A Comparative Study to find an Effective Image Segmentation Technique using Clustering to obtain the Defective Portion of an Apple

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***Abstract*— This paper aims at quality evaluation of the apple fruit to identify the surface defects based on the application of image processing and the computer vision systems. The external appearance of a fruit is one of the most important quality features and the manual assessment of the same by the human inspectors is costly, highly variable and inconsistent. Hence to meet the ever-increasing demand for the uniform and high quality fruits, an automated visual inspection technique using computer vision and image processing will undoubtedly be the preferred method. A crucially significant process for the automated fruit grading system is image segmentation. A comparative end result of the segmentation techniques based on the concept of clustering to find the defective portion of the apple fruit is presented. The motivation behind the proposed method is to improve the time complexity and accuracy of the clustering technique with the use of preprocessing.**

Keywords*— *quality evaluation of apple, defect detection, image segmentation, clustering

I. Introduction

The apple is one of the most cultivated and consumed fruits worldwide. It is referred to as “Miracle fruit” for its various health benefits and is used in a variety of applications such as fruit juice production, trade etc. As the consumer's knowledge about the quality has increased, a high-quality product needs to be developed. With this increasing requirement for maintaining the standard of the quality, the traditional methods for evaluating the quality of an apple are time-consuming, expensive and highly subjective due to which an automated visual assessment using image processing and computer vision technology is essential. It is more reliable and objective than traditional human inspection.

The surface defect detection in apple food production and processing has become absolutely indispensable nowadays. External fruit properties give a base to find the defective portion of a fruit. To find these defective portions, Image segmentation is one of the most critical phases in the image processing. In this phase in the input image is partitioned into its components to extract desired features. Different procedures such as threshold, edge, cluster, neural network based can be used to achieve segmentation of the image for a particular purpose. From these, one of the most efficient and widely used is the technique of clustering in which objects are grouped together into a cluster based on their characteristics. The objects within a cluster are highly similar in nature but are very dissimilar to the objects fitting to additional clusters. The K-means clustering method is quite well known for its simplicity and being computationally faster for large data. In this, the input data points are categorized into many groups produced on their inherent distance from one another. It is a statistical algorithm in which the number of clusters or partitions is predefined. K-means algorithm is non-supervised, iterative, nondeterministic and numerical. K-means performs well with large data sets but is limited mainly to compact groups. Another clustering algorithm known as the Fuzzy C-Means algorithm abbreviated as FCM is an iterative algorithm in which the idea of fuzzy behavior is used. It lets in one piece of data to belong to more than one clusters as each data can have distinctive membership values on each cluster. This approach is most often used in recognition of a pattern.

II. Literature survey

A lot of analysis has been done in the field of quality evaluation of fruits. Quality of fruit is affected due to the presence of defects which lead to economic losses. Vimala Devi et al. [1] proposed that since manual fruit grading is a time-consuming process, an automated machine vision-based fruit grading system are used for fruit defect identification. Various machine vision techniques and applications utilized for robot assistance employed in quality inspection of tropical fruits were analyzed in order to sort and grade these fruits. It was also examined that removing the noise will enhance the image for further processing. For quality evaluation of apples, Zhang et al. [2] developed an imaging system with hyperspectral reflectance in combination with spectral analysis and image processing for detecting early rottenness with an overall accuracy of 98%. In the evaluation of the various computer vision technologies in the external fruit defect detection, Li et al. [3] stated that hyperspectral imaging is an emerging technology and has potential uses in the analysis of fruit safety and quality. Lu et al. [4] reviewed different imaging and spectroscopic methods to detect defects in apples after

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the harvest in an apple orchard and presented an outlook for the future. Computer vision systems will provide effective solutions to the increasing demand for research and application developments.

