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IMAGE SEGMENTATION ANALYSIS USING OTSU THRESHOLDING AND MEAN DENOISING FOR THE IDENTIFICATION COFFEE PLANT DISEASES

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Abstract

In Indonesia, coffee is one of the plantation products with a relatively high level of productivity and is a source of foreign exchange income for the country. However, unfortunately, certain factors can threaten productivity and quality in cultivating coffee plants, one of which is rust leaf disease. This disease causes disturbances in photosynthesis, thereby reducing plant yields. Therefore, to maintain and control productivity in coffee cultivation, this research carried out the process of observing coffee leaf images through segmentation using the Otsu Thresholding and Mean Denoising methods. The entire series of processes in this research was carried out using the Python programming language and succeeded in providing output in the form of image comparisons showing areas affected by Rust Leaf disease using the Otsu thresholding method alone and the Otsu thresholding method combined with a non-local means denoising algorithm. The test results prove that the Otsu thresholding method with the non-local means denoising algorithm has a smaller MSE value. It is the most optimal method for handling coffee leaf disease image segmentation with an accuracy level of 88%. It is hoped that this research can support farmers in providing insight into early detection of coffee plant diseases and increasing productivity through visual analysis.

Keywords: coffee; mean denoising; otsu thresholding; leaf rust; image segmentation

Abstrak

Di Indonesia, kopi merupakan salah satu hasil perkebunan dengan tingkat produktivitas yang terbilang cukup tinggi dan menjadi sumber pendapatan devisa negara. Meskipun begitu, sayangnya ada berbagai faktor tertentu yang dapat mengancam produktivitas dan kualitas dalam budidaya tanaman kopi, salah satunya ialah penyakit daun karat (Rust Leaf). Penyakit ini mengakibatkan gangguan pada fotosintesis sehingga menurunkan hasil tanaman. Oleh karena itu, untuk menjaga dan mengendalikan produktivitas pada budidaya tanaman kopi, maka pada penelitian ini dilakukan proses pengamatan citra daun kopi melalui segmentasi menggunakan metode Otsu Thresholding dan Mean Denoising. Seluruh rangkaian proses dalam penelitian ini dilakukan dengan memanfaatkan bahasa pemrograman python dan berhasil memberikan keluaran berupa perbandingan citra yang menunjukkan area yang terkena penyakit Rust Leaf menggunakan metode otsu thresholding saja dan metode otsu thresholding yang dikombinasikan dengan non-local means denoising algorithm. Dari hasil uji coba membuktikan bahwa metode otsu thresholding dengan non-local means denoising algorithm memiliki nilai MSE lebih kecil yang berarti menjadi metode paling optimal dalam menangani segmentasi citra penyakit daun kopi dengan tingkat akurasi sebesar 88%. Penelitian ini diharapkan dapat mendukung petani dalam memberikan wawasan untuk mendeteksi dini penyakit tanaman kopi dan meningkatkan produktivitas melalui analisis visual.

Kata kunci: kopi, mean denoising, otsu thresholding, karat daun, segmentasi citra

INTRODUCTION

Coffee is often used as the main ingredient in the coffee beverage industry. Coffee plants significantly contribute to the national economy as a commodity with high economic value (Ramadhan et al., 2021). In Indonesia, coffee is one of the plantation products that has been cultivated for a long time with a relatively high level of productivity. It is a source of foreign exchange income for the country (Marina et al., 2022). This is increasingly strengthened by evidence from data from the USDA, which ranked Indonesia as the second ASEAN country active in producing and exporting coffee (Alfian, 2021). However, Indonesia cannot meet 4.9% (Windiawan et al., 2019). This is due, in part, to a decrease in productivity and quality of coffee produced due to plants being susceptible to attacks from various pests and diseases on coffee plants (R. Lumbanraja et al., 2020).

Several diseases can damage coffee plants: leaf rust, leaf spot (Cercospora) and leaf fungus (Yasin & Al Maki, 2022). Rust leaf or Hemileia vastatrix, which is usually called leaf rust attack, is a disease of coffee leaves which is thought to play a significant role in the decline in coffee production due to reduced photosynthetic leaf surface area due to the reddish brown spots on coffee leaves that it causes (Siska et al., 2018). This disease causes physical damage to the leaves, which can reduce the productivity of coffee plants (Helmy Abdillah et al., 2023).

