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Machine Vision Based Color Grading of Kinnow Mandarin

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Abstract—The Kinnow mandarin fruits are graded manually by visual inspection, which is error prone, time consuming and expensive. The automatic system for the Kinnow grading ensures the much accurate results as compare to manual grading. This paper presents a new method for the classification of Kinnow fruit on the basis of color contents. K-means color based segmentation method is used to segment the images of Kinnow fruit and color based feature are obtained from RGB and HSI components of segmented image. The Kinnow is graded into three classes; Unripe, Ripe and Overripe. The Artificial Neural Network is used for the classification. The results are evaluated on the basis of Accuracy, Sensitivity and Specificity and compared with manual gradation of Kinnow, which shows the acceptable nature of proposed method.

Keywords— Kinnow Mandarin, K-means Segmentation Technique, Artificial Neural Network.

I. INTRODUCTION

Agriculture is the backbone of Indian economy as more than three-fourth of its population is directly or indirectly engaged in this profession [1]. After Mexico, India is the leading producer of citrus fruits [2]. Among citrus crops, Kinnow mandarin bears highest place in productivity, juice content and fruit quality. The Kinnow is a variety of citrus fruit cultivated mostly in Punjab region. It is orange in color and has a spherical shape. It matures in January or February. It is a rich source of calcium and vitamin C, due to which it is of great economic importance [3].

It has been estimated in recent research that 20 to 30% of the horticultural produce is lost before consumption which accounts for Rupee 5000 Crores because of poor harvesting, handling, storage, transportation and marketing practices [2]. One of the major reasons behind this is the time consuming manual grading. Because of the ever-growing need to supply high quality food products within a short time, automated grading of agricultural products is getting special priority among many farmers association.

Grading is sorting of vegetables and fruits into different grades according to their size, shape, colour, texture and volume to fetch high price in market and graded fruits are more welcome in foreign markets. Various machine vision based system has been developed so far for grading of different fruits and vegetables. For feature extraction, [4, 5] used RGB colour model, [6-8] used HSI colour model, [9] used the L*a*b colour model, [10] used the spectral signatures of different tissues and [11] used the Gaussian mixture density. For classification, Back propagation Neural Network(BPNN) was used by [8, 12, 13], [14] used the Perceptron Neural network(PNN), Wavelet Neural network(WNN) was used by [6], [10] used pixel based Neural Network, threshold values based classification was done by [15 16], [17 18] used Support vector machine(SVM), [19] used K-mean classifier and Linear discriminant analysis and quadratic discriminant analysis was used by [5].

Despite all these methods available for grading, none has been developed for Kinnow yet. So, it will be of great help to Kinnow growing farmers and Kinnow processing units, if some automatic grading machine is there which could automatically grade the Kinnow on the basis of specific characteristic like colour, as it is the most important feature for classification. This will reduce the processing time of grading which will results in faster transportation of quality Kinnow for export purposes.

II. MATERIAL AND METHODS

A. Kinnow Fruit Dataset

The images of Kinnow fruit were acquired using Sony cyber-shot (DSC-W360) 14.1MP camera with Carl Zeiss lens, f 3.5, exposure time .02sec, focal length 8mm, aperture 2.9 at 1.7 zoom. A dark imaging chamber was created to avoid the backscattering effects from other light sources. Each Kinnow sample was manually placed on a white background to capture the image from a fixed distance of 30 cm at 4320 x 3240 Resolution. All acquired images had been stored in a personal computer and were used for further processing.

Kinnow fruit was obtained from Punjab region of India in the period of December 2014 to march 2015. Samples of different grades were collected from different fields of Kinnow producing region (Abohar, Fazilka and Hoshiarpur). A total of 303 images of Kinnow were collected and graded into three classes on the basis of fruit colour by the experienced graders from Punjab Agriculture University, Ludhiana (India).

B. Segmentation

Image segmentation is a mid-level processing technique used to analyse the image and can be defined as a processing technique used to classify or cluster an image into several disjoint parts by grouping the pixels to form a region of homogeneity based on the pixel characteristics like gray level, colour, texture, intensity and other features [20]. Many approaches are available for segmentation like region based, edge based, thresholding based, clustering based and histogram based but in this study, a clustering based segmentation technique is used known as k-means clustering method because of its simple design and better time complexity (O(n)). Another reason to use this method is that the original colour of the fruit is preserved in segmented image.

