Harumanis Mango Leaves Image Segmentation on RGB and HSV Colour Spaces using Fast k-Means Clustering

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Abstract. Harumanis mango leaves are the signature fruit in Perlis due to its delicious taste and its sweet-smelling. A good quality Harumanis mango tree requires rich in nutrition (healthy), and the tree will grow lots of fruits compared to the trees which are poor in nutrition (unhealthy). The health condition of a tree can be observed through the leaves in term of shape of leaves. For a healthy Harumanis tree, the leaves grow in scattering shapes. Meanwhile, an unhealthy Harumanis tree grows in gathered shapes. Therefore, this research is focusing on Harumanis mango leaves image segmentation by comparing between RGB and HSV colour spaces in order to obtain the best segmentation performance. 100 of Harumanis mango tree leaves images are used in this research. These images have undergone image pre-processing such as modified linear contrast stretching and colour components extraction based on RGB and HSV colour spaces. Then, the colour component images have been segmented by using fast k-means clustering in order to obtain the leaves segmented images. Finally, quantitative analyses have been performed to measure the segmentation performance based on sensitivity, specificity and accuracy. Overall, the results show that S component of HSV colour space archives the highest accuracy with 85.81%.

1. Introduction
Harumanis mango leaves are one of the signatures in Perlis due to its delicious taste and sweet smelling. However, Harumanis can only flowering once per year, and the difficulties to take care during flowering phase are very high. It requires very hot environment to ensure the fruits quality during day time, and cold windy environment during night [1]. Since the weather unable controlled by human, the quality control of fruits can be replaced by monitoring system. Leaves disease detection system is one of the methods to monitor the health condition of plants. Meanwhile, the old method of manually monitoring system will slowly replace by advance technology such as digital image processing. This is because digital image processing able to provide more standardized system to monitor the health condition of plants.

Before Harumanis flowering stage, the tree branches can be easily predicted by observing the shape of the leaves. This is because the nutrient content for each branch was separated, which mean the nutrient content between each branch will be different even though the branches was grew from the same Harumanis tree. There are two types of leaves growth for Harumanis tree: oval/circle shape and spider web shape. For oval/circle leaves shape, it was considered as unhealthy branch. It grew gathered, and the branches had very low chance to grow up a fruit-bearing flower. For the spider web shape leaves, it can be considered as healthy branch. As a result, the success chance to grow up a fruit-bearing flower is very high.
An image contains various types of information [2]. This information can be extracted with fundamental contactless by the help of digital image processing. Image processing is the core element in every real time response technologies [3]. This is because image processing able to process every information that visualize by human, from unidimensional to multidimensional aspect. Hence, image processing very suitable in extract features of images, such as leave shape and leave disease. In this research, the colour image is extracted into two different colour models, which are RGB (Red, Green, Blue) and HSV (Hue, Saturation, Value) colour model. The RGB colour model is chosen because RGB is the most general model that used in process colour image, while HSV colour model is chosen due to this colour model is too familiar to the colour that can be sensed by human eye.

Table 1 shows the review of various image segmentation techniques used for the leaves disease identification.

| Authors           | Plant Species | Diseases                      | Method                  | No. of Image in Dataset | Accuracy  |
|-------------------|---------------|-------------------------------|-------------------------|-------------------------|-----------|
| D.G. Sena Jr. et al. [4] | Maize leaf    | Fall armyworm                  | Thresholding            | 720                     | 94.72%    |
| Kurniawati et al. [5]  | Paddy crop   | Blast, brown narrow & brown spot | Otsu method             | 94                      | 94.7%     |
| D. Zhihua et al. [6]   | Cotton leaf   | Mite diseases                  | Thresholding            | 30                      | 94.79%    |
| Z. Husin et al. [7]    | Chili leaf    | Fungal & bacterial             | Clustering              | 107                     | N/A       |
| S. Shrivastva et al. [8]| Soybean leaf | Frog eye, rust bacterial       | Bi-level Thresholding   | 1000                    | N/A       |
| A. K. Dey et al. [9]  | Betel vine    | Rotten                        | Thresholding            | 12                      | N/A       |
| P. Revathi et al. [10]| Cotton leaf   | Leaf spots                     | Homogeneous Pixel Counting Algorithm for Cotton Diseases Detection (HPCCSS) | N/A | 98.1% |
| K. Padmavathi et al. [11]| Unknown leaf | Unknown disease                | Statistical region Merging (SRM), Clustering | 1 | RGB better than grayscale |

In this research, FKM (fast k-means) clustering method is used for image segmentation. FKM clustering is able to process a huge dataset by splitting the algorithm into two stages. For the first stage, it is fast, but only process part of the dataset and finds the most suitable center point. After that, for second stage, it is slow, but it can directly use the center point that is found from the first stage. In this case, FKM can save a lot of time in finding center point compare to k-means.