Many kinds of research have been completed in the image segmentation using clustering area. The partitions created as a result of image segmentation are different objects in the image which have the same texture or color. Wang et al. [5] described that the K-means clustering algorithm was effective in the recognition and localization of occluded apples to divide the original input image into apples, leaves, branches. A value of k equal to 3 was used so that it ensures that the process is not time-consuming, and the input image was not over-segmented. For better accuracy, image filling and mathematical morphology preprocess was used. Dubey et al. [6] applied the K-means clustering method to detect infected fruit part for apple fruit disease classification. The input image of apple was first transformed into the L*a*b* color space for better processing time of the segmentation process and then K-means method was applied to partition this image into four regions. The portion with most diseased portion was selected manually for further processing. Moallem et al. [7] offered a computer vision-based algorithm to grade golden delicious apples in which image was converted into YCbCr color space and the K-means technique was applied on the Cb component in the YCbCr to detect the calyx region. Colors play a major role in determining fruit maturity and detect defects on the surface. Hou et al. [8] used different combinations of L, a*, b* components for studying the stages of ripening of banana based on the changes of color of banana peel at three different areas of banana fingers namely apex, middle and stalk. Lee et al. [9] by mapping color 3-dimensional color spaces to 1-dimensional color indices using the colors which are previously selected according to the applicable interest for the calculation of a set of coefficients which are unique employed in the automated grading of color. This helped in specifying and adjusting the settings for preferred color in the evaluation of maturity of tomato and date and also in detecting surface defects in date.

Anjana et al. [10] stated that the improvement of contrast features in the image is more valuable in examining, interpreting and processing the image further which can be done through the process of histogram equalization. Sert et al. [11] used K-means clustering on histogram equalized image for segmentation of mushroom and measurement of its cap width and found that this approach gives improved results. Zhang et al. [12] designed an effective algorithm using K-means clustering with color space decomposition for segmenting the White blood cell. Adjustment of color was done for accuracy gain before sending the data for clustering. In the k-means cluster, the feature vectors were constructed by employing color components of different color spaces such as HSI, CMYK, and RGB. Yin et al. [13] compared K-means and Fuzzy C-means methods for arterial input function and found that K-means gives more precise and strong results for AIF than FCM but takes more time to execute. K-means was preferred over FCM due to the accuracy. Dubey et al. [14] compared the Fuzzy C-means(FCM) and K-means algorithm for the breast cancer data and found that the K-means algorithm was more prominent with respect to the computation time while the FCM algorithm gave better accuracy which indicates that the clustering techniques can be used according to the requirement of the area in which study is being carried out. Lin et al. [15] developed a fast version of the K-means techniques using the level histogram for each image which improved the response of the traditional K-means. It also provided better efficiency and performance when the initial clusters were selected randomly. Küçükkülahlı et al. [16] also used the concept of the histogram for the automatic image segmentation using the K-means techniques wherein the main intention was to discover the optimum number of cluster centers and the clusters. Lu et al. [17] studied the performance of different thresholding techniques in segmentation for the detection of a bruise in apples and concluded that most of the thresholding techniques perform well when they were applied on the partial histogram of the image. Li et al. [18] introduced an approach termed as the agglomerative fuzzy K-Means clustering method which was not susceptible to initial cluster centers. It also aided in defining the number of clusters which need to be produced.

Nandi et al. [19] used the concept of fuzzy classification in the proposed algorithm to grade the mango fruit according to defects on surface, shape, size and other quality attributes and also taking into consideration level of maturity with regard to a number of days to rot. Almost 87% of accuracy was achieved with the proposed system. One of the important factors which affect the fruit quality is the maturity of the fruit. Peaches are harvested when they are ripened. Matteoli et al. [20] adopted fuzzy logic to define categories of maturity in terms of firmness of the flesh of the peach fruit which was acquired using multivariate techniques. It was used in the approach suggested based on spectroscopy for nondestructive grading of peaches based on maturity. This method was productive when the degree of variation was high in peach fruits. Wazarkar et al [21] discussed various clustering methods and the applications in real word to which they can be applied. The pros and cons of each method in respective domains were presented. It was observed that most of the application domains considered used the strategies which utilize fuzzy clustering. Gamino Sánchez et al. [22] presented Fuzzy C-Means clustering with block matching denoising for the color images with noise to determine if the pixel in the center of the sliding window is noisy or not. The JK component of the IJK color space was used to improve the ability of the procedure.

