Harumanis Mango Leaves Image Segmentation based on Wavelet Transformation with Phansalkar and Sauvola Thresholding

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Abstract. Harumanis mango is one of the economic sources of the Perlis state. It has a sweeter taste compared to other mangoes. However, the Harumanis mango tree required specific weather, soil nutrient contents and pH level. This makes the farmer does not know the health condition of their Harumanis mango tree. Therefore, this project aims to provide the best method of leaves detection to the farmer. The leaves image samples are collecting from the orchard and undergo pre-processing. Then the input image was converted into grayscale with principal component analysis (PCA). Wavelet transformation was implemented to increase the discriminability of the segmentation technique for separating the leaf and background. The leaf segmentation is done by using Phansalkar and Sauvola thresholding techniques. After that, fill hole and area opening techniques are implementing to reduce noise in the image. These two thresholding techniques are comparing and discuss with their segmentation performance. Overall, Phansalkar thresholding has produced better performance in segmenting healthy and unhealthy Harumanis mango leaves with sensitivity, specificity and accuracy of 92.05%, 81.37% and 83.51%, respectively.

1. Introduction
Perlis has an iconic agro-tourism product that has been brought a lot of profit which is Harumanis Mango. Harumanis mango is one of the economic sources of the local resident in Perlis. However, there are many challenges that have been faced by the farmer during the growth of the Harumanis mango tree. The first challenge is the detection of the leaves of the Harumanis mango tree. The leaf detection by human eye was difficult to classify the healthy and unhealthy leaves. Apart from that, some of the leaf diseases have very small symptoms that are very difficult to be seen by human eye. These challenges can be solved by using digital image processing techniques.

Digital image processing is one of the modern technologies of the modern computer to process digital images. This technology is a method that converts the image into digital form and achieves some action to obtain desired output or specific useful information. The image processing system treats the digital images in a two-dimensional signal or a form of matrix. Digital image processing has been classified into several types such as edge detection and region-based segmentation.

Region-based segmentation is a segmentation technique to determine the specific region directly. This technique helps the computer to recognize the object from the image. For edge detection, it is a method for computers to detect the edge of the object in the image. Region-based segmentation divides into two types which are clustering and thresholding [1].
In this paper, thresholding segmentation method will be used to extract the leaf from the digital image. Thresholding is a method that converts the digital image to binary image. It extracts the object from the background by using threshold value. The input image is required to convert to grayscale image before implementing the thresholding method. The grayscale value of the region that is lower than the threshold value will be extract as the object while the region will be recognized as background if the grayscale value is more than the threshold value. The object will be represented in white colour (bit ‘1’) while the background will be represented in black colour (bit ‘0’) [2]. The output image is in binary form and several filters are uses to reduce the noise of the output image. Therefore, the useful information in the output image can be seen more clearly.

There are various researches regarding leaves detection by using digital image processing technique has been done by previous researchers. Numerous methods have been discussed in the literature review, which accurately detects infected parts of the leaf by using image processing techniques. Rewar et al. [3] implemented in the research was the edge detection method. Several edge detections have been implemented for detection of leaf diseases such as Prewitt edge detection, Robert edge detection and Canny edge detection. Those methods were tested by varied the window size, disk size, Weiner filter and Histogram and Adaptive Histogram Equalizer. The Weiner filter was used to remove noise in pre-processing phase. In this research, window size and disk size were changed to obtain the best binary image. Canny edge detection gave the best accuracy of 80 – 99% in detecting the infected part of the leaf. Robert edge detection and Prewitt edge detection gave 70 – 80% and 60 – 70% respectively.

Vyshnavi et al. [4] have introduced a framework to identify and classify plant disease. In the first state, types of disease are studied and identified by human eye. There were three types of plant diseases identified were a viral disease, fungal disease and bacterial disease. In the pre-processing step, the filter was implemented for reducing the noise of the image. Next, color space transformation was carried out to obtained high similarity between original images but with different color spaces. This helped to improve the accuracy of the disease detection and classification process. The color space was changed from RGB to L*a*b. In the image segmentation process, the proposed technique used was Hierarchical clustering. The colour, texture and shape were the features for the classification process. A Support vector machine (SVM) technique was used to classify the disease of leaves based on the features.

Apart from that, the detection of the disease on the mango leaf has been studied. The image segmentation used in this study is k-means clustering. The researcher has developed and neural network that can detect the healthiness of the leaf. This study utilized k-means clustering to extract the feature from each layer of the image. The features were used to train the neural network [5].

Furthermore, a researcher proposed a method for unhealthy region detection and classification of mango tree leaves. Image of five classes of the disease leaves with a total number of 286 samples was captured. All the images were undergone contrast enhancement and color space transformation. The image was transformed from RGB color space to HSI color space. The k-means clustering segmentation was implemented in color image segmentation process. Ten features were used to classify unhealthy leaves were contrast, homogeneity, entropy, energy, correlation, mean, standard deviation, moment, kurtosis and skewness. The support vector machine was trained to classify the unhealthy leaves of mango trees [6].