2. Methodology
In this study, the proposed work includes four main steps. These consisted image acquisition, resize image, image enhancement, colour components extraction and image segmentation.
2.1. Image Acquisition

Data acquisition is a very important procedure for image processing. A good quality image for image processing contains object element, and unified background. This is because the unwanted elements such as noise and background element can reduce the accuracy and efficiency during image processing. The images that captured is around 100 (50 healthy leaves image and 50 unhealthy leaves images). The images are captured by using Huawei Nova 5t smartphone, while the image save as .jpg format with 2992*2992 pixels. Meanwhile, the aspect ratio of camera is set as 1:1, which the images will be square in shape. The reason of using image ratio of 1:1 is the leaves usually in circle shape. Rectangle ratio might increase the amount of noise since the leaves can be captured by square ratio. Furthermore, the focal length of each image must be standardised for increase the accuracy during image segmentation performance. The focal length of each image is around two steps away from the leaves.

2.2. Image Resizing

The smaller the pixels dimension in the image, the shorter time taken in image processing. This is because image processing will process and extract the information from each pixel in an image. Thus, the resizing technique can improve the overall image processing time. However, the quality of image will be reduced as the pixels of image are reduced. Hence, to maintain the overall accuracy, the resized image must not be blur during visualize by user. The original image size is 2992*2992 pixels, while the image will be resized to 500*500 pixels.

2.3. Image Enhancement by Using Modified Linear Contrast Stretching (MLCS) Technique

The images are usually captured at day time. Thus, the shadow element might be included inside the image. The shadow can disturb and reduce the accuracy of image processing by dim the affected region. Thus, Modified Linear Contrast Stretching (MLCS) [12] is applied to improve the quality of image. MLCS is a technique that able to determine a new minimum and maximum value for the R, G and B colour components that is beyond the original value in an image. Next, MLCS process as using the specific minimum and maximum values, which is lie in a certain percentage of pixels in the image. There are few calculation processes to calculate the new minimum and maximum values for each R, G and B colour component. In this research, the new minimum value and the new maximum value is set as ‘1’. Below are the steps to calculate new minimum and maximum values for MLCS enhancement [12]:

1. Choose any minimum percentage, \( \text{min}_p \) and maximum percentage \( \text{max}_p \)
2. Set the initial value of specified minimum percentage, \( T_{\text{min}} \) and the specified maximum percentage, \( T_{\text{max}} \) are equal to 0. Then, set the value of current pixel level, \( k \) as 0.
3. Ready histogram for the R colour component first.
4. To obtain the number of pixels, \( T_{\text{pix}}[k] \):
   \[
   \text{If } T_{\text{pix}}[k] \geq 1, \quad T_{\text{min}} = T_{\text{min}} + T_{\text{pix}}[k] \tag{1}
   \]
   \[
   \text{else, } \quad T_{\text{pix}}[k] = k \tag{2}
   \]
5. To obtain new maximum value \( N_{\text{min}} \):
   \[
   \text{If } \frac{T_{\text{min}}}{\text{Total number of pixels in the image}} \times 100 \geq \text{min}_p,
   \]
   \[
   N_{\text{min}} = \frac{T_{\text{min}}}{\text{Total number of pixels in the image}} \times 100
   \]
   \[
   k = N_{\text{min}} \tag{3}
   \]
   \[
   \text{else, } \quad k = k + 1 \tag{4}
   \]
6. If the condition enters used equation of (4) instead of (3), repeat the steps 4 to 5 for the next pixel levels until the \( N_{\text{min}} \) condition meets to use equation (3).
7. After that, set \( k \) as 255 to obtain \( T_{\text{pix}}[k] \) at \( k \).
8. If $T_{pix}[k] \geq 1$, 
   \[ T_{max} = T_{max} + T_{pix}[k] \]  
(5)

9. To obtain new maximum value, $N_{max}$:
   \[ \frac{T_{max}}{\text{Total number of pixels in the image}} \times 100 \geq \text{max}_p, \]
   \[ N_{max} = \frac{T_{max}}{\text{Total number of pixels in the image}} \times 100 \]
   \[ k = N_{max} \]

   else,
   \[ k = k - 1 \]  
(7)

10. If the condition enters used equation of (7) instead of (6), repeat the steps 8 to 9 for the next pixel levels until the $N_{min}$ condition meets to use equation (6).

11. Repeat the same steps from 4 to 10 for G and B colour components until the value of $N_{min}$ and $N_{max}$ for G and B colour components are calculated.