An improved version of the clustering techniques can be developed with the use of preprocessing such as the histogram equalization. Their performance can be compared to suggest an optimal segmentation technique with better time complexity and accuracy for finding the defective portion of apple fruit.

III. METHODOLOGY

The flowchart for the proposed methodology is shown in Fig. 1. The first stage of any vision system is the image acquisition stage wherein an image is taken and stored in the computer. After the image has been obtained, preprocessing can be applied to the image so as to improve the quality of the digital image. Then the image is segmented using techniques such as K-means and FCM clustering. Finally, the apple is classified into defective and healthy one.

A. *Image Acquisition*

Through the step of image acquisition image of an apple with and without defects is taken and stored in the computer to classify them into healthy and defected ones. The resolution, size and format of an image contribute to the accuracy and speed of the process. An image with lower resolution has less accuracy but it is usually smaller in size and is faster to process whereas the high-resolution image displays all the intricate details but takes large amount of time to process. Hence an image with appropriate resolution needs to be selected which will be suitable for a particular application. In the proposed system, images in jpeg format with resolution 100x100 are taken.

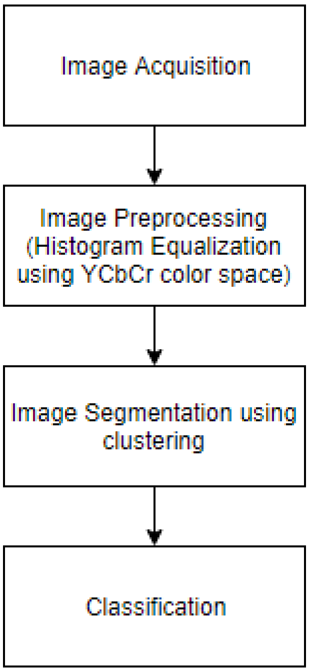


Fig. 1. Proposed methodology.

B. *Image Preprocessing*

The intent of Image preprocessing is to heighten some features and suppress other unwanted ones for improvement of an image which is crucial for further processing. Here the contrast of an image is enhanced by adjusting the intensities through the process of Histogram equalization. For histogram equalization of a grayscale image {x} first, we calculate the probability of an occurrence of a pixel using (1) which calculates the ratio of the number of pixels which has gray value i to the total number of pixels in the image. The gray levels range from 0 to $L-1$, where L is the total number of gray levels.

$$p_x(k) = \frac{n_k}{n} \quad (1)$$

The cumulative distribution of the probabilities is calculated using (2) and this distribution is then linearized using (3) with some constant C for each gray level to get new image {z}.

$$cdf_x(k) = \sum_{j=0}^{k} p_x(j) \quad (2)$$

$$cdf_z(k) = kC \quad (3)$$

The values are mapped back to their using (4).

$$z' = z(\max\{x\} - \min\{x\}) + \min\{x\} \quad (4)$$

The histogram equalization of color images can be achieved by converting the original image to another color space and then applying the algorithm to the value channels. Here the image is transformed to YCbCr color space using (5), (6), (7) and the histogram equalization technique is applied to Cb component to get histogram equalized image.

$$Y = 16 + \frac{65.738}{256}R + \frac{129.057}{256}G + \frac{25.064}{256}B \quad (5)$$

$$Cr = 128 + \frac{112.439}{256}R - \frac{94.154}{256}G - \frac{18.285}{256}B \quad (6)$$

$$Cb = 128 - \frac{37.945}{256}R - \frac{74.494}{256}G + \frac{112.439}{256}B \quad (7)$$

C. *Image Segmentation using clustering*

The histogram equalized image is segmented using the clustering techniques.

1) K-means clustering: In this algorithm number of clusters K and a set of data points X_i where i takes value from 1 to n is taken as input. Cluster centers C_j, j taking value from 1 to K are selected and placed at random locations.

