DETECTING BASAL STEM ROT (BSR) DISEASE AT OIL PALM TREE USING THERMAL IMAGING TECHNIQUE

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Abstract. *Basal stem rot (BSR), caused by Ganoderma boninense is known as the most damaging disease in oil palm plantations in Southeast Asia. Ganoderma could reduce the productivity of oil palm plantations and potentially reduce the market value of palm oil in Malaysia. Early disease management of Ganoderma could prevent production losses and reduce the cost of plantation management. This study focuses on identifying the thermal properties of healthy and BSR-infected tree using a thermal imaging technique. Thermal images of canopy section of oil palm trees from healthy and BSR-infected trees were captured. The images were processed to extract pixel value representing thermal properties of the trees. These values were statistically analysed. Selected principal component scores were used in classification k-nearest neighbour (kNN) and Support Vector Machine (SVM) multivariate classification algorithms. The algorithms were tested to classify the thermal images into healthy and BSR-infected group. The results demonstrated that when average pixel value of trees were used, the SVM-based model resulted in the highest average overall classification accuracy of 89.2% for training set and 84.4% for test set. This verifies the potential of thermal imaging for BSR detection in oil palm trees.*

Keywords. *machine learning, classification, support vector machine.*

Introduction

Oil palm is a major contributor to Malaysia's economy. In 2015, oil palm contributed 46.96% to the Gross Domestic Product (GDP) of agriculture sector. Malaysia is the world's second largest producer and exporter of the palm oil, producing 17.89 tons/ha of oil palm fresh fruit bunch for 5.81 million hectares in 2017 (Malaysian Palm Oil Board (MPOB), 2018).

Nonetheless, the oil palm tree in Malaysia is also vulnerable to disease. Amongst other diseases, a fungal disease known as Basal Stem Rot (BSR) causes great losses in palm oil production. BSR which was caused by *Ganoderma boninense* is also recognized as the most destructive disease of oil palm plantations in Southeast Asia, especially in Malaysia and North Sumatra (Flood et al., 2000). It attacks the basal stem of oil palm trees making them rot and slowly affecting the xylem of the trees, and disturbing water transportation to the upper part of oil palm, thus the leaves at the frond of oil palm turns yellow.

A variety of study and approach has been explored for the detection of BSR disease in oil palm trees. Detection of BSR infected trees by visually identify the *Ganoderma* specific foliar symptoms and fungus fruiting bodies (Basidiomycota mushroom) on the trunks is the most common method to detect BSR used in the plantation. It requires a labour force with knowledge to differentiate BSR infected trees with healthy trees as well as unhealthy trees of different disease. It is also time consuming as the oil palm trees are needed to be observed carefully and closely to check for the symptom. Other available techniques such as Ganoderma Selective Medium (GSM) (Ariffin *et al*., 1993); Polyclonal Antibodies Enzyme-Linked Immunosorbent Assay (PAbs- ELISA) (Idris and Rafidah, 2008); Multiplex PCR-DNA Kit (Idris *et al*., 2010); and GanoSken Tomography (Idris *et al*., 2010) require laboratory analysis which is time consuming. GSM test used to test the trunk sample of oil palm trees also requires a bigger labour force as the sample collections must be taken from the trunk of the oil palm trees by drilling. It is also time consuming as the test needs to be done in a laboratory involving biochemical analysis. Likewise, PAbs-ELISA test is also constrained by its complex and costly procedures. It is shown that the capability of these techniques to detect BSR in oil palm tree is still limited in term of labour force, cost and time.

Thermal imaging has been used in many agricultural application, for example, to determine the plant physiological state and irrigation scheduling (Jones, 1999). It was also used to detect infestation by *Cryptolestes ferrugineus* inside wheat kernels (Manickavasagan *et al*., 2007). Citrus greening disease can be detected with thermal imaging technique by measuring the canopy temperature changes which indicate stress due to the disease (Sankaran *et al*., 2013). These reports had shown the potential use of thermal imaging to detect disease in plants. Up to recently, the study on detecting the infected BSR tree in palm oil plantation using thermal imaging is still a largely unexplored research area to date. This research will explore and provide a new benchmark in evaluating the potential of thermal imaging in detecting BSR at oil palm trees.

