International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 – 5161
Available at http://inpressco.com/category/ijcet

Research Article

Ripeness, Size and Shape based Automated Mango Grading using Image Processing and Machine Learning Techniques

Amruta Supekar and Prof. Madhuri Wakode

Department of Computer Engineering SCTR'S Pune Institute of Computer Technology

Received 10 Nov 2020, Accepted 10 Dec 2020, Available online 01 Feb 2021, **Special Issue-8 (Feb 2021)**

Abstract

Mangoes are one of the most favorite fruits in the world. A large scale of mangoes is globally exported and also locally consumed. During mango exports and local marketing, quality inspection is essential. It directly affects customer satisfaction and thereby vendor's monetary gains. Mango grading is a postharvest operation in which mangoes are classified according to grading parameters like size, shape, ripeness, defect, sweetness, etc. This process of quality assessment is usually done manually just by inspection with a naked eye. However, it can lead to inconsistent and inaccurate grading. A computer vision-based automated system, utilizing a mango image can provide a better, accurate, consistent and reliable solution. In this research work, an attempt to grade Kesar mangoes based on its maturity, size, and shape has been made. Firstly, the mango image is analyzed to determine its size, ripeness, and shape category. Further, three parameters are combined using pre-defined grading rules to determine mango grade as rejected, grade1 or grade2 quality.

Keywords: *Computer Vision; Image Processing; Machine Learning; Mango Grading; Mango Classification*

Introduction

India, due to its diverse climate is a leading producer of many fruits and vegetables. It ranks first in mango production and second in mango exports. Mango is known as "King of Fruits" and is one of the most popular fruits worldwide. India generates huge revenue from exports and local mango marketing. According to APEDA export statistics, during the year 2018-19, India has exported 46510.27 MT of fresh mangoes to the world worth Rs.406.45 crores/ 60.26 USD Millions [21]. After harvesting mangoes, its quality is checked and mangoes are graded according to different grading parameters. This postharvest operation is called mango grading in which fruits are classified according to different parameters. Mangoes can be graded according to appearance parameters like size, shape, ripeness, defect or internal parameters like nutrients, sweetness, etc. Appearance grading according to size and shape directly affects customer satisfaction and thereby trader's profits. Maturity based sorting can help farmers to make important marketing and packaging decisions. Appearance-based mango sorting is usually done manually just by inspection with a naked eye. However, it can lead to inaccurate and inconsistent sorting. A better solution is essential. Currently, image processing and machine learning techniques are being utilized to solve many agricultural problems like crop disease detection, yield estimation, fruit classification, etc. Such techniques can also be applied for fruit grading in which mango image is examined and classified into various grades. This computer vision based automated fruit grading system would be more accurate, consistent and reliable. In this work, such an image based mango classification method is developed. Image acquisition, preprocessing, feature extraction (according to parameters) and classification are some of its important stages. Initially, the mango image is preprocessed. Appropriate image processing techniques are then applied to extract parameter specific features. These features are used to determine mango ripeness, size and shape category. Once the mango category according to parameters is determined, then predefined grading rules can be applied to classify mango into one of the three grades namely rejected, grade1 or grade2.

Literature Survey

Many researchers have performed mango grading/sorting using computer vision based techniques. Few research works grade mangoes based on a single parameter and some of them perform multi-parameter grading. However, the general methodology followed is image acquisition, preprocessing, feature extraction and finally classification/regression using proper machine learning techniques.

Ripeness Classification: Mango ripeness is directly correlated with its physicochemical properties (Total soluble solids-TSS, Titratable acidity-TS, firmness, etc). Analyzing physiochemical properties for ripeness analysis can be destructive and timeconsuming. As mango ripens there are significant variations in its peel color. Such variations can be analyzed to classify mangoes into different ripening stages. This method is nondestructive and has gained good accuracy [7, 9, 12]. Mango image is usually acquired using digital cameras in RGB color space. However, RGB color space cannot separate the color component from the brightness. Hence HSV (Hue-SaturationValue), HSI(Hue-Saturation-Intensity), CIELab, CYMK, YCbCr are explored by many researchers. Mim et al. (2018) classified mangoes into six ripening stages using HSI and RGB color models. Decision tree classifier was employed which gained an accuracy of 96% [7]. Nambi et al. (2016) extracted 18 features related to HSV and RGB color spaces. Quadratic discriminant analysis outperformed Linear discriminant analysis for 5 stage ripeness classification [9]. Velez-Rivera et al. (2013) gained 100% accuracy while performing a detailed analysis of mango ripeness using color (CIELab and HSB) and physicochemical features. Feature extraction was performed using Principal component analysis and classification were done using multivariate discriminant analysis [8]. Ripeness classification into two stages was experimented by Limsripraphan et al. (2019) using RGB color properties. Naïve Bayes and SVM classifiers achieved an accuracy of 90% and 83% respectively [4]. Nagle et al. (2016) performed a regression analysis between color measurements taken from the calorimeter and those extracted from image in Lab color space. A three stage classification based on yellowness index achieved an accuracy of 72%-92% for Nam Dokmai and 98-100% for Maha Chanok mangoes [12]