For each point X_i find the nearest center and assign the point X_i to cluster j. For each cluster j ranging from 1 to K, calculate new cluster centers C_j using (8) which is mean of all the image data points X_i assigned to cluster j in the previous step.

$$C_j = \frac{1}{n_j} \sum_{x_i \to C_j} X_i \quad (8)$$

Repeat the steps to assign the data points to a cluster and finding new cluster centers till convergence is achieved and cluster assignments do not change.

*2) Fuzzy C-means clustering: T*he fuzzy C-means algorithm was developed as an improved version of K-means method. It is similar in nature to K-means. Given a set of data $X=(X_j)$ is a two dimensional matrix where j ranges from 1 to n. The algorithm attempts to find an optimal value for u which minimizes the objective function given in (9).

$$O(u,v)=\sum_{i=1}^{c}\sum_{j=1}^{n}{u_{ij}}^{m}d^{2}(x_j,v_i) \tag{9}$$

The constraints given in (10) needs to be satisfied.

$$\sum_{k=1}^{c}u_{ij}, u_{ij}\in[0,1], 1\le j\le n, 1\le i\le c \tag{10}$$

The value u_{ij} defines the membership value j^{th} data in the cluster I and cluster center of fuzzy cluster i is defined by v_i. The fuzziness of a cluster is controlled by parameter m which is taken as m=2 in the proposed method. Using Euclidian norm mentioned in (11), the distance between the cluster center and the data point is calculated.

$$d^{2}(x_j,v_i)=\|x_j-v_i\| \tag{11}$$

The values for the membership degree and cluster centers are updated using (12) and (13) respectively.

$$u_{ij}=\left[\sum_{k=1}^{c}\left(\frac{d(x_j,v_i)}{d(x_j,v_k)}\right)^{\frac{2}{m-1}}\right]^{-1} \tag{12}$$

$$v_i=\frac{\sum_{j=1}^{n}{u_{ij}}^{m}x_j}{\sum_{j=1}^{n}{u_{ij}}^{m}} \tag{13}$$

The algorithm continues to iterate and update values in (12) and (13) until the convergence criterion is satisfied. A membership value will be related to each data point and the segmented image can be obtained by assigning data to the cluster class with the highest membership value.

*3) Modified Fuzzy C-means clustering with histogram: T*his modified fuzzy C-means algorithm is an improved version of FCM. In this histogram is calculated and this histogram with gray levels 'g' is used FCM alogorithm instead of using the data points. The objective function for modified algorith is given in (14).

$$O_m=\sum_{j=1}^{g_{\max}}\sum_{i=1}^{c}{u_{ij}}^{m}His(g)d^{2}(g,v_i) \tag{14}$$

The value u_{ij} gives the membership value j^{th} gray level in the cluster i. The values for the membership degree and cluster centers for the modified version are updated using (15) and (16) respectively.

$$u_{ij}=\left[\sum_{k=1}^{c}\left(\frac{d(g,v_i)}{d(g,v_k)}\right)^{\frac{2}{m-1}}\right]^{-1} \tag{15}$$

$$v_i=\frac{\sum_{j=1}^{g_{\max}}{u_{ij}}^{m}His(g)g}{\sum_{j=1}^{g_{\max}}{u_{ij}}^{m}} \tag{16}$$

The algorithm continues to iterate and update values in (15) and (16) until the convergence criterion is satisfied as done in FCM.

D. Classification

Using the segmented images obtained from the previous step, the respective apples are classified into healthy and defective classes.

IV. RESULTS AND DISCUSSION

A set of 180 golden apple images were used for determining the accuracy and time complexity of K-means, K-means with histogram equalization, FCM, and FCM with histogram equalization technique. Table I gives the summary for accuracy while Table II gives the average time taken for each technique with respect to the number of clusters. The accuracy was calculated based on the number of correctly segmented images. Through Table I and Table II certain observations can be made. K-means and K-means with histogram equalization method have the lowest accuracy among others while FCM with histogram equalization has the highest.

