance of this point from the V axis. The parameter *H* is determined by calculating the relative position of the point within each sextant of the hexagon. The values of RGB are defined in the range [0, 1], the same value range as HSV. The value *H* is the ratio converted from 0 to 360 degree [7].

The passage from RGB to HSV was made by a transformation, not Shelf space. Several operators were proposed for its Conversion. The HSV system is defined as follows:

The RGB image is transformed into HSV with the 'rgb2hsv' routine of the image processing toolbox, of Matlab , which uses the following equations (Eq1):

RGB Image to HSV conversion relation.

$$\mathbf{H} = \begin{cases} \theta & B \leq G \\ \theta - 360 & B \geq G \end{cases}$$

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

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

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

Since the RGB values generally lie in the range of 0 to 255 we need to use the formulae given below, which will convert the Hue values between 0° and 360°, Saturation values between 0 and 1 and values between 0 and 1.

$$\mathbf{H} = \left[\frac{H}{255} * 360\right] |360|$$

$$\mathbf{S} = \frac{S}{255}$$

$$\mathbf{V} = \frac{V}{255}$$

After the conversion from RGB color space to HSV color space of the entire image, the image is divided into m different regions depending on the values of hue and saturation.

III. THE ACTUAL PROCEDURE

Defect Detection and calculating amount defected:-

1. **Using RGB color model:**

First image is spitted into R, G and B color bands. Each color band is thresholded. The values used are as follows:

Threshold values:

Redthreshold=218;
Greenthreshold=126;
Bluethreshold=63;

Thresholding is an operation which involves testing an image against threshold value T. RedMask which is in binary form is obtained when redband value of image in this channel is greater then Redthreshold value. Similarly greenmask and bluemask are obtained greenband is less than greenthreshold and blueband is less than bluethreshold respectively. Then all the three masks are combined to find where all three are true. This can also be obtained in RGB for multiplying the image where all 3 values are true with each channel and then combing the images obtained in each channel we get brown defect.

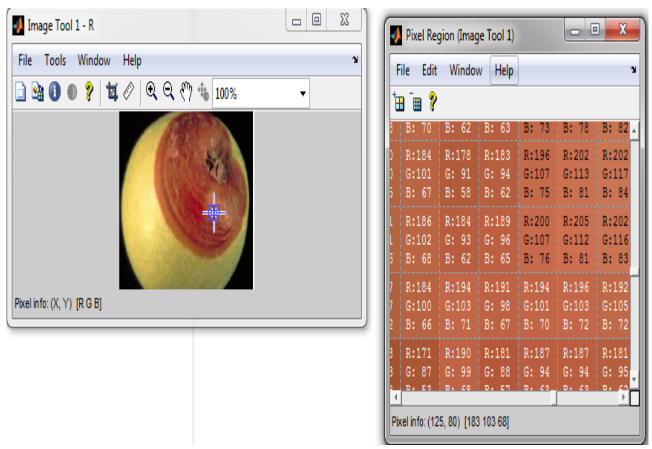


Fig 5:Pixel information of defected part

Here, we can see that maximum R vaule of defected part is about 210,G vaule is 117 and B value is 81.

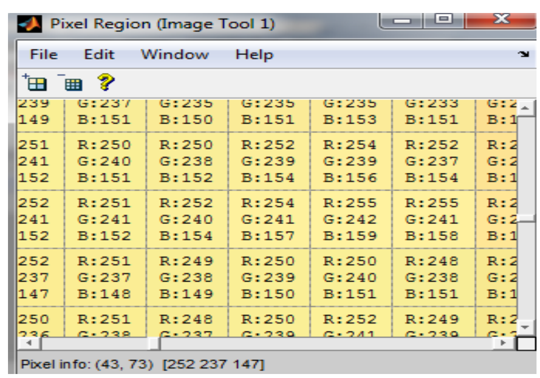


Fig 6: Pixel information of healthy part.

The healthy part i.e. yellow part in fruits like mango are having R value greater than 220,G value greater than 150 and B value in the range 120 to 160 as shown in Fig 6.Pixel having these or greater values are masked to get exact defected part.

Fig 7: RGB image of fruits

Fig 8: Total area of fruit

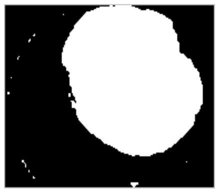


Fig 9: Binary image of defected part of sample 1

Table:2

Total Area	Defected Area	Percentage Defect
2.1096e+004	1.0993e+004	52.1064

2. Using HSV method:

The HSV color space is fundamentally different from the widely known RGB color space since it separates out the Intensity (luminance) from the color information (chromaticity). Again, of the two chromaticity axes, a difference in Hue of a pixel is found to be visually more prominent compared to that of the Saturation. For each pixel we, therefore, choose either its Hue or the Intensity as the dominant feature based on its Saturation.