Size Classification: Many size related properties like area, major axis, minor axis, perimeter, diameter etc. have been extracted by researchers to perform size based classification. Mango area is calculated from the binary image obtained after thresholding. Many researchers have utilized the area for size based mango classification [6, 11, 13, 15-16]. Area combined with diameter was utilized in [14] and [15] which obtained an accuracy of 91.41% and 97% respectively. Mango Area together with weight could achieve a 96% recognition rate using fuzzy analysis for Kesar mangoes [6]. Accuracy of 89.5% was gained when an area was used as the only parameter for size classification [16]. Mango shape is closest to an ellipse, hence ellipse fitting has been used by many to find its major and minor axis. An attempt to compute actual length and width from image extracted major and minor axis was done by Nandi et al. (2016) which achieved an error rate of 3.07%. A fuzzy classification performed in [18] using major and minor axis gained 96.58% accuracy.

Shape Classification: Deformed mangoes can lead to decreased customer satisfaction. Hence finding deformed mangoes and rejecting them is necessary. Most of the research works perform shape based binary classification as well-formed and deformed. Fourier descriptors have been utilized by many researchers and it has achieved best shape classification results [3, 5, 10]. Eccentricity, extent, cross-ratio and area ratio have also been used [6]. However, they do not provide good shape based classification. SVM classification on image extracted Fourier descriptors achieved an accuracy of 100% for Harumanis mangoes [10] and 91% for multi-variety mangoes [3]. Fourier descriptors combined with area ratio could achieve accuracy of 98.3% using discriminant analysis for Harumanis mangoes [5].

Multi-parameter classification: Few of the researchers have employed multiple parameters for grading [1-3,6,11,17-19]. Grading based on size, ripeness, and shape is performed in [1] using a deep learning approach (Convolution neural networks). The best accuracy of 83.97% has been achieved for four grade classification. Agilandeeswari et al. (2017) sorted mangoes into three classes good, very good and bad based on geometric, textural and histogram features. Accuracy of 97% [2] was achieved on Kent dataset by COLIFB lab [22]. Naik et al., (2015) classified Kesar mangoes based on its shape, size and ripeness using fuzzy classification. The integration of all features resulted in average accuracy of 90%. Grading time 2.1 sec was obtained [6]. A four-grade classification was performed in [3] based on ripeness and quality (shape, size, defect). The grading system obtained an accuracy of 88% using fuzzy rulebased classifier. Tomas et al. (2014) classified mangoes into three classes based on size, roundness and defect using K nearest neighbor classifier. Maturity and size were utilized by Yossy et al. (2017) for four-class classification using Artificial Neural Networks which gained accuracy of 94% [19].

A size, defect, and maturity based grading using a fuzzy classifier obtained an accuracy of 97.47% [18].

Proposed Methodology

The proposed mango grading methodology is as depicted in Fig 1. It consists of six modules- image preprocessing, mango segmentation, ripeness determination, size determination, shape determination, and grade determination.

