



Classification of Mangosteen Surface Quality Based on Image Processing Using Support Vector Machine

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DOI: <https://doi.org/10.30880/ijie.2021.13.05.029>

Received 06 August 2020; Accepted 14 September 2021; Available online 24 November 2021

Abstract: Mangosteen is one of the highest export commodities among other fruits in Indonesia. Mangosteen should be free from defects and damages to be accepted as export quality. In most of the mangosteen plantation in Indonesia, sorting of mangosteen is performed manually with human eye. This method is less effective and inaccurate because it depends on workers' conditions and perceptions. The use of image processing technology for quality inspection has been done for various fruits. However, mangosteen quality inspection in Indonesia has not used image processing technology. The objective of this research is to develop a method using support vector machine to classify defect and non-defect mangosteen surface. The method involved mangosteen surface image capture, pre-processing, defect features extraction using Curvelet transformation and classification using support vector machine. We collected 120 input images using camera from defect and non-defect mangosteens. The proposed method resulted 96.67% of accuracy. It can be concluded that the proposed method has successful classify mangosteen surface.

Keywords: Mangosteen surface defect, features extraction, discrete curvelet transform, support vector machine

1. Introduction

Mangosteen grows in Southeast Asia and tropical countries. The contribution of mangosteen fruit exports is very large in increasing the country's and farmer's income. The economic value of mangosteen fruit is relatively higher when compared with the price of other fruits. Currently, not all demand for mangosteen fruit exports can be fulfilled, because the quality of mangosteen does not meet the requirements. From the total production, only 5% to 20% meet export standards [1]. Currently, exporters and farmers still use the traditional way to sort the mangosteen fruit which is manual observation using human eye. This traditional method is less effective because it is highly dependent on workers conditions, different perceptions among workers, time consuming, and costly.

Many researchers have used image processing technology to improve effectivity of fruit processing work. Some image processing technologies such as Wavelet transform and Curvelet transform have been proposed for fruits quality analysis and classification. These include predicting vitamin C content in Navel Orange using Wavelet [2], detecting fruit skin damage [3] and skin defect identification for fruit grading [4] using Curvelet transform. Image processing technology for detection or classification requires cutting edge algorithm and also learning capability. Support Vector Machine (SVM) is a machine learning technology that has high precision in the classification task. SVM performed 96% accuracy when it was implemented to identify whether the skin of citrus is a defect or non-defect [4]. Other researchers that use SVM in their methods are Pujari et al. [5] to classify plant diseases, and Zheng and Lu [6] to detect browning degree on a mango.

The use of image processing or machine learning technology is also used for mangosteen related research. The SVM was used to estimate mangosteen maturity stage [7]. While other research used Linear Discriminant Analysis (LDA) to classify mangosteen based on skin surface defect [8]. Those studies focused on finding which statistical features extraction methods that have been proposed is the best to detect the defect. This research proposes a curvelet transform method for feature extraction prior to classification process. Curvelet transform will be able to extract unique features and thus will improve the classification analysis capability [9]. In this paper, textural quantification based on curvelet transform such as mean, standard deviation energy and entropy [4] were used to perform feature extraction and characterize fruits surface texture which is then used in the classification task to discriminate between defect and non-defect surface of mangosteen. For a better understanding, the rest of this paper is organized as follows. In section 2, we described the Methodology that we used in the research. In section 3, we presented our research results and discussions. Finally, the conclusion is stated in section 4.

2. Methodology

This detection of mangosteen surface defect involves procedures summarized in Fig. 1. The first procedure involves capturing of the images followed by image pre-processing. This involves image resize and change of image colour. The third procedure is image transformation and feature extraction using statistical properties. Finally, SVM is applied to classify the images as “defect” or “non-defect”.

