

The 2nd Universitas Lampung International Conference on Science, Technology, and Environment (ULICoSTE) 2021

Bandar Lampung, Indonesia • 27–28 August 2021

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HALAMAN PENGESAHAN

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Instansi : LPPM Universitas Lampung
Publikasi : ULICoSTE
ISBN :
Volume :
No :
Tanggal Publikasi : 31 Juli 2021
Penerbit : IoP Publishing
Website : <https://jurnal.um-palembang.ac.id/senergi>


Bandar Lampung, Juni 2023

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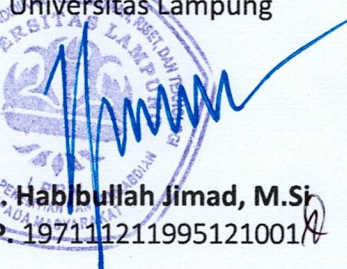
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DOKUMENTASI LEMBAGA PENELITIAN DAN PENGABDIAN KEPADA MASYARAKAT UNIVERSITAS LAMPUNG	
TGL	27/06/2023
NO. INVEN	105/P/B/H/FT/2023
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Disease detection in banana trees using an image processing-based thermal camera

To cite this article: N Anasta *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **739** 012088

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Disease detection in banana trees using an image processing-based thermal camera

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Abstract. Banana is a fruit plant that is widely produced in Indonesia. Unfortunately, this plant is very susceptible to diseases, which can reduce the crop's quality and quantity. This paper proposes disease detection in banana plants using a thermal camera. The detection is carried out using image processing techniques with multilevel thresholding methods. The image is captured using a thermal camera; then, the image is preprocessed to suit what is desired. After that, the image produced by the thermal camera is carried out by an image registration process so that the position is the same as the image taken using a digital camera. The image processing result is compared with the ground truth image obtained from a digital camera to determine the effectiveness of the proposed method. The proposed method's effectiveness is measured using the parameters Recall, Precision, F-measure, and Accuracy. The effectiveness of the proposed method is quite effective because it produces parameter values above 80%, namely the recall value of 85.4%, the Precision of 89.35%, the F measure of 87.33%, and the accuracy of 92.8%.

1. Introduction

The banana is one of the important plants in Lampung Province in Indonesia. This province produces more than 1.5 million tons of bananas per year. In 2016, there was a decrease in production caused by a disease that attacked this plant in Indonesia (Figure 1). In Indonesia, diseases that often attack this plant are Sigatoka spot and Fusarium wilt [1]. This disease not only causes a decrease in production but also causes a decrease in the quality of the harvest. Figure 1 shows Banana production in Indonesia during the last five years.

Detection of disease in plants is one of the studies that many researchers do. Phytoplasma is one of the causes of plant disease in about 300 plant species including banana. Phytoplasma is a potential pathogen that is considered quite dangerous for plants. Research on banana plant diseases caused by phytoplasma has been done before [2].

Symptoms of disease in banana trees are shown by old leaves that turn greenish-yellow. This color change can be detected using the human eye, but the human eye has a disadvantage, namely that it cannot detect small changes that occur in plants. To overcome this deficiency, many researchers use cameras as a substitute for the human eye and employ image processing techniques to determine the presence of disease in plants.

The image processing technique is one technique that is widely used to help detect disease in plants. One of the techniques used in image processing-based disease detection is segmentation. By utilizing soft computing, this segmentation technique provides an average accuracy of more than 80% for banana, bean, lemon, and rose plants [3]. Several other image processing techniques used to detect disease in plants provide an average accuracy rate of more than 65% [4]. Specific research for disease detection in banana trees using image processing techniques has also been conducted before [5] [6][7][8]. In this research, the detected disease is black Sigatoka and uses an artificial neural network



using the MatLab programming language [9]. In these researches, images were taken using an ordinary digital camera instead of a thermal camera.