K-means clustering algorithm assumes that the data features form a vector space and tries to find natural clustering in them [21]. The points are clustered around centroids μ_i for i=1:k, which are obtained by minimizing the objective

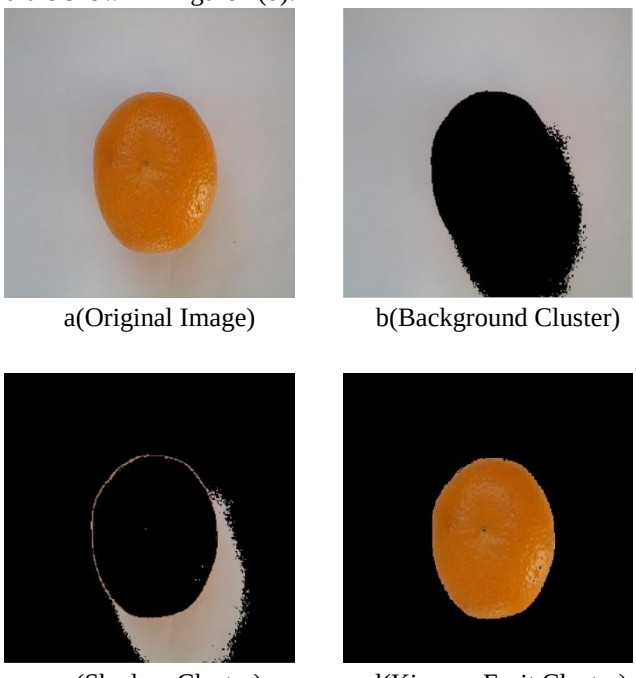
$$V = \sum_{i=1}^{k} \sum_{x_j \in s_i} (x_j - \mu_i)^2 \qquad (1)$$

Where there are k clusters S_i, i = 1: k and μ_i is the centroid or mean point of all the points x_j S_i.

The implementation of the segmentation algorithm is done as follows:

1. Resize the image to reduce the processing time using matlab command 'imresize' to one tenth of its resolution.
2. Convert the image from RGB colour space to L*a*b* colour space and classify the colours of a*b* colour space using k-means clustering method.
3. Repeat the clustering 3 times to avoid the local minima.
4. Label every pixel and create images that segment the image by colour.
5. Select the cluster which contains the segmented image.

In this study, the clusters are formed on the basis of three different colour intensities present in the images representing background, shadow and Kinnow fruit. Following Figure shows the original image (Figure 1(a)) which is segmented into three clusters. The cluster related to background is represented in Figure 1(b), Figure 1(c) shows the shadow cluster and cluster representing Kinnow fruit is shown in Figure 1(d).



a(Original Image) b(Background Cluster)

c (Shadow Cluster) d(Kinnow Fruit Cluster)

Figure 1: K-means Segmentation

C. Colour Feature Extraction

Mostly the colour of Kinnow fruit is orange in colour, but as it matures, it becomes orange yellow and finally golden. To detect the colour of the fruit effectively, 12 features are calculated from R-channel, G-channel, B-channel, Hue, Saturation and Intensity of the Kinnow. Mean and Variance of each of the six components is taken as feature.

Kinnow Mean Class: Arithmetic mean is the one selected in this algorithm and is often simply called as mean [22]. For a given data set, the average is the sum of the measurements divided by the number of measurements. The formula of mean μ is defined as follows:

$$\mu = \frac{\sum_{i=1}^{n} p_i}{n} \qquad (2)$$

Where p is the pixel value and n is the number of pixels.

Kinnow Variance Class: Variance is the simple method to find the spreadness of a data [22]. A low variance indicates that all pixel values are very close to the mean of the class, while high variance indicates that all the pixel values are clearly more spread out across a large range of levels. The formula for calculating variance is:

$$\sigma^2 = \frac{\sum_{i=1}^{n}(p_i - \mu)^2}{n} \qquad (3)$$

Where p is the pixel value, μ is the class mean and n is the number of pixels in the class.
Algorithm for finding the mean and variance features of Kinnowcolour is given below:

1. Red, green and blue components of segmented image are calculated as follows:

$$r = \frac{R}{R+G+B} \qquad (4)$$

$$g = \frac{G}{R+G+B} \qquad (5)$$

$$b = \frac{B}{R+G+B} \qquad (6)$$

2. To find Hue (H) of image following conversion formulas are used:

$$num = 0.5 \times ((r-g)+(r-b)) \qquad (7)$$

$$den = \sqrt{((r-g)^2 + (r-b) \times (g-b))} \qquad (8)$$

$$theta = \text{acos}(\frac{num}{(den + eps)}) \qquad (9)$$

$$theta(b > g) = 2 \times pi - theta(b > g) \qquad (10)$$

$$Hue(H) = \begin{cases} 0 & if\ S = 0 \\ theta/(2 \times pi) & if\ S \neq 0 \end{cases} \qquad (11)$$

3. To find Saturation (S) of image following conversion formula is used:

$$min = minimum\ of\ (R, G, B) \qquad (12)$$

$$Saturation(S) = 1 - \frac{min}{Intensity(I)} \qquad (13)$$

4. Intensity(I) of an image was calculated using following formula:

$$Intensity(I) = \frac{R+G+B}{3} \qquad (14)$$

5. Calculate mean and variance of the above six calculated components of the Kinnowcolour and store them in a 12-by 303 matrix.

D. Classification

Back propagation neural network is the one chosen in this study for classification. BPNN is a multilayer neural network which is widely used for pattern classification problems. It has advantages of simple design, versatility and accuracy. Its design is divided into three layers: Input layer, Hidden layer and Output layer. Nodes at Input layer takes input in the form of values which is passed to the hidden layer nodes along with their weighted sum. The number of nodes in a hidden layer determines the 'expressive power' of the network [23]. Output of hidden layer nodes is computed with the help of activation function. In this study, activation function used is log sigmoid function which has range of [0, 1]. It is represented as:

$$y(x) = \frac{1}{1 + e^{-x}}$$

The output of the hidden nodes multiplied with their weighted sum is given as input to the output layer nodes and mean square error is calculated. The error is then distributed throughout the network using concept of back propagation and weights are repeatedly adjusted until error function is reached to its minima.
The extracted colour features are fed to the BPNN for the training and testing of the proposed method. Training and target vectors are created. Training vector contains the feature vector and target vector contains the class vector to which the corresponding training vector belongs to. For implementation, neural network toolbox present in MATLAB® is used.

E. Performance Parameters

The selection of the correct metrics in evaluating the performance of the Kinnow grading system is vital to the result and the validation of the system. The parameters chosen to evaluate the performance of the proposed system are sensitivity, specificity and accuracy.

Sensitivity: Sensitivity is the proportion of true positives that are correctly identified by classifier during testing [24]. The higher the numerical value of sensitivity, the less likely false positive results will be returned.

$$Sensitivity = \frac{TP}{TP + FN} \times 100 \qquad (15)$$

Where, TP is True positive(i.e. subjects that belong to the class and are correctly identified) and FN is False Negative(i.e. subjects that belong to the class and are incorrectly identified) [25].

Specificity: Specificity is the proportion of the true negatives correctly identified by classifier during testing [24]. The numerical value of specificity represents the probability of a test identifying a particular class without giving false-positive results.

$$Specificity = \frac{TN}{TN + FP} \times 100 \qquad (16)$$

Where, TN is True Negative(i.e. subjects that do not belong to the class and are correctly identified) and FP is False Positive(i.e. subjects that do not belong to the class and are incorrectly identified) [25].

Accuracy: Accuracy is the proportion of true results, either true positive or true negative, in a population [24].

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \times 100 \qquad (17)$$

III. RESULTS AND DISCUSSIONS

The proposed methodology was implemented with image processing toolbox and neural network toolbox present in MATLAB® 2013a. The tests are performed on 303 Kinnows to find the performance parameters and the results were compared with results obtained from manual grading by experts. The Kinnowcolour features are extracted from the mean and variance of RGB and HSI components. The analysis was carried out on images of 303 Kinnow fruits of which 213 were used for training, 45 for validation and 45 for testing.

The samples of features extracted are shown in table1, 2 and 3 for Unripe, Ripe and Overripe category respectively. It is found that the feature values show sudden change when compared with other category. This difference results in effective training and accurate classification by ANN.

