Automatic Defect Detection And Grading of Single Color Fruit

Mr.O.K.Firke[1], Rutuja S. Ingale[2]
[1, 2] Assistant Professor, Dept of EXTC
[1, 2] J.T.Mahajan,College of Engineering,Faizpur

Abstract- *In this paper present the advance 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 and HSV system is suggested as the best color space for quantification in fruit defect detection. In addition to this one of clustering technique used. 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, also study in bettern HSV and k-means clustering and the results so formed demonstrate the feasibility of our proposed method in color segmentation for various fruits.*

Keywords- defect detection, fruit, grading, HSV color space, k-means clustering, Machine vision.

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. Also used one of the technique of clustering. Clustering based image segmentation is the process of assigning a label to every pixel in an image such that pixels with the same label share certain visual characteristics. In cluster oriented segmentation partition the image pixels into clusters. It uses the multi-dimensional data to do this.

Section II shows machine vision, section III given materials and method used in this experiment, section IV shows proposed method of this experiment, Section V shows results and Discussion, Lastly Section VI shows conclusion.

II. 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 [3].Machine vision[5] as well as image processing method have been found increasingly helpful 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 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[6]. 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.

RGB color space

There are several ways to specify colors. The RGB color model is the most common in this paper. 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[7].The intensity of each color can vary from 0 to 255, which gives 16,777,216 different colors, in today's displays which are mostly used. (Older displays with less memory might only allow 256 colors, and really ancient displays might have only 16). The combination of red, green and blue light makes RGB color model which are then added added together in various ways to reproduce a broad array of colors[8]. 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.MATLAB[9] 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.

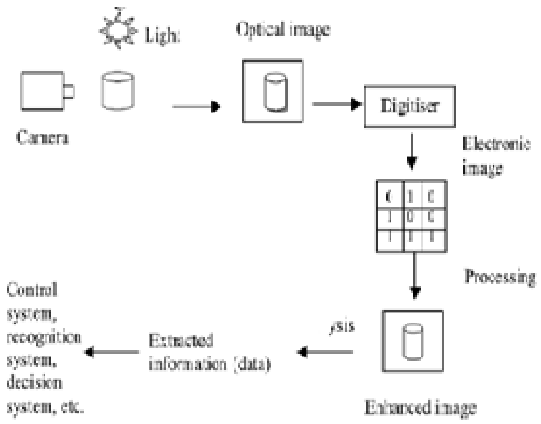


Fig.1 Principle of computer vision system.

RGB to HSV conversion

HSV (Hue, Saturation and Value) defines a type of color space. It is analogous 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. In the HSV point equivalent to the position 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 value of parameter H is obtained by calculating the comparative 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.

$$H = \begin{cases} \theta & B \le G \\ \theta - 360 & B \ge G \end{cases}$$

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

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

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

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.

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

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

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

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. MATERIALS AND METHODS

Materials

A machine vision system was employed for defect detection and grading of some single-color fresh fruits such as mango and banana. The mango and bananas were from local fruit market. They were got from market and were ripe. For this purpose, the following procedure was implemented.

Image Acquisition

One of the most important factors having influence the quality of captured images and the performance of image processing is the illumination. A Nikon D5500 digital color camera with 1920*1080 video resolution ,24MP-CMOS sensor was used for image capturing. The camera was set on autofocus and a white heavy coated paper with an L* value of about 95 was used for white balancing. The camera was located over the sample at the distance of 50 cm. The angle between the sample and the camera was adjusted to zero. A matte black surface was taken as background. Images were stored in JPEG format using high quality level, and the camera was connected to the USB port of a computer provided with a Remote Capture Software to monitor and acquire images.

IV. THE PROPOSED METHOD

Color Space

The color space used by the camera is optionally sRGB or Adobe RGB. It is well known that other color spaces such as CIE 1976 L*a*b* and HSV correlate better with human visual perception and might be resulted better for introducing a machine vision system instead of human detection. The CIE 1976 L*a*b* space, shortened as "CIELAB", was proposed for equal perceptual differences for equal changes in the coordinates L*, a* and b*. It is used intensively in many industries and provides a standard scale for comparison of color values. The CIELAB coordinates (L*, a*, b*) can be calculated from the tristimulus values X, Y and Z. The tristimulus values, X, Y and Z of the samples can be computed with the following formulas:

$$X = \sum_{\lambda} \overline{x_{\lambda}}.e_{\lambda}.R_{\lambda}$$
$$Y = \sum_{\lambda} \overline{y_{\lambda}}.e_{\lambda}.R_{\lambda}$$
$$Z = \sum_{\lambda} \overline{z_{\lambda}}.e_{\lambda}.R_{\lambda}$$