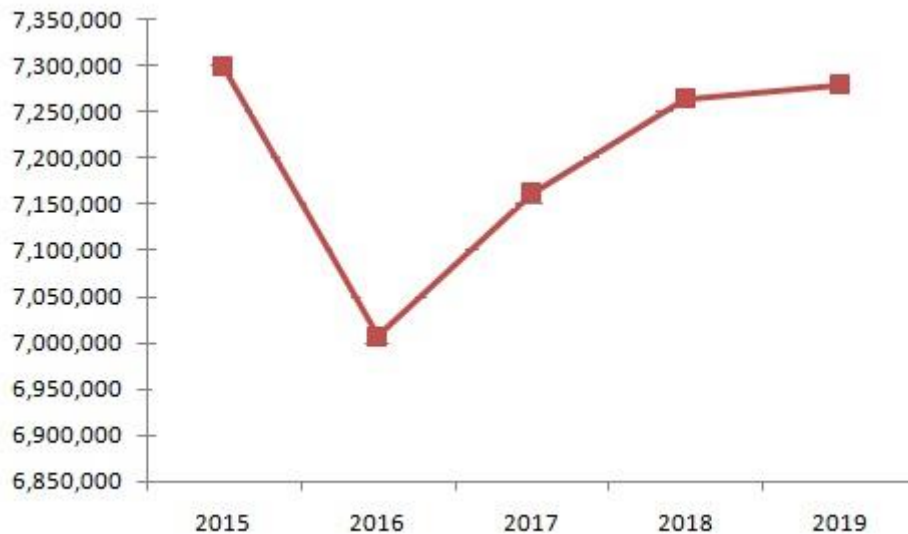


Figure 1. Banana fruit production in Indonesia.

This research proposes the use of a thermal camera to detect disease in banana plants. Detection is done through image processing techniques from thermal images obtained using a thermal camera. Thermal cameras are different from ordinary digital cameras. Digital cameras generally capture wavelengths between 300 until 700nm whereas thermal cameras capture wavelengths between 8 until 14 μm . The wavelength range of the electromagnetic spectrum is shown in Figure 1 where the thermal camera operates in the LWIR region.



Figure 2. The wavelength range of the electromagnetic spectrum.

Thermal cameras detect the temperature by recognizing and capturing different levels of infrared light emitted by objects. This light is not visible to the eye but can be felt as heat if the intensity is high enough. The hotter of the object, the more infrared radiation it produces. Thermal cameras can see this radiation and convert it into images that can then be seen with the eye. For example, a night vision camera can capture invisible infrared light and convert it into an image that is visible to the eyes. Figure 2 shows a comparison of examples of images taken using a digital camera with a thermal camera.

Thermal cameras are widely used for object detection related to the temperature emitted by the object. Previous research used thermal cameras to analyze the patient's health condition [10]. This research reviewed the use of thermal cameras to detect fever, diabetes, skin cancer, breast cancer, and hypothermia. Another research used thermal cameras to detect early vascular dysfunction [11] and inflammation detection in diabetic foot [12]. From this research, it was concluded that vascular disease causes more deaths than other diseases.

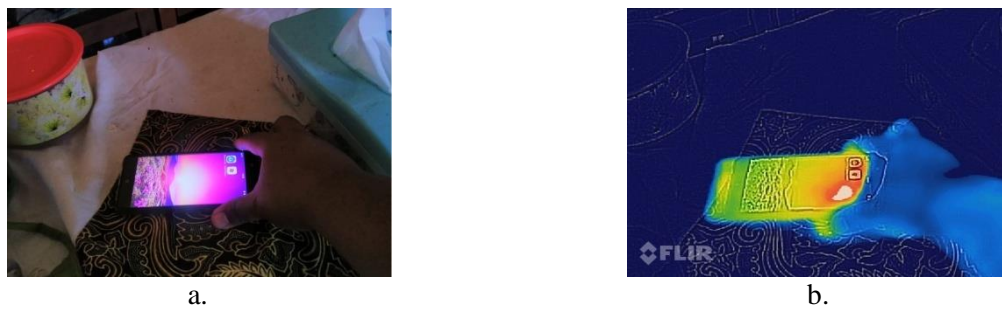


Figure 3. a. Image from ordinary digital camera and b. Image from thermal camera.