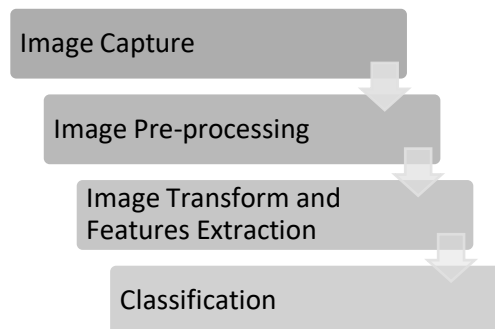


Fig. 1 - The classification process

2.1 Image Acquisition

Mangosteen samples of various quality were collected from an orchard and transported to the laboratory. The camera was set up in a fixed position, as shown in Fig. 2, to obtain an image of mangosteen surface. The mangosteen was put in front of a white background to simplify the object segmentation task. Uniform light was also provided around the object.

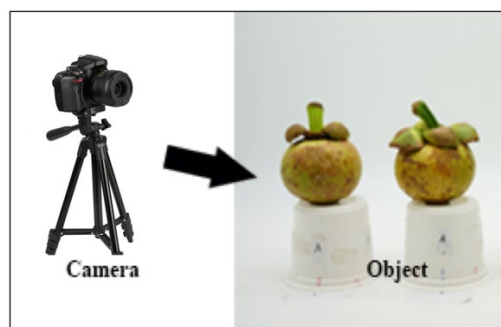
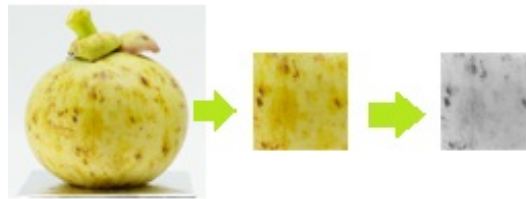


Fig. 2 - The setup of image acquisition

2.2 Image Pre-processing

Pre-processing stage aimed to prepare the image before it was processed by curvelet transformation. The original image with 4000x6000 dimensions was cropped into a 512x512 dimension. Then the image was converted into grayscale image mode. The purpose of the previous processes was to simplify and to reduce processing time. The process of cropping and grey scaling mangosteen surface defect and non-defect images is shown in Fig. 3.



2.3 Curvelet Transform

Curvelet transform has two forms namely Continuous and Discrete Curvelet Transform [4]. Continuous Curvelet Transform divides the image into frequency domain along the annular radial angle using window. The second form, Discrete Curvelet Transform, divides the image using same-center square [4]. Thus, the second one is better for image processing [10].

Curvelet transform provides extensive information representing edges of an object. For that reason, curvelet transform was then modified as Fast Discrete Curvelet Transform (FDCT) [4]. FDCT starts with interpolation step. In this step, the image was sampled into 2D Fourier frequency plane divided into wedges (refer the shaded region in Fig.4). The partitioning of the Fourier plane into radial (concentric circles) and angular divisions gives wedges their parabolic form. The decomposition of an image into several scales (used for band passing the image at various scales) and the angular divisions that partition the band passed image into different angles or orientations are handled by the concentric circles. To deal with a specific wedge, it is necessary to describe it at scale j and angle θ . To speed up this process, interpolation applied fast approximate transform using 1-dimensional unequally spaced Fast Fourier transform (USFFT). This step resulted in multiscale curvelet objects for every image that was used in the classification process. The next step of FDCT was Riesz Representers and the Dual Grid. This is the step that makes the curvelet object well presented in tile as shown in Fig.5. [4].