Table 1: Mean RGB and HSI components of sample for unripe category

Colour features	**Image 1**	**Image 2**	**Image 3**
R_mean	0.0776	0.0845	0.0846
G_mean	0.0394	0.0455	0.0454
B_mean	0.0092	0.0122	0.0116
H_mean	0.0268	0.0331	0.0346
S_mean	0.1521	0.1711	0.1706
I_mean	0.0780	0.0850	0.0852
R_variance	0.0462	0.0485	0.0488
G_variance	0.0128	0.0148	0.0149
B_variance	0.0015	0.0016	0.0017
H_variance	0.0117	0.0144	0.0159
S_variance	0.1174	0.1276	0.1273
I_variance	0.0461	0.0484	0.0488

Table 2: Mean RGB and HSI components of sample for ripe category

Colour features	**Image 1**	**Image 2**	**Image 3**
R_mean	0.0785	0.0860	0.1180
G_mean	0.0436	0.0449	0.0579
B_mean	0.0100	0.0095	0.0137
H_mean	0.0296	0.0357	0.0403
S_mean	0.1454	0.1684	0.2308
I_mean	0.0791	0.0867	0.1188
R_variance	0.0508	0.0548	0.0636
G_variance	0.0167	0.0185	0.0163
B_variance	0.0016	0.0015	0.0017
H_variance	0.0133	0.0167	0.0169
S_variance	0.1131	0.1292	0.1598
I_variance	0.0508	0.0547	0.0635

Table 3: Mean RGB and HSI components of sample for overripe category

Colour features	Image 1	Image 2	Image 3
R_mean	0.1303	0.1283	0.1308
G_mean	0.0689	0.0695	0.0716
B_mean	0.0121	0.0132	0.0136
H_mean	0.0497	0.0490	0.0485
S_mean	0.2545	0.2459	0.2453
I_mean	0.1311	0.1293	0.1318
R_variance	0.0746	0.0734	0.0768
G_variance	0.0219	0.0222	0.0236
B_variance	0.0017	0.0022	0.0023
H_variance	0.0220	0.0218	0.0212
S_variance	0.1750	0.1708	0.1704
I_variance	0.0744	0.0732	0.0766

The results of BPNN are shown in Table 4. It has been observed that the classification error rate is no more than 2%. The results also show that 1 image from unripe, 4 from ripe and 1 from overripe categories are misclassified in other categories, which is an acceptable level of error.

Table 4: classification results by BPNN

Colour	(TP)	(FN)	(FP)	(TN)
Unripe	186	1	2	114
Ripe	86	4	2	211
Overripe	25	1	2	275

Further, it has been found that the overall accuracy of the system is 98.66%, sensitivity measures 97.05% and specificity of the system is 98.86%. The details of evaluating parameters are shown in Figure 2.

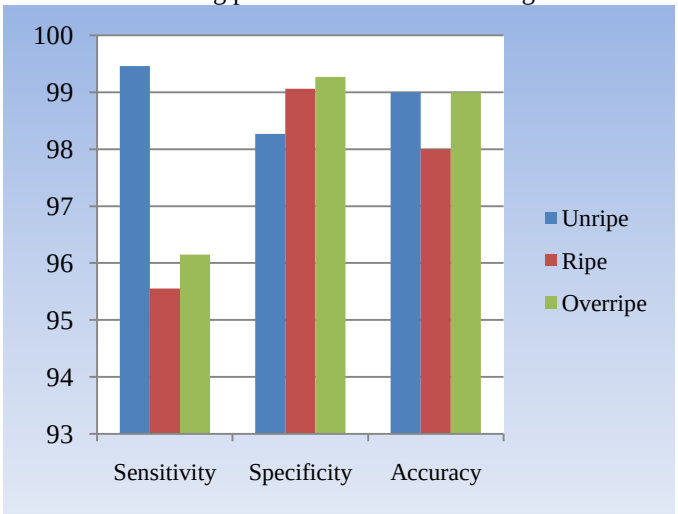


Figure 2: Calculated Performance Parameters

IV. CONCLUSION

This research was conducted to determine and differentiate Kinnow fruit on the basis of colour properties. The grading system successfully detected the Kinnow class as Unripe, Ripe and overripe by analysing RGB and HSI data from the image. The computer program was written in MATLAB® 2013a which uses mean and variance of the RGB and HSI components to differentiate between colour and ripeness of Kinnow fruit. 12 colour features were obtained for each Kinnow image which are used for classification using BPNN. The performance of the proposed system is evaluated in terms of Sensitivity, Specificity and Accuracy. The result shows that the system identifies the Kinnow Fruit to their respective class with an accuracy of 98.66%.

In future work, incorporation of some more important parameters such as shape and size will be done to increase the grading accuracy of the Kinnow fruit.

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