Besides being used in the health world, thermal cameras are also used for disease detection in plants. Research on the application of thermal cameras for horticultural agriculture has also been carried out [13] [14]. In this research, thermal cameras are used for monitoring water pressure, detecting soil moisture, monitoring drought, and controlling temperature distribution. The detection of plant diseases using a thermal camera has been carried out on various plants, for example, tea plants [15], chili [16], cucumber [17], and tomato [18]. Besides being used for disease detection in plants, thermal cameras are also used for detecting pests in plants [19].

This research proposes the use of a thermal camera for disease detection in banana plants. The detection is carried out by analyzing the change in leaf color on the tree due to a disease. The image of the leaves that experience colour changes are captured using a thermal camera and then segmented to see the colour composition.

2. Method

This research was conducted in banana plantations for image data retrieval, while data processing was carried out in the Electronics Lab, Electrical Engineering Department, Engineering Faculty, Lampung University. Data processing was performed using an i5 computer with 4GB memory, 2GB GPU, Windows 7 Enterprise 32 bit, and the MatLab programming language. Meanwhile, the camera used in this study is a thermal FLIR camera. This research uses stages as shown in Figure 3.



Figure 4. Block diagram of the research method.

2.1. Image Acquisition

The results of image data retrieval are stored in external storage to be processed using a computer. An example of image data collection is shown in Figure 4 where 4a is an image of a banana tree taken using an ordinary digital camera and 4b is an image of a banana tree taken using a thermal camera. Data retrieval is carried out on a scheduled basis with the same object.

2.2. Image Registration

The difference in format and capturing angle of data resulted in the image being captured cannot be identical. It is necessary to register the image so that the two images approach the same shape so that they can be compared. The image registration process is the process of placing objects in the form of pixels in an image that does not yet have a coordinate system reference into a specific coordinate and projection system. In this research, the image of a Banana tree was taken using a thermal camera and an ordinary digital camera with a distance of 3 meters, a camera height of about 1.5 meters, and an upward angle of 30°.

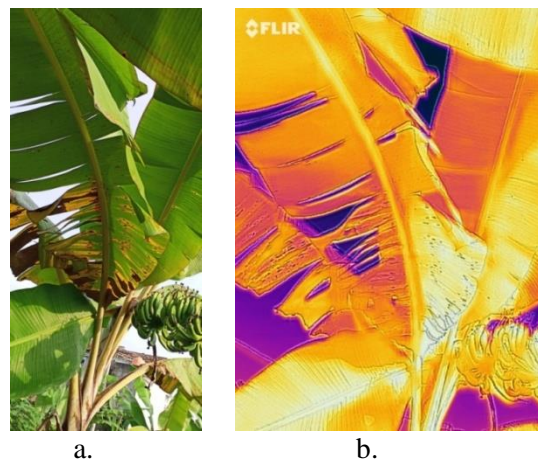


Figure 5. Example of image data.

The image registration process involves two images that have overlapping image scopes. Where one image is used as a reference and others adjust it. This registration process is carried out using the Matlab program. Image registration procedure is:

The first step : reading the reference image and the image to be registered,

The second step : selecting a control point on the image, which is to mark a location that is considered the same in both images, for example the location of a road intersection in both images.

Step three : save control points into the MatLab workspace.

The fourth step : re-detailing the control points so that the registration process produces the same exact image.

Fifth step : determine the type of transformation and its parameters required so that the control-point predetermined can move according to the target corresponding to the control point.

Image registration: Perform image registration.

An example of the results of the image registration process is shown in Figure 6 where Figure 6a has the same position as Figure 6b.