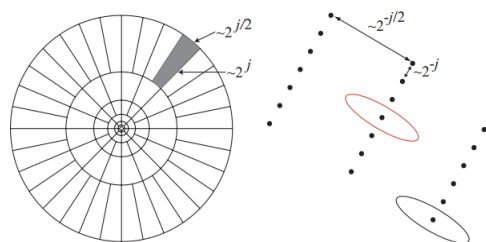
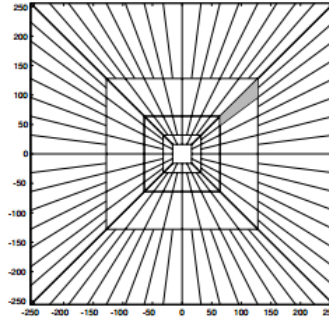


Fig. 4 - Curvelet transform in frequency domain (left) and in the spatial domain (right) [4]

In the first algorithm (FDCT via USFFT), the Curvelet coefficients were found by the irregular sampling of the Fourier coefficients of an image. In this research, the grayscale images were converted to Curvelet objects using FDCT method. After performing curvelet transform for each grayscale mangosteen image, the result is a curvelet image similar to Fig. 5. It is the squared curvelet shape from the radial shape in Fig. 4 using wave atoms algorithm [16]. Defect and non-defect mangosteens in curvelet form have different views. As shown in Fig. 9, defect type would make the curvelet image has many small white spots scattered around the black tile. Meanwhile the non-defect image in curvelet form has fewer small white spots as shown in Fig. 10.



2.4 Statistical Properties Extraction

Feature extraction is a task to extract quantitative unique characteristics of an object which will be used for further process. Studies done in this area are [11], [12], and [13]. In this research, we used four (4) statistical Curvelet-based texture descriptors namely mean, standard deviation, energy, and entropy to investigate the discriminating capability for fruit quality grading. Each of these features was computed from the Curvelet coefficient matrix [4]. The computed statistical properties are mean μ computed using equation (1), standard deviation σ was computed using equation (2) where M and N represents a greyscale image dimensions, energy Erg was calculated using equation (3), and entropy Ent was computed using equation (4) where p is contained the normalized histogram and R is the length of the histogram of an image. Fig. 6 indicates feature extraction plot. The blue x signs in Fig. 6 are the values generated from non-defect mangosteen surface and the red o sign are the values generated from defect mangosteen surface. Every extraction method that is shown in Fig. 6 are unique and if extraction methods have similar result pattern it will be less useful to be used in SVM [8]

$$\mu = \frac{1}{M \cdot N} \sum_{i=1}^M \sum_{j=1}^N X_{i,j} \quad (1)$$

$$\sigma = \sqrt{\frac{1}{M \cdot N} \sum_{i=1}^M \sum_{j=1}^N |X_{i,j} - \mu|} \quad (2)$$

$$Erg = \sum_{i=1}^M \sum_{j=1}^N |X_{i,j}| \quad (3)$$

$$Ent = - \sum_{r=1}^R p \cdot \log_2 p \quad (4)$$

2.5 Support Vector Machine

Classification method that has been used in this research is the SVM. Support Vector Machine is a method used in statistics, pattern recognition and machine learning to find a hyperplane that serves as a separator of two classes in the input space. Two parallel hyperplanes are constructed on each side of the hyperplane that separates the data [14]. Classification is divided into two classes, namely “defect” and “non-defect”.

3. Result and Discussions

This SVM classification method used four inputs, namely the values of feature that have been extracted. These values are the mean, standard deviation, energy, and entropy. Then training phase was performed to differentiate defect and non-defect by classifying hyperplane line. This training produced a SVM classifier model. Fig. 6 shows plots of four features extracted from the Curvelet coefficient. Testing stage used this SVM classifier model to classify the mangosteen surface. This classification used 4-Fold cross validation to strengthen the accuracy of the results of the research, as shown in the Fig.7. In Fig. 6, non-defect images that are signed by blue x sign tend to have higher value in mean and energy than defect images that are signed by red o sign. Moreover, its tend to have lower value in standar deviation and entropy than the other label. However, many defect or non-defect images have value that it should be for the opposite of its for every featured extraction methods. Therefore SVM classifier played the important role for the classification step.