Where $\overline{x}, \overline{y}$ and $\overline{z}$ are the CIE color matching functions, *e* presents the spectral power distribution of the illuminant and R is the spectral reflectance of the samples. The equations for CIELAB color space are as follows [14, 15]:

$$L^* = 116 f\left(Y/Y_n\right) - 16$$
$$a^* = 500\left[f\left(X/X_n\right) - f\left(Y/Y_n\right)\right]$$
$$b^* = 200\left[f\left(Y/Y_n\right) - f\left(Z/Z_n\right)\right]$$

Where *Xn* , *Yn* and *Zn* are the tristimulus values of the reference white. The L*, a* and b* present lightness, redness-greenness and yellow-blueness, respectively. Figure 2 shows a schematic form of this color space.

The CIELAB color coordinates can also be expressed in cylindrical coordinates with chroma * *Cab* and hue *hab* . The **Cab* axis represents chroma or saturation, which is obtained as a distance between the origin (center or achromatic axis of CIELAB color space) and the point expressed by the coordinates *a** and *b** according to Eq. (3).

Higher saturated color represents higher chroma value and is closer to the edge of the circle and vice versa.

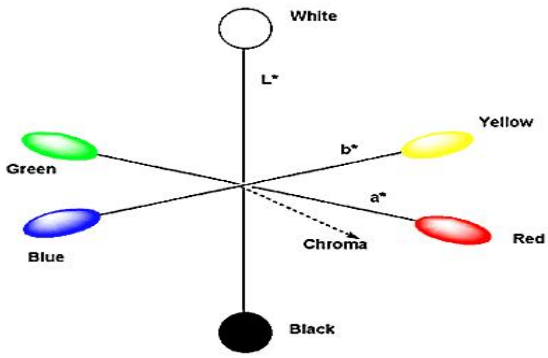


Figure 2 A schematic form of CIELAB 1976 color axis.

$C^*_{ab} = (a^{*2} + b^{*2})^{1/2}$

The CIE 1976 hue angle (*hab*) is obtained by the following equation:

$h_{ab} = \tan^{-1}(b^*/a^*)$

Where *hab* lies between 0° and 360° based on signs of *a**and *b** [14, 15]. If camera storage is set as sRGB, L*a*b* and HSV measures can be estimated by standard equations and for this MATLAB software was used. Application of different color spaces showed that HSV color space is appropriate for the purpose of this research. This is discussed in the next section.

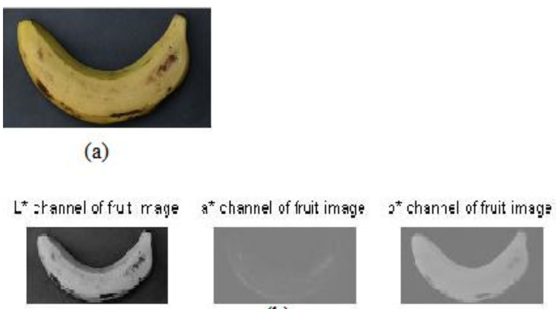
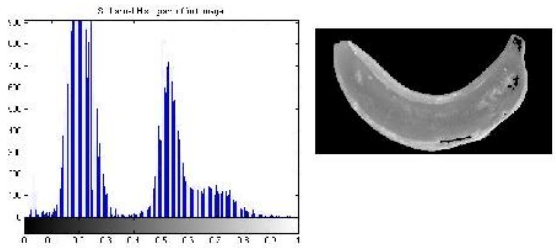


Figure 3 (a) original image of fruit for test(b) HSV color space with first image is L*channel of full image, second image is a* channel of full image, and last one ,b* channel of full image.

Background Removal

At first, it was necessary to remove the background from the image. Evaluating the captured images showed that because of implementing a black background, the histogram of the image in saturation channel gives a distinct threshold between the object and background which can be precisely used for background detection. Figure 4 shows an S channel histogram of a captured image. As illustrated, the first part of the histogram which is related to the background can be feasibly separated from the object. In the other way the background was a black surface which was constant for each image. Different captured images showed that the S values of the background was less than 0.3, therefore it was simply used as threshold value to separate the background from the object.