Methodology

Image acquisition

Image acquisition was done at the oil palm plantation in Perak, North of Malaysia. The palm trees were categorized into two groups; healthy trees and BSR-infected trees. 53 healthy trees and 53 BSR-infected trees were used, making up a total of 106 oil palm trees samples used in the study. A BSR-infected trees usually have a yellowed or dead leaves and the fruiting bodies will be visible on the trunk of the oil palm. Healthy and BSR-infected oil palm trees were shown in Figure 1.

(a)

(b)

(c)

(d)

Figure 1: (a) healthy oil palm tree (b) oil palm tree with mild BSR infection (c) oil palm tree with moderate BSR infection (d) oil palm tree with severe BSR infection

The experts from Malaysian Palm Oil Board (MPOB) has provided a guideline in order to identify BSR infection as shown in Table 1.

Table 1: Category and description of healthiness level of the oil palm trees

Healthiness level	Description
T1	Healthy palm, no foliage symptom (0%), no fruiting body
T2	Mild infection, no foliage symptom (0-25%), produce fruiting body
T3	Moderate infection, produce foliage symptom (25-50%), fruiting body
T4	Severe infection, produce foliage symptom (50-75%) and fruiting body

Thermal images of the oil palm trees were captured using FLIR E60 (FLIR Systems, Inc., Oregon, United States) thermal camera. The camera is able to measure a wide temperature range from -20°C to +650°C with its thermal sensitivity less than 0.05°C (Figure 2). The thermal camera was hand-held and the images were captured from the ground level. For each tree, three thermal images were captured randomly in three different angles focusing on the canopy section of the oil palm tree.

Figure 2: FLIR E60 thermal camera

Image processing

The thermal images captured (shown in Figure 3) were pre-processed using MATLAB software (Version R2016b, The MathWorks Inc., Massachusetts, United States) before being analysed to extract the information from the images. The pre-processing starts by cropping the images in order to remove the temperature scale on the right side of the image. This is to avoid confusion and error during analysis.

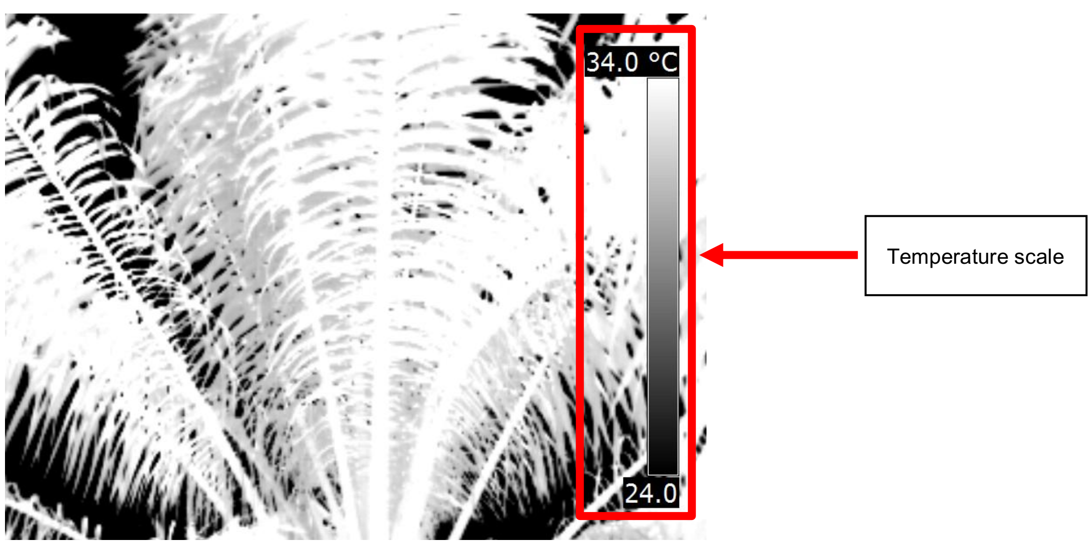

Figure 3: Thermal image of oil palm tree obtained from the thermal camera

The cropped images were then processed using an image segmentation technique to isolate pixels of the palm trees and background of the image using threshold value of Otsu's method. The segmented image was used as a mask to create a region of interest (ROI) of the image, focusing on the oil palm tree's canopy. Only pixels inside the ROI will be analysed. Steps involved in the image processing technique is shown in Figure 4.