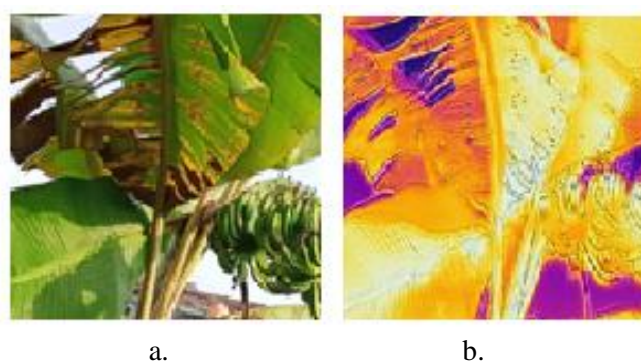


Figure 6. Results of the image registration process.

2.3 Image Segmentation

The thresholding process is an important technique in the image segmentation process because it produces images that have a small file size, fast processing, and ease in the manipulation process [20]. The thresholding technique can be done in bi-level or multi-level depending on the number of image segments desired. In the bi-level thresholding process, the image is divided into two different areas. Pixels with a gray value greater than a certain threshold are classified as object pixels, and other pixels

with a gray value smaller than the threshold are classified as background pixels. Mathematically, the bi-level thresholding is expressed using Equation (1).

$$f'(x, y) = \begin{cases} a_1 & \text{if } f(x, y) < T \\ a_2 & \text{if } f(x, y) \geq T \end{cases} \quad (1)$$

Where $f'(x, y)$ is the new intensity of the pixel at position (x, y) , a_1 the lower intensity value, a_2 the upper intensity value, $f(x, y)$ the intensity of the old image at position (x, y) , and T are set threshold value.

In multi-level thresholding, the pixels are compared against some set threshold values. The number of threshold values depends on the number of image segments that want. Mathematically, the multi-level thresholding process is expressed using Equation (2).

$$f'(x, y) = \begin{cases} a_1 & \text{if } f(x, y) < T_1 \\ a_2 & T_1 \leq f(x, y) < T_2 \\ a_3 & \text{if } f(x, y) \geq T_2 \end{cases} \quad (2)$$

Where $f'(x, y)$ is the new intensity of the pixel at position (x, y) , a_1 the lower intensity value, a_2 the middle-intensity value, a_3 the upper-intensity value, $f(x, y)$ the old image intensity at position (x, y) , and T_1 is the lower threshold value and T_2 is the specified upper threshold value. The Multi-level thresholding allows as many as n desired segments.

2.4 Image Analysis

The system effectiveness is calculated based on the parameters Recall, Precision, F-Measure, and accuracy. This calculation uses Equation (3), (4), (5), and (6).

$$\text{Recall} = \frac{TP}{TP+FN} \quad (3)$$

$$\text{Precision} = \frac{TP}{TP+FP} \quad (4)$$

$$F - \text{Measure} = 2 \times \frac{\text{Recall} \times \text{Precision}}{\text{Recall} + \text{Precision}} \quad (5)$$

$$\text{Akurasi} = \frac{TP+TN}{TP+FP+TN+FN} \quad (6)$$

Where TP is the true positive region, TN is the true negative region, FP is the false positive region, and FN is the true negative region. True positive (TP) is an overlap part between the ground truth and detection results. The part which is included in the ground truth, but not in the detection result and this part is False Negative (FN). The part which is included in the detection result, but not in the Ground Truth and this part is False Positive (FP) [21].

3. Results and Discussions

Taking an image using a thermal camera obtained the image shown in Figure 7.

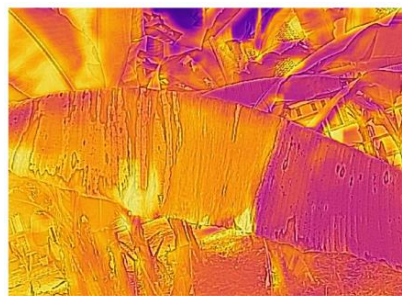


Figure 7. Image of leaves on banana plants that have spots caused by plant diseases.