12. Calculate the RGB colour model new minimum value, $N_{min_{RGB}}$ and new maximum value $N_{max_{RGB}}$ based on the value $N_{min}$ and $N_{max}$ of R, G and B colour components.

13. After obtain value $N_{min_{RGB}}$ and $N_{max_{RGB}}$, insert the values to the following equation:
   \[ out_{RGB}(x, y) = 255 \times \left( \frac{in_{RGB}(x, y) - N_{min_{RGB}}}{N_{max_{RGB}} - N_{min_{RGB}}} \right) \]  
(8)

where:
- $in_{RGB}$ = input RGB colour image
- $out_{RGB}$ = output RGB colour image
- $(x, y)$ = the location image pixels

2.4. Colour Component Extraction from RGB and HSV Colour Models

In this study, the colour of R, G, B, H, S and V will be extracted from the image for comparison of image segmentation performance in terms of sensitivity, specificity and accuracy.

Processing a grayscale image is a necessary instead of RGB colour image in image processing. A grayscale image only has one colour component (gray colour) and contains less information needed to process for each pixel, while colour image contains multiple colour component. In this research, the colour image is extracted into two different colour models, which are RGB and HSV colour model. The RGB colour model is chosen because RGB is the most general model that used in process colour image, while HSV colour model is chosen due to this colour model is too familiar to the colour that can be sensed by human eye.

A RGB image contains three layers of colour components. By using image processing technique, the digital image will be converted in matrix form, while the size of matrix is belonging to the size of pixels of the image. After the extraction of each individual colour components of RGB colour space is done, the image will be only displayed in grayscale form only.

To obtain HSV colour image, the equations of RGB to HSV conversion formula are need. First of all, the range of RGB colour model is $0 \sim 255$, while the range for HSV colour model is $0 \sim 100\%$.

The conversion of RGB to HSV can be done by using the following equations:

\[ H = \cos^{-1} \left( \frac{\sqrt{3}}{2} \left| \sqrt{(R-G)^2 + (R-B)^2} \right| \right) \]  
(9)

\[ S = 1 - \frac{3}{(R+G+B)} \min(R,G,B) \]  
(10)

\[ V = \frac{1}{3}(R, G, B) \]  
(11)

\[ S = 1 - \frac{3}{(R+G+B)} \min(R,G,B) \]  
(12)
2.5. Segmentation of Leaves Images by using Fast k-Means (FKM) Clustering

Since the leaves image is captured from the real world, the presented of inconsistency intensity might become the challenge in image segmentation. The object element with different intensities can caused lighter and dim region, which may reduce the accuracy in normal image segmentation. Meanwhile, the image can be easily segmented through fast k-means clustering algorithm. Below are the steps of FKM clustering [13]:

1. Since the image that selected to FKM is single colour components, so the histogram discrete function value will be \( h(r_{i1}, r_{i2}, r_{i3}, \ldots, r_{in}) \) until all the pixels in an image are processed.

2. The value of ‘\( k \)’ is set as 3, which the image will be segmented into 3 clusters only.

\[ c_k = (c_{k,1}, \ldots, c_{k,n}) \]  

   \( k = 1, 2, 3 \)

3. Calculate the Euclidean distance between each level value and cluster center \( c_k \). After that, each level value will be arranged and clustered to the closest cluster center point. The Euclidean distance can be calculated by the equation:

\[ d(r, c_k) = \sqrt{(r_1 - c_{k,1})^2 + \cdots + (r_n - c_{k,n})^2} \]

4. Mean value will be used to determine the new center point.

5. In this study, the value of ‘\( k \)’ is already set as 3, so the exact of 3 center point will be created. The steps will be repeated from step 1 to 3 to identify exact 3 center points.

2.6. Noise Removal by using Morphological Operation

Every object element in an image is difficult to be segmented with 100% segmentation accuracy. As a result, the segmented image will remain some black pixels. Those regions also called as ‘holes’. The holes can be defined as the black pixels are surrounded by white pixels. The sequence of morphological operations that used to remove the holes are closing operation, and follow by hole filling. The Structuring Element (SE) of closing operation is set as square shape with 9*9 pixels in size.

Closing morphological operation is an operation combine with dilation, and followed by erosion. Erosion able to makes a region inside the image smaller, while dilation able to enlarges the region. The shrink and enlarge size are based on the size of SE. The closing morphological operation mainly used to close up internal holes and remove small pixels of noise at the image boundaries. After that, hole filling has been used to fill the holes. This is because the image after closing morphological operation might remain few holes in the image. Thus, hole filling operation is performed to entirely remove all holes in the images.