Leaf rust disease can generally be recognized directly using human visuals based on signs and symptoms (Sugiarti, 2019). However, several conditions in coffee plants show similar symptoms, so it is possible that errors can occur, which result in the treatment process being slower (Fibriani et al., 2020). Improper identification and handling processes can cause disease to become uncontrolled and ultimately impact the quality and productivity of coffee, which can lead to losses (Ramadhan et al., 2021). Currently, coffee beans of good quality and meet market criteria can immediately be sold at high prices in specific marketing channels. Still, coffee that does not meet standards is generally sold at low prices or will even be thrown away (Pratita et al., 2022). Apart from that, the use value of the coffee plant does not only lie in the fruit seeds but the coffee leaves can also be used to make tea or what is usually called kawa leaf, which is suitable for consumption and has antioxidant levels and nutritional content that are no less high (Asyhari et al., 2020). Therefore, to control diseases that arise in coffee cultivation, it is necessary to identify coffee plant diseases by observing the image on the leaves (Ardiansyah & Hasan, 2023). Observing this image can be done by using segmentation techniques on digital photos. This can provide advantages in the resulting process, making it easier and quicker to analyze because it is through a system (Sukmawati & Sadikin, 2023). This research aims to develop image segmentation that produces a deeper understanding of the condition of coffee plants and helps farmers make decisions through visual analysis.

Below are several previous studies that have applied image segmentation techniques to identify plant diseases. First, research from (Hakim et al., 2020) successfully implemented the L*a*b method in the image segmentation process to detect smallpox, stem rot and insect attacks on dragon fruit stems. Then, researchers (Ratnawati & Sulistyaningrum, 2019) applied the K-Means method in the segmentation process, resulting in an image that could differentiate infected and non-infected parts of the apple leaf image. Apart from that, there is also research from (Saputra et al., 2021), which utilizes image segmentation techniques on coffee beans before proceeding to the classification stage to determine the quality of the coffee being tested.

Referring to the findings from the research above, an image segmentation process will be carried out to identify and map areas in the image of coffee leaves infected with Rust Leaf disease. To segment coffee leaf images, a good quality image dataset is needed, so in this research, a series of preprocessing stages will be applied first, consisting of variations in lighting conditions, noise reduction, and image conversion. Then, proceed with the image segmentation process using the thresholding method and evaluate with Mean Square Error (MSE).

By utilizing image segmentation, it is hoped that it can contribute to farmers and coffee plant cultivators in understanding the spread of the disease effectively so that they can determine more optimal preventive steps, mainly for handling and preventing Rust Leaf disease in coffee plants.

RESEARCH METHODS

Types of research

This research is qualitative research with elements of light quantitative analysis in the computer field. The main focus is on the interpretation and visual understanding of the symptoms of Rust Leaf disease on coffee plants through image segmentation.

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Time and Place of Research

This research was carried out between July and October 2023. The process of data collection and image analysis took place during this period. Apart from that, data processing and experiments are carried out centrally using prepared hardware and software.

Research Target / Subject

To obtain accurate image area mapping results in identifying Rust Leaf disease, segmentation was used using the Otsu Thresholding and Mean Denoising methods in this study. This method was chosen based on carefully considering the need for image analysis of diseased coffee leaves. The Otsu Thresholding method was selected because it can determine the threshold automatically to produce infected leaf areas with precision. The Mean Denoising algorithm is also used to overcome potential noise in the image. These two methods were combined to increase the effectiveness and reliability of the segmentation process and ensure more accurate results in this research. The following is a diagram of the system workflow used:

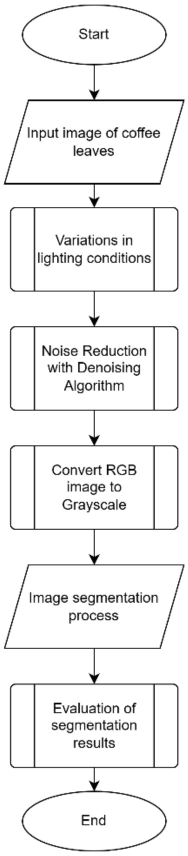

Figure 1. System Workflow Diagram

The first stage begins with carrying out the image reading process on the coffee leaf dataset. Then, the lighting conditions were changed to adjust the lighting in the image to suit the analysis's needs. After that, so that the image processed in the future is cleaner and more precise, a noise reduction process is carried out on the image using the denoising means algorithm technique. This technique is used to overcome image disturbances due to sensor errors, electronic noise and non-optimal image acquisition processes (Munawar et al., 2023).