To determine whether a leaf spot can be detected, it is necessary to compare it using images taken using a digital camera. The image is taken at the same position, shown in Figure 8. In order to have the same position, it is necessary to carry out an image registration process.



Figure 8. The image was taken using 8a. digital cameras and 8b. thermal camera in the same position.

The image from the digital camera is used as a guide for the position of the leaf spot by turning it into a ground truth image, shown in Figure 9. The ground truth image is created by manually marking the position of the spots in the image.



Figure 9. Result of making ground truth manually.

The image obtained by using a thermal camera is processed to produce a black and white image where the white color shows the leaf spots and the black color is the background. Image processing used is a multi-level thresholding technique. Image processing results are shown in Figure 10.

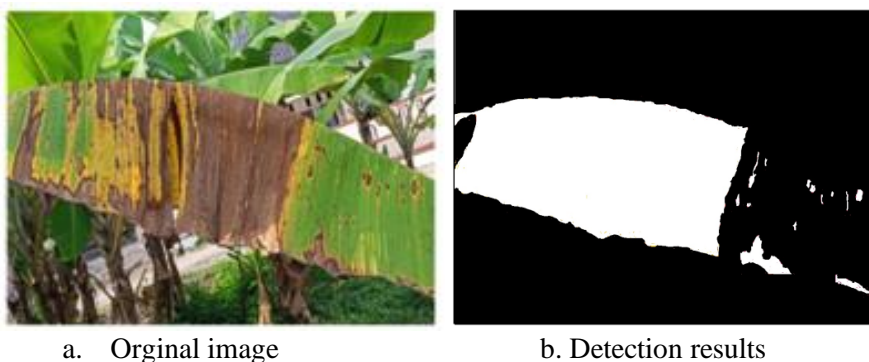


Figure 10. Image results from processing thermal image.

The resulting image from thermal image processing is compared with the ground truth image to obtain true positive, False Negative, False Positive, and True Negative values. Image comparisons are shown in Figure 10. The comparison of the two images produces the pixels including 235425 pixels of

True Positive, 40137 false negatives, 28046 false positives, and 644575 true negatives. The image size is 1100 pixels wide by 800 pixels high.



Figure 11. a. ground truth image and b. image of leaf spot detection using a thermal camera.

The effectiveness of the method offered can be measured by calculating the values of Recall, Precision, F-Measure, and Accuracy. The method offered is considered quite effective if the Recall and Precision values are greater than 60%.

$$\text{Recall} = \text{TP}/(\text{TP}+\text{FN}) = 235.425/(235.425+40.137) \times 100\% = 85.4\%$$

$$\text{Precision} = \text{TP}/(\text{TP}+\text{FP}) = 235.425/(235.425+28.046) \times 100\% = 89,35 \%$$

$$\text{F-Measure} = 2 \times (\text{Recall} \times \text{Precision})/(\text{Recall}+\text{Precision}) = 87.33\%$$

$$\text{The level of accuracy is} = (\text{TP} + \text{TN})/(\text{TP}+\text{FP}+\text{TN}+\text{FN}) = 92,8\%$$

4. Conclusions

This paper proposes a technique to detect disease-induced leaf spot in banana plants using a thermal camera. The proposed method is quite effective in detecting disease-induced spots on banana leaves. This is obtained from the recall value, which reached 85.4%, the Precision value was 89.35%, the F-Measure value was 87.33%, and the accuracy level reached 92.8%. In future work, more observations are needed to determine the speed at which the disease is spreading and to prevent it.

Acknowledgement

Thanks to LPPM UNILA for providing financial support through the Postgraduate Research scheme DIPA BLU, the number of a research assignment letter (from Chairman LPPM Unila) 1352/UN26.21/PN/2020.

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