2. Methodology

In this project, leaves detection was done by using digital image processing techniques and the processes are presented in Figure 1. First, the image acquisition was done to obtain the leaves sample of Harumanis mango tree in orchard. Then the input image was undergone pre-processing such as resizing, grayscale conversion, morphological closing and others step before going to the segmentation process. Then, the thresholding segmentation method was implemented to extract the object from the background. Fill hole and area opening techniques were implemented in order to reduce the noise of the output image.
2.1. Image Acquisition

The leaf image of Harumanis mango tree was captured by using the camera of the mobile phone which is Huawei nova 5t in orchard as shown in Figure 2. The orchard is located at Kampung Guar Nangka and the coordinate is 6.4758320, 100.2849120. A cardboard was placed behind the leaf to obtain a clear shape of chosen leaf and without others leaf in the image. The cardboard was used to increase the contrast between the background and the leaf. The dataset contains 100 leaf images. The leaf image was captured with the pixels of 2992 x 2992 which was clear enough for information extraction.
2.2. Pre-processing

The input image was undergone several steps in order to proceed segmentation process. The input image was first resized into a suitable size which is 500 pixels x 500 pixels. In these sizes, the resolution of the leaf image was still suitable for the image segmentation process. The input image was converted into a grayscale image with Principal component analysis (PCA). Then the morphological closing was applied to the grayscale image. Then wavelet transformation was implemented to filter the signal.

2.2.1. Principal Component Analysis (PCA)

The principal component analysis is a method to reduce the dimensionality of the image. It helps to reduce the complexity of RGB image for image segmentation but retain most of the information that exists in the image. Firstly, PCA standardizes all the variable which contains information of three-layer in RGB image. Then the PCA performs the covariance matrix computation in order to reduce redundant information which carries by each layer. The covariance matrix can be calculated by using equation below [7].

\[
\text{COV}(X, Y) = \frac{\sum_{i=1}^{n} (X_i - \bar{X})(Y_i - \bar{Y})}{n - 1}
\]  

The eigenvectors and eigenvalues were found from the covariance matrix. The eigenvector represents the principal component which is the new variable and the eigenvalues represent the numbers of information in the eigenvector. Basically, the first principal component will have the most information squeezed in it and follow by the second principal component. In simple words, PCA as depicted in Figure 3 will squeeze all information and put it into the first principles component until reaching the maximum information that the first principles component can carry. Then the maximum remaining information will be put into the second principal component. By putting information in this way, the variable and the size of dimensional can be reduced.

![Figure 3. Information carry by principal component.](image)

PCA standardizes the information in three-layer of RGB image and remains the information that is useful and not duplicate. PCA will form a new variables set which to contain all the squeezed information. The new variable is the intensity of the grayscale image. Therefore, PCA reduces the dimensionality of the image and increases the processing speed in the enhancement of the grayscale image.

2.2.2. Wavelet Transformation

Wavelet transformation is the technique of the signal filter. It helped to search for the best mapping of signal from actual space to wavelet function space. This technique will remain the best resolution and characteristic of the original image.
2.3. Image Segmentation

In image segmentation, thresholding techniques were implemented to obtain the object from the background. Thresholding is one of the region-based segmentation which is converting image to binary image. Thresholding using the threshold value to differentiate the object and background. In the thresholding segmentation method, there were two techniques chosen in this project which were the Phansalkar Thresholding method and the Sauvola Thresholding method. Both methods were implemented to compare the accuracy of the result. The global threshold method does not use in this project because the difference between the background and the object is not distinct. Therefore, local thresholding techniques were chosen [8].

2.3.1. Sauvola Thresholding Technique

Sauvola thresholding technique is a technique proposed by Sauvola et al. in 1997 [9]. It is a method inherits from Niblack method. This method can solve the black noise problem that is the limitation of the Niblack method. It can be said that is a better version of Niblack method. The thresholding equation of Sauvola method as show below:

\[ T = m \left[ 1 - k \left( 1 - \frac{\sigma}{R} \right) \right] \]  

Where
\[
\begin{align*}
    k &= \text{control factor}, \ [0.2 \ - 0.5] \\
    R &= \text{predetermine image gray level value} \\
    \sigma &= \text{standard deviation} \\
    m &= \text{mean}
\end{align*}
\]

The value of \( k \) recommend by Sauvola is 0.5 while the value of \( R \) is 128. The value of \( k \) is used to control the value of the threshold. From the equation shown above, the threshold value increases when the value of \( k \) decreases. The standard deviation and mean are the pixel intensities in the center of the image [9].