A three dimensional representation of the HSV color space is a hexagon, where the central vertical axis represents the Intensity [9]. Hue is defined as an angle in the range [0,2π] relative to the Red axis with red at angle 0, green at 2 π /3, blue at 4 π /3 and red again at 2 π.

Saturation is the depth or purity of the color and is measured as a radial distance from the central axis with value between 0 at the center to 1 at the outer surface. For S=0, as one moves higher along the Intensity axis, one goes from Black to White through various shades of gray

On the other hand, for a given Intensity and Hue, if the Saturation is changed from 0 to 1, the perceived color changes from a shade of gray to the most pure form of the color represented by its Hue. Looked from a different angle, any color in the HSV space can be transformed to a shade of gray by sufficiently lowering the Saturation. The value of Intensity determines the particular gray shade to which this transformation converges. When Saturation is near 0, all pixels, even with different Hues, look alike and as we increase the Saturation towards 1, they tend to get separated and are visually perceived as the true colors represented by their Hues. Thus, for low values of Saturation, a color can be approximated by a gray value specified by the Intensity level while for higher Saturation; the color can be approximated by its Hue. The Saturation threshold that determines this transition is once again dependent on the Intensity. For low intensities, even for a high Saturation, a color is close to the gray value and vice versa. Saturation gives an idea about the depth of color and human eye is less sensitive to its variation compared to variation in Hue or Intensity. We, therefore, use the Saturation value of a pixel to determine whether the Hue or the Intensity is more pertinent to human visual perception of the color of that pixel and ignore the actual value of the Saturation. It is observed that for higher values of intensity, a saturation of 0.2 differentiates between Hue and Intensity dominance.

Detection of brown defect using H value and V value:

The image is first converted to HSV using 'rgb2hsv',routine image processing command, Matlab. Image is spitted into three channels H,S and V. Size [m n] of H channel image is calculated

where , m=no.of rows

n= no.of columns.

The pixels having Hue value greater 0.112 or whose saturation vale is less than 0.3 or saturation value greater than 0.9 are stored in column matrix.

Thresholding:

[r c v1]=find(HIma>0.112 | SIma<=0.13 |SIma>0.9);

numid=size(r,1);

The pixel in this range are pixel of healthy part.

The value are selected by displaying the image using 'imtool' command in MATLAB and getting the information of pixels.

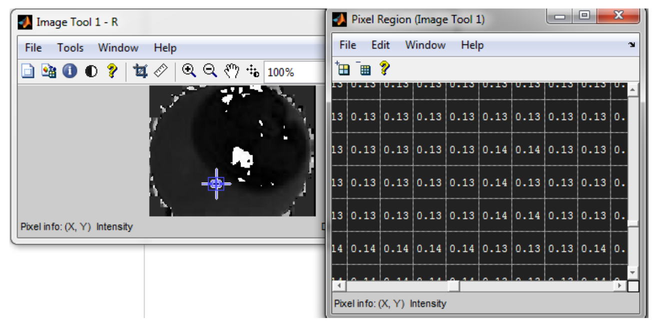


Fig 10: H value of healthy part.

Here we can see that the H value of healthy part is above 0.112.So all the pixels above 0.112 are made zero i.e black and thus we get only defected part in RGB which is converted to binary image to get defected area.

Fig 11: Defected part using HSV method for sample1

Table:3

Total Area	Defected Area	Percentage Defect
2.1096e+004	1.1474e+004	54.3900

3. Morphology Mathematics.

Morphology is based on set theory. A structuring element is a special mask filter that enhances an input image. It can be of different sizes and of different shapes (square, diamond, and circle). Following are the main mathematical morphological operators .

Dilatation, Erosion , Opening, Closing.

Three morphological operations, closing, region filling and area opening, were used in order to identify the region of interest: Fundamental morphological operations are as follows:

(a) The dilatation of A by B:

(b) The erosion of A by B:

(c) The opening of set A by structuring element B:

(d) The closing of set A by structuring element B:

The aim of area opening is to eliminate small area blemishes that can be ignored by our processes. The small areas are eliminated less than the threshold T experimentally predefined.

IV. SORTING BASED ON AMOUNT OF DEFECT:

Percentage of defected part is calculated based on below formula:

Percentage defect=(Defected area/ Total area)*100

Pg=percentage defect.