3. Result

In this research, the six colour components Red (R), Green (G), Blue (B), Hue (H), Saturation (S) and Value (V) have been applied on 100 Harumanis leaves images which include of the healthy and unhealthy leaves. Then, the image segmentation performance based on sensitivity, specificity and accuracy is implemented to figure out the highest accuracy among all colour components.

3.1. Qualitative Analysis

The capture image is resized and maintain its majority characteristic as shown in Figure 1(a) and (b). The resized image then enhances by using MLCS technique as shown in Figure 1 (c). MLCS is an image contrast enhancement method to enhance the quality of image. The level of MLCS method can be easily adjusted by changing the minimum and maximum value. Noted that, exceedingly high value of the minimum and maximum value in MLCS formula might mischaracterise the original image characteristics. Thus, the minimum and maximum value is set as ‘1’ in this research. After that, various colour components will be extracted from the MLCS enhanced image such as R, G, B, H, S and V colour components as shown in Figure 2. Each colour component image will be segmented through fast k-means clustering method with \( k = 3 \). Lastly, after applying closing and hole filling morphological operation, the noise and holes have been removed as shown in Figure 3.

Figure 1(a) shows an unhealthy original leaf image, while Figure 1(b) shows the image that has been resized into 500*500 pixels. The resize image will be enhanced by using MLCS
technique as shown in Figure 1(c). After that, various colour components will be extracted from the MLCS image such as R, G, B, H, S and V colour components as shown in Figure 2. Each colour component image will be segmented through fast $k$-means clustering method with $k = 3$. Lastly, Figure 3 shows the result of segmented image after applying closing and hole filling morphological operation. The purpose of applying the morphological operation to the segmented image is to noise removal and holes filling.

Overall, by applying the MLCS technique as pre-processing step, the S and V colour components have produced the best segmentation performance as the segmented leaves pixels are clearly identified. Furthermore, the background is clear with no noise. However, H colour component segmentation performance has been affected by MLCS technique as the detected noise pixels region is more than another colour component. For R, G and B colour components, these colour components have the moderate segmentation performance compare to others. Most of the leaves pixels have been segmented, but there are some parts of leaves pixels are missing.

Figure 1. Result of MLCS technique for the unhealthy leaves image

Figure 2. Results of colour components extraction from RGB and HSV colour models
Based on the result of final segmented images as seen in Figure 3, the results show that B colour component gives the best overall segmentation performance as most of the leaves pixels are segmented and has the least noise in result. Meanwhile, S and V colour components segmentation performance become worse as the background and leaves pixels do not segmented properly. H colour components still has the low segmentation performance among all colour components due to unclear segmented result, hence more of background element has been detected as leaves in result. Meanwhile, R and G colour components still have the moderate segmentation performance.

3.2. Quantitative Analysis
In this research, 100 images enhanced MLCS technique (50 healthy and 50 unhealthy leaves images) has been processed in image segmentation. Meanwhile, the image segmentation performance requires another 100 manual segmented image (50 healthy and 50 unhealthy leaves images) to determine the sensitivity, specificity and accuracy. The manual segmented image is segmented manually by using Microsoft Office Power Point background removal function and the procedure can be referred in [14]. Table 2 shows the sensitivity, specificity and accuracy based on the 100 images.

Table 2. Result of image segmentation performance of 100 images for each colour component based on sensitivity, specificity and accuracy.

| Colour component | Sensitivity | Efficiency (%) | Specificity | Accuracy |
|------------------|-------------|----------------|-------------|----------|
| Red (R)          | 80.13       | 84.12          | 84.87       |
| Green (G)        | 72.11       | 77.98          | 77.55       |
| Blue (B)         | 75.00       | 87.31          | 85.18       |
| Hue (H)          | 24.78       | 61.76          | 43.26       |
| Saturation (S)   | 74.60       | **89.31**      | **85.81**   |
| Value (V)        | 72.68       | 86.35          | 81.43       |
Overall, the results show that B colour component has the highest accuracy among R, G and B colour components with 85.18%. Meanwhile, S colour component has the highest accuracy among H, S and V colour components with 85.81%. However, H colour component has achieved the lowest segmentation performances for the three performances measure with 24.78%, 67.76% and 43.26% for sensitivity, specificity and accuracy, respectively. This is due to hue component is not suitable to be applied on image with local contrast, hence resulting on this low result.

4. Conclusion
From the result shows in image segmentation performance, S colour component is the most suitable colour component to be used in this research. This is because S colour component has the highest specificity and accuracy with 89.31% and 85.81% respectively. Furthermore, the sensitivity is just 5.33% away from the highest value (Red colour component). However, H colour component is the worst choice to be used in this research due to its overall bad segmentation performance. H colour component has the lowest sensitivity, specificity and accuracy among all colour components with 24.78%, 61.76% and 43.26% respectively.

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