2.3.2. Phansalkar Thresholding Technique

The phansalkar method is a local thresholding method introduce by Phansalkar et al [10]. This method was modified from the Sauvola method. The modification made by Phansalkar has specified some parameters and make the threshold calculation more suitable in the image with low contract between object and background. The threshold equation is shown below:

\[ T = m \times \left[ 1 + pe^{-qm} + k \left( \frac{\sigma}{r} - 1 \right) \right] \]  

Where
\[
\begin{align*}
    m &= \text{mean} \\
    k &= \text{control factor} \\
    r &= \text{predetermine image gray level value} \\
    \sigma &= \text{standard deviation} \\
    p &= 2 \\
    q &= 10
\end{align*}
\]

Phansalkar recommends that \( k \) is 0.25, \( r \) is 0.5. The value of \( p \) and \( q \) are fixed which are 2 and 10 respectively. The value of \( k \) is used to control the thresholding value. In Phansalkar thresholding technique, there are two extra parameters which are \( p \) and \( q \). The parameter \( q \) is used to prevent the threshold value too low and cause the region which is darker but belongs to the object cannot be detected. Therefore, the value of \( q \) was set to a value to make the exponential term negligible. This will be helpful for the image with low contrast. The parameter \( p \) is used to control the magnitude of the exponential term. As the \( p \) increase, the threshold value will increase [10].
3. Result and Discussion

There are a total of 100 leaves images have been chosen for comparison of image segmentation based on Phansalkar and Sauvola thresholding techniques. By referring to Figure 4, the original images have undergone several image pre-processing techniques. The original images were first converted to a grayscale image based on normalization and enhancement by PCA technique. The grayscale image was converted with PCA to obtain the intensity value of the grayscale images. Figure 4(b) shows the intensity of the grayscale image has been increased by using the PCA technique. Then, morphological closing technique was applied to the image to smooth the edge of the object. It was essential to remove the dark spot and connect the edge of the object. The shape of the pixel in morphological closing used was disk shape with a radius of 1 pixel. The radius of 1 pixel was chosen because it gives the best overall performance for all the image samples. Wavelet transformation was implemented on the resultant morphological image and the result is shown in Figure 4(d). The implementation of wavelet transformation has increased the discriminability of the segmentation technique to distinguish the leaf and background. As the image has undergone wavelet transformation, the intensity of the region that belongs to the object becomes brighter.

![Original Image](image1.png)

(a) Original Image

![Grayscale image with PCA](image2.png)

(b) Grayscale image with PCA

![Morphological closing and image complement](image3.png)

(c) Morphological closing and image complement

![Wavelet transformation](image4.png)

(d) Wavelet transformation

**Figure 4.** Result of pre-processing techniques.

After the images have been enhanced, Phansalkar and Sauvola thresholding techniques have been applied and the results of both segmentation techniques are shown in Figure 5. In comparison to the output image after both image segmentation, the output image segment by using Sauvola thresholding has less noise in the object compare to the output image that used Phansalkar thresholding. However, the output image by using Sauvola thresholding has more noise than the output image that used Phansalkar thresholding.
The binary image was then undergone complement to reverse the colour of the region. Then area opening and fill hole techniques were implemented in the binary images that have been segmented. From Figures 6 and 7, the leaf has been extracted successfully from the image with low noise in object and background. The noise that existed in the binary image after segmentation has been reduced by using these two methods. The area opening was used to reduce the noise in the background while the fill hole was used to reduce the noise in the object region.

The performance of image segmentation was obtained by comparing the image which is manually segment. 100 of image samples was segment manually by using photoshop. After that, the image that segment manually was used to compare with the image that segment by using thresholding technique. The performance was calculated by using a concept of true positive (TP), true negative (TN), false
positive (FP) and false negative (FN). This is the four conditions that needed to calculate the accuracy, sensitivity and specificity of an image segmentation technique. The numbers of TP, TN, FP and FN pixels determine the sensitivity, specificity and accuracy of image segmentation and the procedure can be referred in [11].

Based on the results of average segmentation performances as presented in Table 1, Sauvola thresholding has higher sensitivity than the Phansalkar thresholding. Sauvola thresholding has achieved 94.29 % compared to Phansalkar thresholding which only has 92.05%. For the specificity and accuracy, the Phansalkar thresholding has obtained the result of 81.37% and 83.51% respectively. The Sauvola thresholding has lower specificity and accuracy than the Phansalkar thresholding. The specificity and accuracy of Sauvola thresholding were 75.36% and 79.74%.

Table 1. Average segmentation performances of leaves image segmentation.

| Methods                 | Dataset | Sensitivity (%) | Specificity (%) | Accuracy (%) |
|------------------------|---------|-----------------|-----------------|--------------|
| Sauvola thresholding   | 100     | 94.29           | 75.36           | 79.74        |
| Phansalkar Thresholding| 100     | 92.05           | 81.37           | 83.51        |

4. Conclusion
In this project, there are two thresholding techniques have been tested and the best technique has been identified which is Phansalkar thresholding. 100 images samples were used to detect by using these two methods. As a result, Phansalkar thresholding has better performance in detection on Harumanis mango leaves. Phansalkar thresholding will be recommended for leaves detection of Harumanis mango tree.

5. References
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