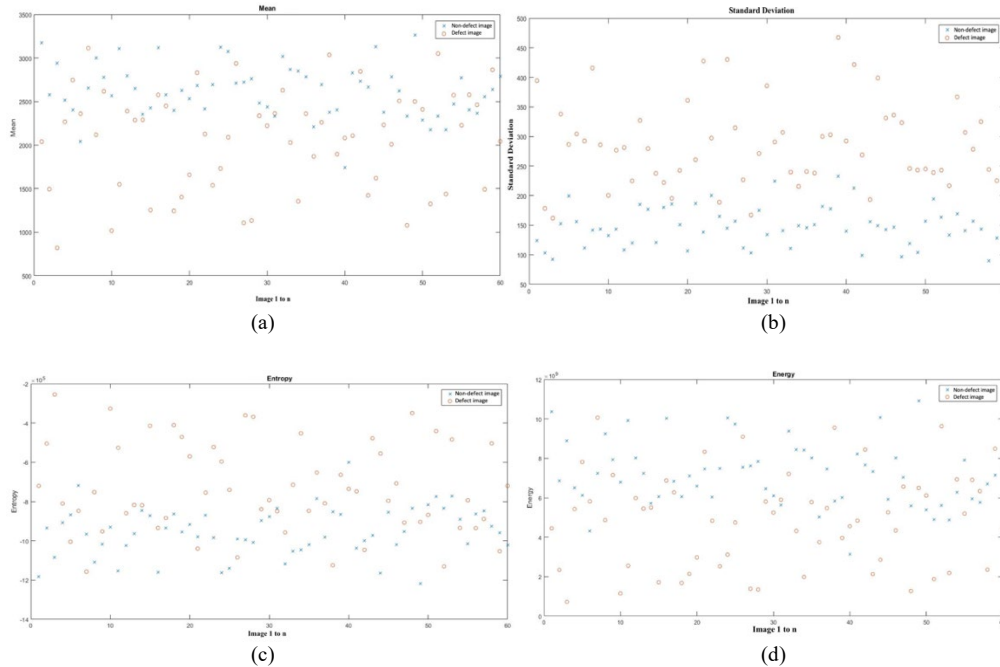


Fig. 6 - (a) Mean plot; (b) standard deviation plot; (c) entropy plot; (d) energy plot

A total of 120 test images were divided into four-fold validation groups where each group contains 30 test images with 15 defect images and 15 non-defect images. Because this research uses 4 featured extraction methods, then a cell contains 120 features values. Testing data in each fold use 1 cell and Training data in each fold use 3 cells. Thus, for 1 classification fold, training data use 90 images and testing data use 30 images. These images were then tested using support vector machine. The sample of mangosteen surface defect image and non-defect image is shown in Fig. 8. Defect mangosteens have big defect spot in its surface. A mangosteen with non-defect label might have small defect in the surface as shown in Fig. 8 as long as it passed the export standard test.



Fig. 7 - K-fold cross validation

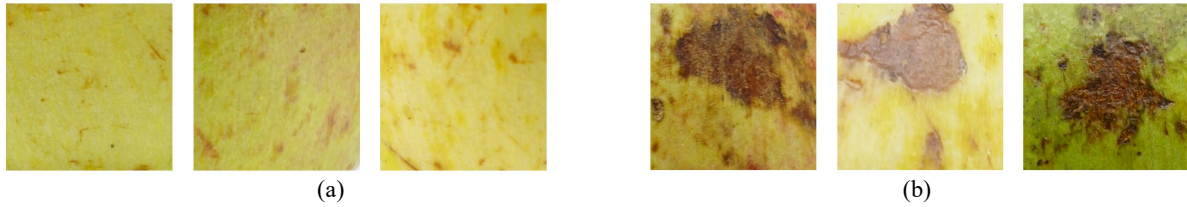


Fig. 8 - (a) Defect surface of mangosteens; (b) non-defect surface of mangosteens