TABLE I. SUMMARY FOR THE ACCURACY WITH RESPECT TO NUMBER OF CLUSTERS

Accuracy (%)	*Number of Clusters*		
	K=3	*K=5*	*K=7*
K-means	66.11	88.88	88.88
K-means with histogram equalization	66.11	88.33	88.33
FCM	68.83	89.44	89.44
FCM with histogram equalization	83.33	93.88	93.88

Use of histogram equalization has no effect on the accuracy of K-means clustering but the processing time for the same increases. FCM with histogram equalization has better accuracy as well as lesser computing time than FCM.

It can also be seen that as the accuracy increases from cluster size 3 to 5 but then attains a constant value.

TABLE II. SUMMARY FOR THE TIME TAKEN WITH RESPECT TO NUMBER OF CLUSTERS

Average time taken	*Number of Clusters*		
	K=3	*K=5*	*K=7*
K-means	0.03497 seconds	0.05650 seconds	0.05912 seconds
K-means with histogram equalization	0.04085 seconds	0.06125 seconds	0.07169 seconds
FCM	0.10522 seconds	0.38889 seconds	1.30617 seconds
FCM with histogram equalization	0.09049 seconds	0.56845 seconds	1.26262 seconds

Table III gives the segmentation of an image with respect to cluster 3, 5 and 7. From this, it can be noted that the segmented areas remain almost the same corresponding to the number of clusters 5 and 7 and hence accuracy related to these clusters also remain same.

TABLE III. SEGMENTATION OF AN IMAGE WITH RESPECT TO NUMBER OF CLUSTERS

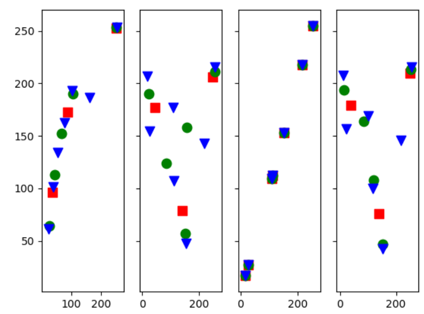
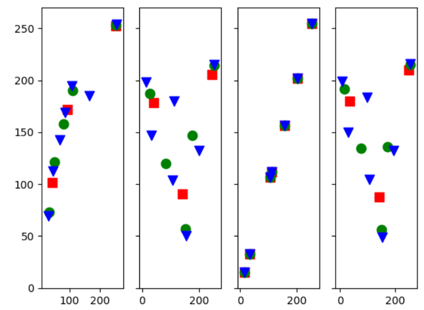
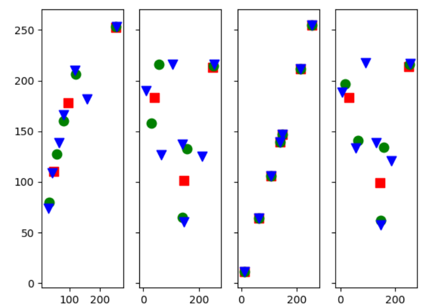
K=3	
K=5	
K=7	

Table IV shows the scatter plots three different images with respect to the R and B feature of the centers obtained. The first scatterplot is for K-means, the second one for K-means with histogram equalization, third for FCM and fourth for FCM with histogram equalization technique. X-axis and Y-axis represent R and B feature respectively. The red square, green circle and blue inverted triangle identify the values for cluster 3, 5 and 7 respectively.

V. CONCLUSION

Above study assessed the performance and accuracy of K-means and FCM segmentation algorithms with and without the preprocessing using histogram equalization. From this, we can conclude that the histogram equalization of images has no effect on the behavior of K-means clustering but the performance and accuracy of fuzzy C means clustering can be improved using the same. Hence FCM using histogram equalization can be considered as an optimal technique to detect defects on apples. Moreover, the efficiency of these segmentation methods can be improved by determining the initial cluster centers. Also, the performance can be further tested by validating and using few channels for L*a*b or YCbCr color space instead of considering full color information.

TABLE IV. SCATTER PLOTS OF THE IMAGES

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