A. Architecture

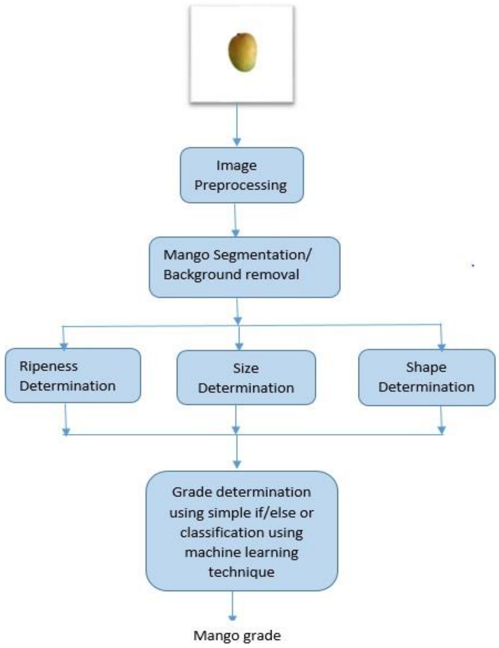


Fig 1: Proposed Mango Grading Methodology

1. **Image Preprocessing-** The input to the mango grading system is a mango image acquired using a digital camera. Initially, the mango image is preprocessed. Image resizing and noise removal are two preprocessing operations performed. Image resizing helps in speeding the image processing operations. Noise removal is done using median filtering to get rid of any salt and pepper noise if present.

2. **Mango Segmentation/Background Removal-** To extract features from mango, it needs to be segmented from the background. RGB to grayscale conversion is first performed. Simple global thresholding with a fixed threshold value is applied on a grayscale image. The output of global thresholding is a binary image in which mango region pixels are white in color and the background region is black. This binary image is anded with a preprocessed image to obtain a segmented image. The segmented image consists of colored mango with a black background. Segmentation of mango becomes easier if mango image is acquired with a white background.

3. **Ripeness Determination-** Ripeness can be closely associated with peel color variation. Hence color features related to HSV and Lab color spaces are extracted from mango image. Such extracted features are given as input to a pretrained SVM model to determine the mango ripeness category as unripe, ripe or overripe.

4. **Size Determination-** In order to determine mango size category, geometric features like major axis, minor axis and area are extracted. Mango area is computed by counting the white pixels in the binary image obtained after thresholding. Ellipse fitting is used for major and minor axis extraction. These geometric features are given as input to pre-trained random forest classifier to find mango size categories as small, medium or large.

5. **Shape determination-** In order to find the shape category, centroid based Fourier descriptors are extracted from the binary image. Such features are given as input to a pre-trained classifier to classify mango as well-formed or deformed. Fourier descriptors are rotation, translation and scale-invariant, hence provide good shape classification.

6. **Grade determination-** Once mango ripeness, size and shape category is found, its grade can be determined using predecided grading rules. Eg if a mango is deformed then the grade is rejected. Such grading rules need to defined by experts. They can also be derived from mango grading standards. A grade can be determined by simple decision making(if-else) or a pretrained machine learning classifier using ripeness, size and shape category as features.

B. Algorithm

For each mango to be graded perform the following steps:

Step 1: Acquire a mango image using proper image acquisition device.

Step 2: Perform median filtering and image resizing on acquired image to obtain a preprocessed image.

Step 3: Convert RGB image to grayscale and apply simple thresholding using a fixed threshold to obtain a binary image.

Step 4: Perform anding of binary image and preprocessed image to get the mango segmented image.

Step 5: Extract color, geometric and shape features from mango segmented image.

Step 6: Determine ripeness, size, and shape using pre-trained classification models.

Step 7: Determine mango grade using simple decision making or pre-trained grade classifier.

Intermediate Results and Discussion

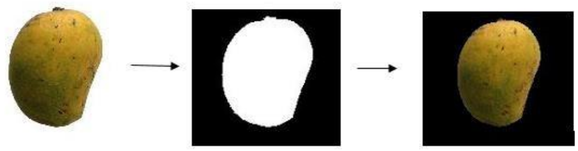
In this research, work grading was performed based on ripeness, size and shape parameters. Implementation was done in python. Experimentation was carried out on publically available Kesar mango dataset [20].

Intermediate results are presented in three sections mango segmentation results, ripeness classification performance, and size classification performance. The dataset details and results are given below:

Dataset: Kesar mango dataset [20] consists of 828 mango images belonging to different categories based on ripeness, size, and shape. Categories according to parameters are ripeness (unripe, partially ripe, ripe), size (small, medium, big) and shape (well-shaped, deformed). Some of the images from the dataset are shown in Fig 2.

Fig 2: Kesar Mango Images [20]

Mango Segmentation: The results of mango segmentation are shown in Fig 3.



(a) (b) (c)

Fig 3. Mango Segmentation Steps

Fig 3 shows the steps of mango segmentation. The original image is shown in (a). Simple global thresholding applied to the original image results in the binary image as shown in step (b). Anding of original and binary image results in a mango segmented image as shown in step (c).