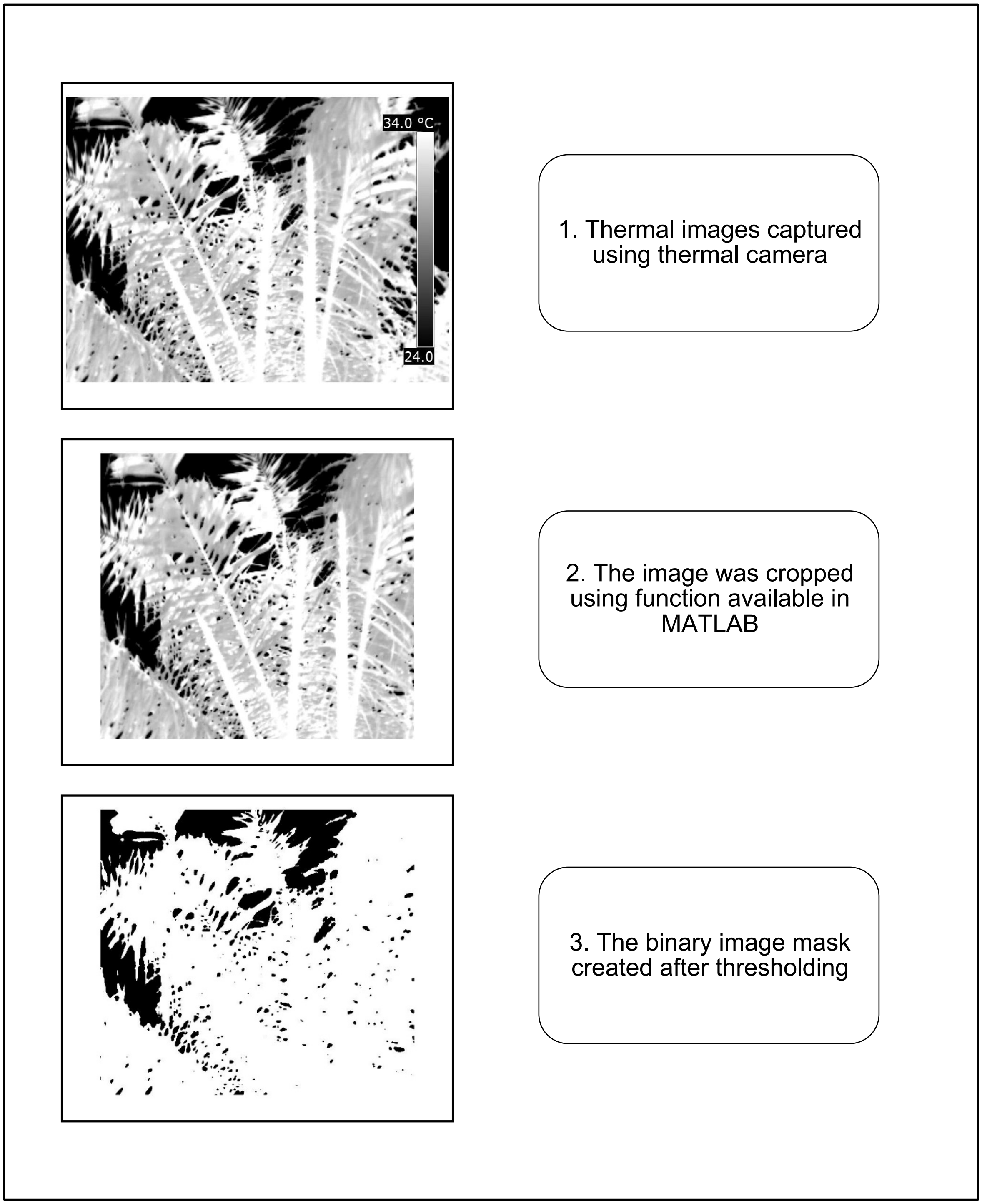

Figure 4: Image processing steps done using MATLAB software

Image analysis

The processed thermal images were analysed to obtain information from every pixels of the image. Information extracted was based on the intensity value of the pixel. The extraction was done using MATLAB. The information extracted from the ROI of the thermal images are:

- Maximum intensity value of pixel
- Minimum intensity value of pixel
- Mean intensity value of pixel
- Standard deviation of intensity value of pixel

For each sample of the tree, every information extracted from the three images taken at different angles were averaged into one value. These averaged values were then used in analysing the characteristics of healthy and BSR-infected oil palm trees. The information was then analysed using statistical analysis in order to determine the suitable information to be used in the classification.

To improve the classification, different indices values were formed based on the mean value of the pixel intensity. The indices were formed into three different indices, Y_H which was based on the average value of mean intensity of healthy tree, Y_{UH} from the average value of BSR-infected trees' mean intensity value, and Y_{ALL}, calculated from the average value of mean intensity value of all tree.

$$Y_H = \left(\bar{x_J} - \bar{x}_H\right)^2 \tag{1}$$

$$Y_{UH} = \left(\bar{x_J} - \bar{x}_{UH}\right)^2 \tag{2}$$

$$Y_{ALL} = \left(\bar{x_J} - \bar{x}_{ALL}\right)^2 \tag{3}$$

where $\bar{x}_j$ = mean intensity value of pixel of each tree, $\bar{x}_H$ = average of mean intensity value for all healthy tree, $\bar{x}_{UH}$ = average of mean intensity value for all BSR-infected tree, $\bar{x}_{ALL}$ = average of mean intensity value for all tree.

A Principal Component Analysis (PCA) were done on the data to extract features for further classification. Information extracted from the object in thermal images were used as the input of PCA along with the value obtained from the indices. The input was divided into two datasets; training dataset which makes up 70% of total 106 number of samples and test dataset, consists the remaining 30%. Features extracted from the PCA were then classified using Support Vector Machine (SVM) and k-Nearest Neighbour (kNN) function available in MATLAB.

Result and Discussion

A total of five features were extracted from PCA analysis, namely PC1, PC2, PC3, PC4 and PC5. By comparing each of the components, there were two features (PC1 and PC3) that were able to show a significant trendline for healthy and BSR-infected trees. It is shown that there were two distinguishable trendline for healthy and BSR-infected trees. The healthy trees have a smaller value for PC1 and PC3 making up a curve at the left side while the BSR-infected trees have a bigger value for PC1 and PC3 to make up a curve line at the right. Both the scores value from healthy and BSR-infected trees are not overlapping between each other.

To support the result, another PCA analysis was done on the test dataset to test the result from previous PCA analysis of the training set. PC1 and PC3 showed a similar trendline for the both healthy and BSR-infected trees as described from the result of training set. Scatter plot of these significant trendline for healthy and BSR-infected trees are shown in Figure 5 and 6.