Thresholding :

if (Pg < 10)

no defect

else if (Pg > 10 && Pg < 40)

less defected

else if (Pg > 40 && Pg < 60)

medium defected

else

more defected

V. LIMITATION

The automated inspection of fruit has some peculiarities and problems that other sectors of industrial production do not have, due to the biological nature of the products inspect. A fruit may show a different color, size and shape from another, even if collected from same tree. The color of a particular area of the skin of a healthy fruit can match the color of a spot on the surface of another fruit of the same variety. It is essential to detect the presence of stems, leaves, dirt on fruit skin. All this greatly complicates the development of algorithms capable of extracting quality decisions from image analyses.

VI. FUTURE SCOPE

To get exact defect and the impact of defect on fruit life span we have to design a complex algorithm which can differentiate between different defects. It has a scope in food industries where fruits are sorted based on their maturity and also in fruit processing industries like jam, fruit juice etc.

VII. EXPERIMENTAL RESULTS

The different fruit images where used to get the percentage defect in them using both methods viz. RGB color model and HSV method.

The database used is as below:

Sample 1 Sample 2 Sample 3

Sample 4 Sample 5

Table 4: Comparision of Percentage defect calculated using HSV and RGB method

Fruit sample	%defect using RGB method	%defect using HSV method	Sorting
sample 1	52.1064	54.3900	medium
sample 2	46.0592	50.6377	medium
sample 3	41.1001	48.9189	medium
sample 4	8.1001	15.4647	1.No 2.less
sample 5	23.2895	23.7150	less

Thus we get almost equal percentage of defected part using RGB thresholding and HSV method. But there is bit difficultly in RGB method as with change in fruit color we have to change the thresholding values. As the R,G and B values are not same even if there is little variation in color shade Fig.1 and Fig.2 whereas, HUE value doesnot have much variation in it Fig.6

VIII. CONCLUSION

By using these methods we get the percentage defect in fruits. However, there is some variation in percentage defect of same fruit which can be rectified by proper thresholding. By changing the values of threshold we can broaden the scope of detection of any kind of defect on any color of fruit.

References

[1] T. Brosnan, D.W. Sun, Inspection and grading of agricultural and food products by computer vision systems: a review, Computers and Electronics in Agriculture 36 (2002) 193-213.

[2] W.C. Lin, J.W. Hall, A. Klieber, Video imaging for quantify cucumber fruit color, Hort. Tech. 3 (4) (1993) 436-439.

[3]F. Mendoza, P. Dejmek, J.M. Aquilera, Calibrated colormeasurements of agricultural foods using image analysis, Postharvest Biology and Technology 41 (2006) 285-295.

[4] S. Somatilake, A.N. Chalmers, An image-based food classification system, Proc. Image and Vision Computing New Zealand 2007, Hamilton, New Zealand, December 2007, pp. 260-265.

[5] Kress-Rogers E (ed.), ''Instrumentation and Sensors for the Food Industry'', *Butterworths-Heine-mann Ltd*., Oxford, UK, 1993, p.375-415.

[6] Huanwen Chen,Yanping Sun,§ Arno Wortmann, Haiwei Gu,§ and Renato Zenobi ''Differentiation of Maturity and Quality of Fruit Using Noninvasive Extractive Electrospray Ionization Quadrupole Time-of-Flight Mass Spectrometry". *Anal. Chem.* 2007, 79,

[7] Foley.J., A. van Dam, S. Feiner, and J. Hughes, *Computer Graphics: Principles and Practice*, Second Edition, Addision-Wesley, 1996 .

[8] Halimi A., El kouraychi A, Bouzid .A, and Roukhe A.'' Defects detection and extraction in textile imageries using Mathematical Morphology and geometrical features''. *Journal of Signal Processing Theory and Applications* (2012) 1: 1-16 .doi:10.7726/jspta.

[9] Sorting date fruit bunches based on their maturity using camera sensor system. *Journal of Theoretical and Applied Information Technology.* 20th October 2013. Vol. 56 No.2 © 2005 - 2013 JATIT & LLS.

[10] Automatic Defect Detection and Grading of Single-ColorFruits Using HSV (Hue, Saturation, Value) Color Space. *Dec. 2010, Volume 4, No.7 (Serial No.32) Journal of Life Sciences, ISSN*

1934-7391, USA

[11].N. M. Z. Hashim1, N. H. Mohamad2, Z. Zakaria3, H. Bakri4, F. Sakaguch Development of Tomato Inspection and Grading System using Image Processing; International Journal Of Engineering And Computer Science ISSN:2319-7242, Volume 2 Issue 8 August, 2013 Page No. 2319-2326.

[12]. Kondo, N. (2009). Automation on fruit and vegetable grading system and food traceability", Trends in Food Science & Technology, doi: 10.1016/j.tifs.

[13]. Understanding Color Image Processing by Machine Vision for Biological Materials by Ayman H. Amer Eissa and Ayman A. Abdel Khalik.