(a) (b)

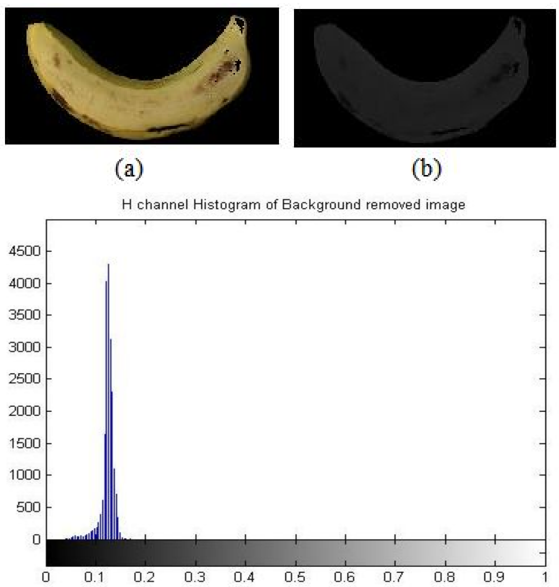
Figure 4. (a)The histogram of the S channel of a captured image; (b) s channel after applying threshold by 0.3

Defect Detection and Grading

Since the defects and aging usually appeared in the color of the object, it can be useful to segment the object based on its color. During preliminary experiments, image segmentation in sRGB color space was tested applying some clustering methods. The obtained results were not acceptable, which was mainly because of the lighting effect which imposed glossy parts on the object. Different soundparts of a sample which was expected to be grouped in a single cluster belonged to different groups because of illuminating effects. Therefore, it was not possible to separate the decayed parts from sound ones. After evaluating each channel of the image (including H, S and V) separately, it was found that the color change because of the defects and aging could be classified in H channel properly. Using the H channel data, the effect of lighting condition, camera position and irregularity of the object (which is the most important one) on the captured image almost disappeared. It might be these parameters have definite effection the lightness of the image which can be observed in the S and V channels. Therefore, at first the images were converted to HSV color space and then the data of the H channel was assessed. To be able to grad the object based on H values it is necessary to get a standard value and compare the other measures with it. It can be easily done by a calibration step in which the standard value for each kind of fruit can be obtained by a preliminary experiment. To do that, a healthy and completely acceptable fruit is to be selected. The image of the sample is captured and converted to HSV space. The mean of pixel values in H channel is applied as the standard value. Figure 5 shows an example, a healthy sample which is segmented from its background (the background is black), together with the H channel image and the histogram of it. As expected, the H histogram of the sample has a sharp Gaussian shape, and it can be used as the dominant H value for this type of banana. It should be noted that this standard value can be also achieved by applying a set of healthy samples and averaging their obtained results. Then, the sample image should be segmented considering the standard value which was obtained from the last step. It is possible to segment the images by thresholding the histogram of H channel. To do that, the standard value is set as the center, and then the H value difference between each pixel value and the center is computed by equation given below.

$\Delta hi = | hi - hs |$

where hi indicates the h value of the ith pixel and hs represents the standard h value.



(c)

Figure 5 (a) The image of banana which is separated from its background; (b) the hue channel of (a); (c) the histogram plot of hue channel

Clustering Method

The k-means algorithm is an iterative technique that is used to partition the image into K clusters. Cluster-oriented technique is a better technique than histogram-oriented one in segmenting an image, where each pixel has several attributes and is represented by a vector. Clustering or either data grouping is a key initial procedure in image processing. Although clustering is sometimes used as a synonym for (agglomerative) segmentation techniques, we use it here to denote techniques that are primarily used in exploratory data analysis of high dimensional measurement patterns. In this circumstance, the clustering methods try to group together patterns that are similar in some sense. This goal is very similar to what we are attempting to do when we segment an image, and indeed some clustering techniques can readily be applied for image segmentation. Clustering is an unsupervised learning task, where one needs to identify a finite set of categories known as clusters to classify pixel. Clustering use no training stages rather train themselves using available data. Clustering is mainly used when classes are known in advance. Clustering technique attempts to access the relationship among patterns of the set by organism the patterns into groups or clusters such that pattern within a cluster are more similar to each other than patterns belongs to different cluster. The quality of a clustering result depends on both the similarity measure used by the method and its implementation. *k*-means clustering is a method of vector quantization, originally from signal processing, that is popular for cluster analysis in data mining. *k*-means clustering aims to partition *n* observations into *k* clusters in which each observation belongs to the cluster with the nearest mean, serving as a prototype of the cluster. This results in a partitioning of the data space into Voronoi cells. The problem is computationally difficult (NP-hard); however, there are efficient heuristic algorithms that are commonly employed and converge quickly to a local optimum. These are usually similar to the expectation-maximization algorithm for mixtures of Gaussian distributions via an iterative refinement approach employed by both *k*-means and Gaussian Mixture Modeling. Additionally, they both use cluster centers to model the data; however, *k*-means clustering tends to find clusters of comparable spatial extent, while the expectation-maximization mechanism allows clusters to have different shapes.