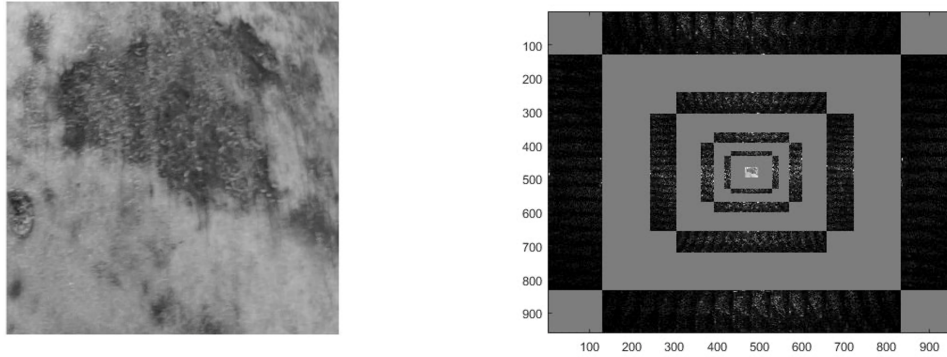


Fig. 9 - Greyscaled defect surface of mangosteen (left) and its curvelet image (right)

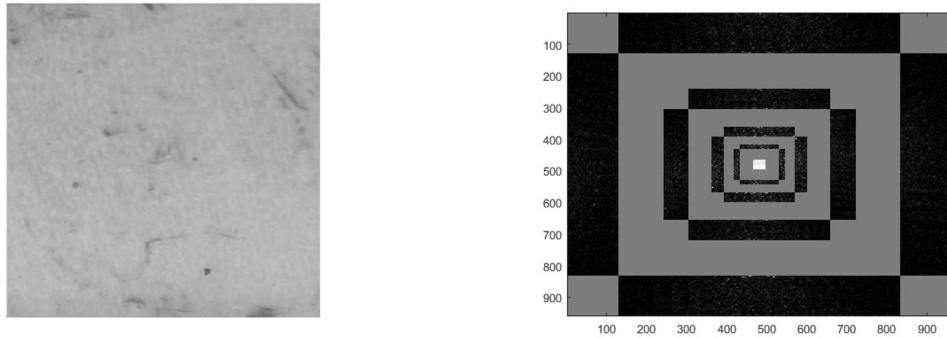


Fig. 10 - Greyscaled non-defect surface of mangosteen (left) and its curvelet image (right)

The detection result of mangosteen surface defect classification was presented in Table 1. The classification results for the fused features of Mean-Std-Energy-Entropy of 120 testing images divided into 4-fold validation groups. According to the result shown in Table 1, classification task performed accuracy of 96.67%, 100.00%, 93.00% and 96.00% for Fold-1, Fold-2, Fold-3 and Fold-4 respectively. The accuracy is calculated by how many SVM model guessed for every testing data in percent. The SVM method accurately classified between defect and non-defect image of mangosteen with average of 96.67%. It showed an improvement on classification accuracy, compare to the previous methods, i.e., 88.00% and 91.70% for statistical features method and curvelet method, respectively [8][9]

Table 1 - Accuracy result

Group of classification	Images		Error	Accuracy
	Defect	Non-Defect		
<i>Fold-1</i>	15	15	1	96.67%
<i>Fold-2</i>	15	15	0	100.00%
<i>Fold-3</i>	15	15	2	93.33%
<i>Fold-4</i>	15	15	1	96.67%

4. Conclusions

Based on this study, it can be concluded that the use of Curvelet transforms and feature extraction to perform detection of mangosteen surface defect based on image processing using SVM has successfully extracted features to detect mangosteen surface defect image. A mean value, standard deviation (STD) value, energy value and entropy value can be used properly to create a mangosteen surface defect detection. The system developed in this study can detect mangosteen surface defect with 96.67% accuracy

Acknowledgement

Authors would like to acknowledge Directorate of Research and Community Services, Directorate General of Research and Development, Ministry of Research, Technology and Higher Education, Republic of Indonesia for the research grant (PTUPT), Universitas Muhammadiyah Yogyakarta and Universiti Utara Malaysia.

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