In the next stage, colour information in the image is no longer needed, so the image conversion process will be carried out from RGB to grayscale so that the processed image only has two colours, namely black and white. Moving on to the next stage, the segmentation stage, where the image is identified using the Otsu thresholding method. This method works by maximizing the variance between classes by dividing the object and background in the image based on the grey level of the processed image to statistically analyze class discrimination (Sampurno & Faryuni, 2016). From these stages, an output is produced as an image showing the area affected by leaf rust disease. Finally, after the image is segmented, the segmentation results will be evaluated using the Mean Squared Error (MSE) evaluation metric. Through this evaluation, we can ensure the accuracy and quality of the segmentation method applied.

Data, Instruments, and Data Collection Techniques

The dataset used in this research is public data from the Kaggle Repository, which contains images of coffee leaves identified as Rust Leaf disease. Seventeen photos were taken to be used in the segmentation process for detecting this disease. The samples were selected selectively based on disease severity, variations in lighting conditions, and genetic differences. Below are some examples from the coffee leaf dataset:

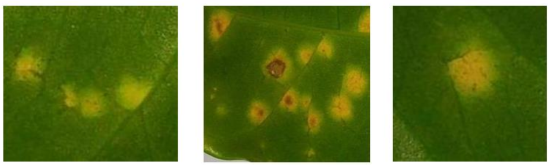

Figure 2. Sample image of coffee leaves

For each stage of the workflow, all images in this research were processed using the Python programming language via the Anaconda Version 3 tool with the input dataset and the resulting output in the form of images in jpg format.

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RESULTS AND DISCUSSION

In this research, two techniques are implemented for image segmentation. The first technique is to segment the image using the Otsu thresholding method, while the second technique is to segment the image using the Otsu thresholding method with a non-local means denoising algorithm. From the image segmentation results obtained, evaluation is then carried out using MSE (Mean Square Error).

Variations in Lighting Conditions

The images in this dataset have uneven illumination, so some photos appear in lighter colors due to the brightness levels between different areas. To overcome this problem, preprocessing was carried out to reduce the contrast and brightness of the image by giving the values alpha = 0.7 and beta = 1. The results of the image change are shown in Figure 3 below:

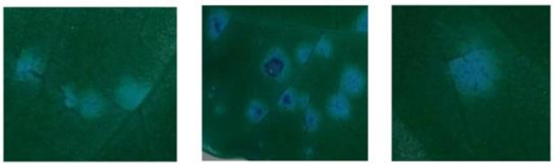

Figure 3. Results of Varying Lighting Conditions

Noise Reduction with Non-Local Means Denoising Algorithm

There is noise in the coffee leaf image, which causes poor image processing. The Non-Local Means Denoising Algorithm technique was used to reduce noise in this research. This algorithm will examine each pixel in the image and find other pixels with a pattern similar to the target pixel. After that, the algorithm will calculate the extent of the similarity, assign a weight to each pair of pixels based on the similarity score and calculate the resulting image by taking the average weight of all pixels in the picture. The resulting noise-reduced image is shown in Figure 4.

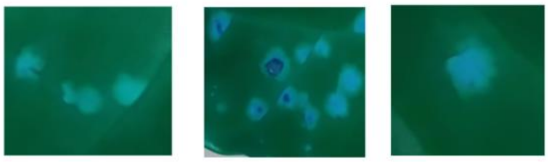

Figure 4. Noise Reduction Results

Convert RGB Image to Grayscale

At this stage, the image is converted to grayscale, meaning that all images that will be processed become black and white images, where each pixel only has one brightness level. The results of image conversion to grayscale are shown in Figure 5.

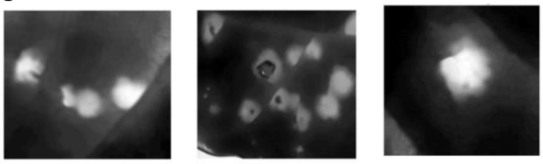

Figure 5. Converting RGB Image to Grayscale

Image Segmentation and Evaluation of Segmentation Results

Image segmentation in this research uses the Otsu thresholding method and the Otsu thresholding method with a non-local means denoising algorithm. This stage is carried out to identify areas affected by rust disease on coffee leaves. The 17 images used in this research and the coffee leaf image segmentation results will be evaluated using the Python programming language with MSE (Mean Square Error). Mean Square Error (MSE) is an evaluation metric commonly used to measure the extent of differences between the original image and the generated or tested idea. MSE focuses on the similarity or accuracy of boundaries between objects. The MSE Evaluation Process is declared to have good segmentation quality if the resulting value is smaller. This shows that the pixel intensity in the segmented image is closer to the original image's. The results of this process can be seen in Table 1 below:

Table 1. Image Segmentation and Evaluation of Segmentation Results

No	Image of Coffee Leaves	Segmentation Results		Evaluation of Segmentation Results	
		Otsu	Otsu & Non-Local Means	MSE Otsu	MSE Otsu & Non-Local Means
1				5443.42	**5241.66**

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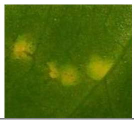
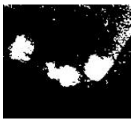
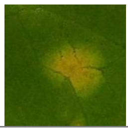
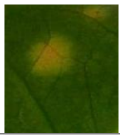
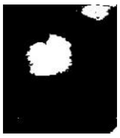
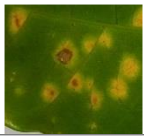
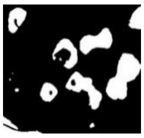
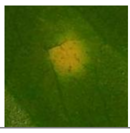
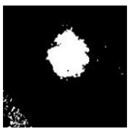
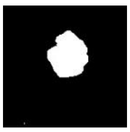
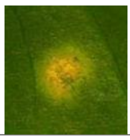
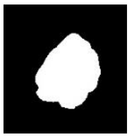
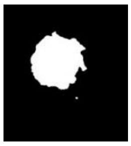
No	Image of Coffee Leaves	Segmentation Results		Evaluation of Segmentation Results	
		Otsu	Otsu & Non-Local Means	MSE Otsu	MSE Otsu & Non-Local Means
2				6457.41	**5802.98**
3				13359.93	**12614.23**
4				13417.70	**12842.95**
5				5890.14	**5240.41**
6				6665.37	**6643.85**
7				5667.88	**5529.85**
8				7979.82	**7648.43**
9				5086.62	**4895.33**
10				4998.30	**4664.09**
11				7012.03	**6809.49**
12				12275.91	**12043.54**

No	Image of Coffee Leaves	Segmentation Results		Evaluation of Segmentation Results	
		Otsu	Otsu & Non-Local Means	MSE Otsu	MSE Otsu & Non-Local Means
13				9959.17	**9899.40**
14				7555.03	**7376.29**
15				9899.12	**9690.79**
16				7502.95	**7443.28**
17				9396.71	**9245.24**

Based on the results of the trials that have been carried out (See Table 1), the Otsu thresholding method with a non-local means denoising algorithm has a smaller MSE value than the Otsu thresholding method alone. This proves that the Otsu thresholding method combined with the non-local means denoising algorithm technique is better in segmenting coffee leaf disease images. Of the 17 pictures tested with both methods, 15 were successfully segmented well, while the other two photos were not segmented well.

In experiments carried out on images of coffee leaves infected with rust disease, the success of a well-segmented idea was influenced by various factors such as more apparent contrast, low noise and optimal light intensity. Meanwhile, images that are not successfully segmented are affected by potential obstacles, such as the complexity of the leaf structure and the presence of noise in the image. This is proven in images 3 and 4, where the object area in the picture looks spread out due to variations in light and shape, resulting in difficulty in detecting the object and background.

From the dataset that has been tested, the success rate of this method can be determined in the following way:

$$A = \frac{jumlah\ data\ berhasil}{jumlah\ seluruh\ data}\ x\ 100\% \quad \text{.................................(1)}$$

$$A = \frac{15}{17}\ x\ 100\% = 88\%$$

The percentage level obtained was 88%. These figures show that the success rate of segmentation is quite good in handling the complexity of the image of coffee leaves infected with rust disease.

CONCLUSIONS AND SUGGESTIONS

Conclusion

Based on a series of processes carried out in this research, the results are that the Otsu thresholding method with the non-local means denoising algorithm technique provides image segmentation results in the form of 15 out of 17 images successfully segmented well. This can be concluded based on the resulting MSE value. Some photos were not successfully segmented due to variations in light, noise and shape in the image, which affected the resulting MSE value. However, from the accuracy level obtained at 88%, it can be concluded that applying the Otsu thresholding algorithm with a non-local means denoising approach is the right choice for handling leaf image identification in cases of leaf rust disease.

Suggestion

Some suggestions for further research include the hope that the test data used will be more extensive and representative of different coffee plant varieties and diseases. Then, using other segmentation methods and implementing them into a system is also a consideration to make the identification process more sophisticated and effective.

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