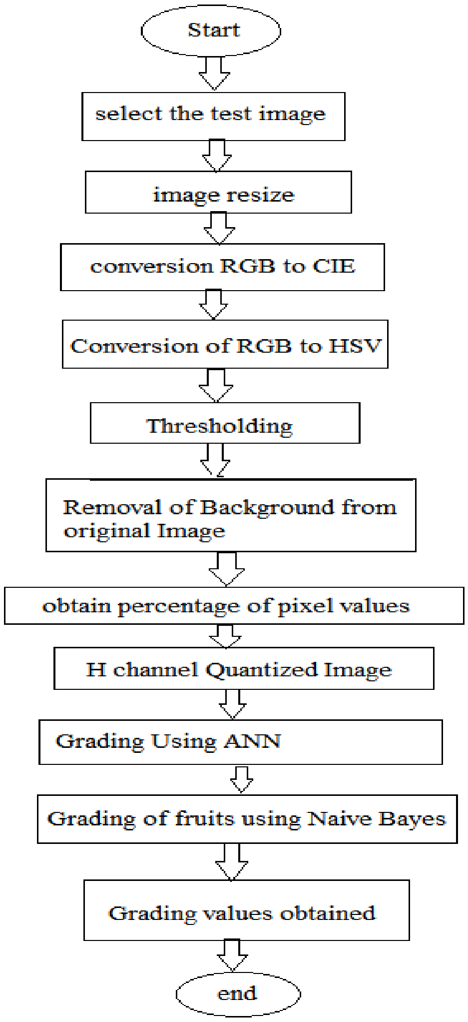
(a) (b) (c)

Figure 6 (a) original image of fruit test;(b) cluster index labeled image; (c) object obtained in cluster 1.

Neural Computers imitate sure processing capabilities of the human brain. Neural Computing is an information processing example, inspired by biological system, collected of a large number of highly organized processing elements (neurons) working in unison to solve specific problems. Artificial Neural Networks (ANNs) is similar to getting peoples, learn by model. An ANN is configured for a specific application, such as pattern recognition or data classification, through a learning process.

The first supervised learning method we introduce is the multinomial Naïve Bayes or multinomial NB model, a probabilistic learning method.

Flowchart of proposed Method



V. RESULTS AND DISCUSSION

Figure 7 shows the captured images of a banana during 5 days and the results of background removal, H channel images, the histogram of H channel and the segmented images. As demonstrated, aging and defect change the color of the samples.

The result is calculated by two methods. One is by using HSV(Hue, saturation and value) and another by using k-means clustering. The values are obtained. Figure 6 shows that the color changes because the decays can be precisely distinguished in H channel. Comparing the part (g) with (a) or (c) indicates that the proposed method can segment the images based on the degree of the defects.

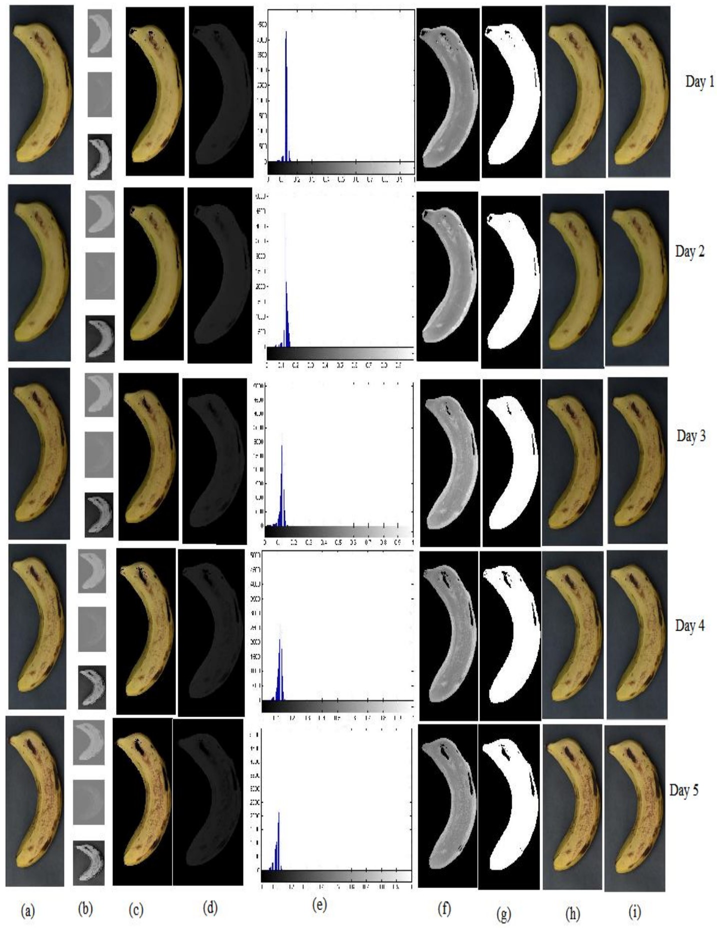


Figure 7. The image of banana of 5 days with the proposed method results.