Ripeness Classification Performance: As mentioned earlier, mangoes are classified in three ripening stages unripe, partially ripe and ripe. 756 images from the Kesar dataset were used for ripeness analysis. It consisted of 335 unripe, 229 partially ripe and 192 ripe mango images. The ripeness dataset was divided into 80% training and 20% test set. An SVM classifier with rbf kernel was trained using 604 images. 10 fold cross-validation was performed and an accuracy of 91% was obtained on the training set. The trained model was tested on a test set of 152 images and 90% classification accuracy was achieved. The confusion matrix for the test set is shown in TABLE 1.

Table 1: Confusion Matrix for Ripeness Classification

Actual	**Estimated**			***Total***
	Unripe	***Partially ripe***	***Ripe***	
Unripe	61	1	1	63
Partially ripe	2	38	7	47
Ripe	0	5	37	42

Size Classification Performance: As mentioned earlier mangoes are classified into three categories according to size big, medium and small. The Kesar dataset consisted of 112 big, 244 medium and 195 small mango images. This dataset is divided into 80% training and 20% test set. A random forest classifier was trained using 440 images. 10 fold cross-validation was performed which achieved an accuracy of 78%. The trained model was tested using test set of 111 images and 80% accuracy was obtained. The confusion matrix for the test set is as shown in TABLE 2.

Table 2: Confusion Matrix for Size Classification

Actual	**Estimated**			***Total***
	Big	***Medium***	***Small***	
Big	8	6	0	14
Medium	3	42	7	52
Small	0	6	39	45

The ripeness and size classification has been tried out on publically available dataset. However, dataset of Dashehari and Alphonso mangoes will be prepared in the future. Defect and sweetness as grading parameter would be added. Defects can be found from mango image using image thresholding technique. While ripeness and defect determination two views of mango front and back would be considered. The results obtained from both views will be combined to determine the final ripeness and defect category. This model approach would be more reliable and accurate.

Conclusion

Computer vision-based mango grading will help in accurate and consistent grading. Image processing methods like contour detection, ellipse fitting, simple thresholding, etc. have been applied to perform ripeness, size, and shape-based mango classification. Experimentation has been tried out on publically available Kesar mango dataset. Ripeness classification into three stages using a support vector machine classifier achieved an accuracy of 90%. A random forest classifier for size-based classification into three classes could achieve an accuracy of 80%. Further shape base classification and integrated grading using all three parameters needs to be performed. Thus the application of image processing and machine learning techniques for mango classification have been successfully studied and implemented.

References

[1]. S. Naik,-Non-destructive mango (Mangifera Indica L., cv. Kesar) grading using convolutional neural network and support vector Machine, SSRN Electronic Journal. DOI: 10.2139/ssrn.3354473

[2]. L. Agilandeeswari., M. Prabukumar, S.A. Goel,-Automatic grading system for mangoes using multiclass svm classifier. International Journal of Pure and Applied Mathematics, 2017, vol. 116(23) pp. 515-523

[3]. C.S. Nandi, B. Tudu, and C. Koley,-Machine vision technique for grading of harvested mangoes based on maturity and quality. IEEE Sensors Journal, 2016, vol. 16(16), pp. 6387-6396. DOI 10.1109/JSEN.2016.2580221

[4]. P. Limsripraphan,, P. Kumpan,, N. Sathongpan, and C. Phengtaeng,- Algorithm for mango classification using image processing and naive bayes classifier. industrial technology Lampang Rajabhat University Journal, 2019, vol. 12(1), pp. 112-125

[5]. M.F. Ibrahim, F.S.A. Sa'ad, A. Zakaria, and A.Y.M. Shakaff,-In-Line sorting of harumanis mango based on external quality using visible imaging. Sensors (Basel), 2016, vol. 16(11). DOI: 10.3390/s16111753

[6]. S. Naik, S., B. Patel and R. Pandey,- Shape, size and maturity features extraction with fuzzy classifier for non-destructive mango (Mangifera Indica L., cv. Kesar) grading, IEEE International Conference on Technological Innovations in ICT for Agriculture and Rural Development. DOI: 10.1109/TIAR.2015.7358522

[7]. F.S. Mim, S.M. Galibb, F.M. Hasan and S.A. Jerin,-Automatic detection of mango ripening stages – An application of information technology to botany. Scientia Horticulturae, 2018, vol. 237, pp. 156-163. DOI: https://doi.org/10.1016/j.scienta.2018.03.057