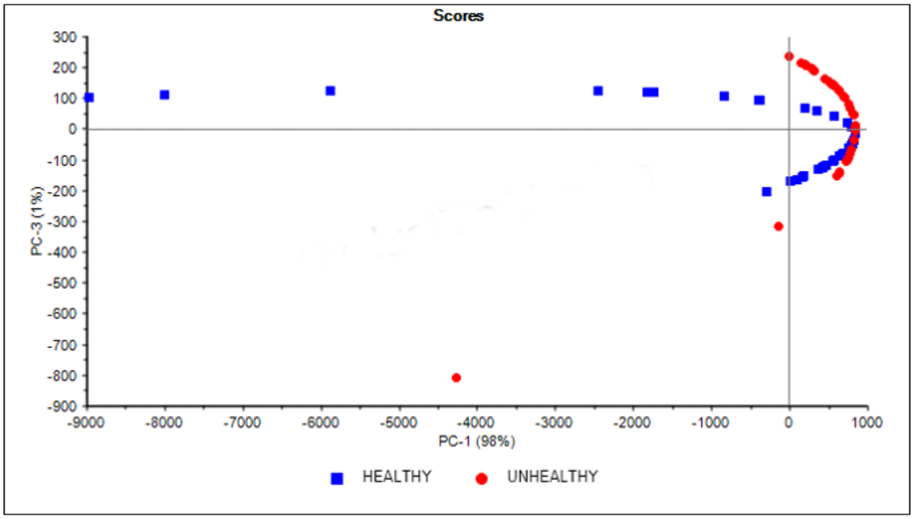

Figure 5: Scatter plot of feature PC1 and PC3 using training set for healthy and BSR-infected trees.

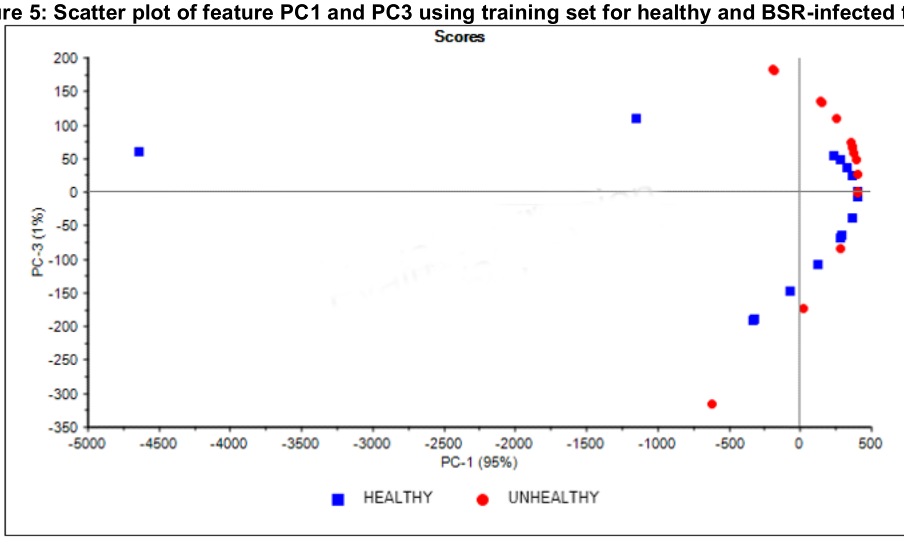

Figure 6: Scatter plot of feature PC1 and PC3 using test set for healthy and BSR-infected trees.

A kNN test was done using the extracted feature value obtained from PCA. Features (PC1 and PC3) from PCA were selected as the input value for kNN as they were the most significant features to differentiate healthy and BSR-infected trees. The k-nearest neighbour (kNN) was able to produce an accuracy of 83.8% for training set of data. Meanwhile, the accuracy value for the testing set is 71.9%. Another classification test was done using SVM approach of the same data. The results show that the SVM gave 89.2% accuracy for training and 84.4% during testing. Summary of the results from both classification techniques are tabulated in Table 2. Although kNN was able to show an accuracy as high as 83.8% for training set, SVM classification has a higher accuracy for both training and testing.

Table 2. Accuracy for different type of classification based on PC1 PC3 of the training and test set of each tree

Classification	Accuracy (%)	
	Training set	Testing set
kNN	83.8	71.9
SVM	89.2	84.4

Conclusion

This paper has analysed the potential use of thermal imaging in detecting BSR disease at oil palm tree. A healthy and BSR-infected trees were able to be differentiated based on the result of the analysis of the thermal images by extracting features using PCA method. Healthy and BSR-infected trees can be differentiated based on the trendline of the data. SVM results has a good and higher accuracy compared to kNN with 89.2% accuracy during training and 84.4% during testing. It can be concluded that healthy and BSR-infected trees can be differentiated using thermal images. In future work, the method can be expended to classify different severity levels of infection.

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