(a): the original image of first day; (b): L*a*b* obtained from original image; (c): the images of 'a' after background removal; (d): H channel of background removed image; (e):H channel histogram of background removed image; (f): s channel applying threshold of 0.3; (g): the quantized images of 'c'; (h): fruit under test is grade 1 using ANN;(i): fruit under test is grade 1 using Naïve Bayes.

Table 1 The percentage of each segment for the images of figure 7

Days	White	Grey 1	Grey 2	Grey 3	Black
1	62.7345	0.9975	0.7562	0.7562	35.5118
2	58.2438	0.8681	0.5621	0.5621	40.3260
3	55.4959	1.6882	1.2506	1.2506	41.5653
4	54.1230	1.8625	0.8821	0.8821	43.1324
5	46.9653	4.7340	1.7039	1.7039	46.5968

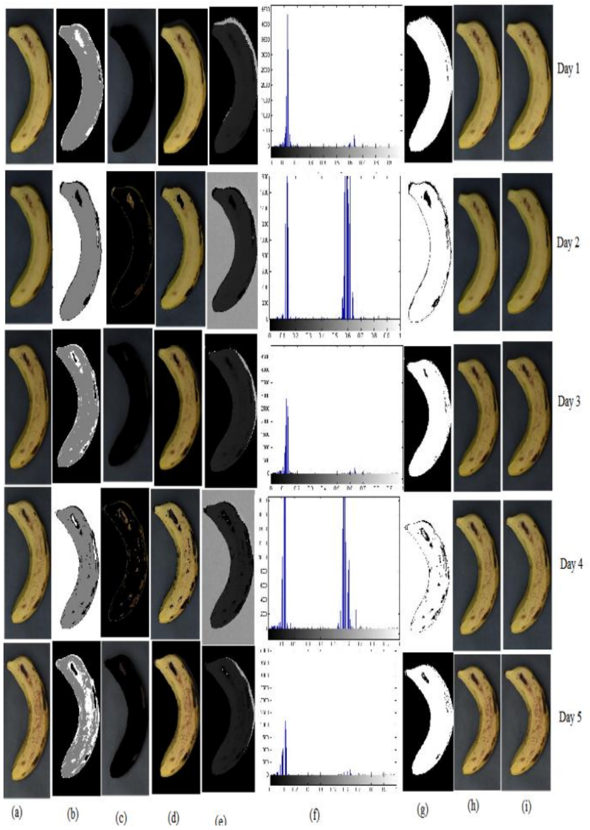


Figure 8: The image of banana of 5 days with the proposed method including K-means clustering.

(a): original image of fruit for test; (b): image labeled by cluster index;(c): object is cluster 1; (d): background removal using k-means clustering of original image;(e): H channel of background removed image; (f): H channel histogram of background removed image; (g):quantized image of H channel;(h): fruit under test is grade 1 using ANN; (i): fruit under test is grade 1 using Naive Bayes.

Table 2 The percentage of each segment for the images of figure 8

1	76.3038	1.2060	0.9683	0.9683	21.5220
2	50.7966	0.1385	0.1291	0.1291	48.9358
3	61.4823	1.8529	1.3397	1.3397	35.3251
4	50.5958	0.1909	0.3996	0.3996	48.8137
5	53.0670	5.1259	2.0700	2.0700	39.7371

Table 1 and table 2 obtained by results of both of the methods .Results obtained in table 1 is more superior than results obtained in Table 2. Finally,we can say that our proposed method (HSV) is better than K-means clustering.

VI. CONCLUSION

The development of digital color imaging gives the possibility of on-line quality control of agricultural and food products. In the present study, machine vision analysis was established for grading of some single color fruits. For this purpose, the images were captured with a RGB digital camera under diffuse illumination. It was found that the best capturing angle was zero. HSV color space was found to be able to give superior results. It was shown that it is possible to remove the background using the S channel information. A histogram-based thresholding in the hue channel was employed for quantization and segmentation the images. The color change due to defect and aging is suitably distinguishable in H channel because of eliminating undesirable illuminating effects. Consequently, the fruit image can be precisely segmented based on the degree of defects, and it is possible to achieve the grade-cluster according to the percentage of each segment.

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