COMPUTER VISION FOR HEALTH ANALYSIS OF RICE PLANT IN AGRICULTURAL AREA

INDRA ADJI SULISTIJONO, ANHAR RISNUMAWAN, ZAQIATUD DAROJAH, MUHAMAD SULTON ENDI VELANI

Mechatronics Engineering Division, Department of Mechanics and Energy Engineering
Politeknik Elektronika Negeri Surabaya (PENS), Kampus PENS, Jalan Raya ITS Sukolilo, Surabaya 60111 Indonesia
E-MAIL: {indra;anhar;zaqiah}@pens.ac.id, m.sulton1312@gmail.com

Abstract:

The world population always increase and the agricultural sector has an important role in maintaining food security on a global and local scale. Indonesia is an agricultural country where the country's economy depends on the agricultural sector. Farmers are often faced with attacks of various rice plant diseases, such as leaf blight, crackle, brown leaf spot, neck cut or fungal attacks. These diseases can reduce the productivity and quality of rice or cause crop failure. Unmanned Aerial Vehicle (UAV) is an unmanned flying machine that has many uses, one of which is to capture and observe the condition of agricultural land based on aerial imagery. This study aims to analyze the state of the plants using aerial imagery data. The UAV flies at the required altitude and takes aerial images around the agricultural land according to the specified waypoint. Some of the aerial images are processed using image stitching to obtain orthophoto images. The orthophoto results are used as material for analysis related to the condition of rice plants using the vegetation index. Several vegetation indices are useful as a method for reading the level of vegetation on agricultural land. The final result of image processing using the vegetation index is useful for providing a visual understanding of the state of agricultural land. This can help identify the actions needed to maintain and improve plant health.

Keywords:

Unmanned Aerial Vehicle (UAV); Visible Atmospherically Resistant Index (VARI); Computer Vision; Precision Agriculture; Image Processing

1. Introduction

The world population always increase and the agricultural sector has an important role in maintaining food security on a global and local scale. Indonesia is an agrarian country that relies heavily on the agricultural sector. The majority of Indonesians consume rice as their daily staple food. Data shows that rice yields in Indonesia have decreased several times over a period of time. This affects the level of national and global food security. Farmers are often faced with attacks of various rice plant diseases, such as leaf blight, crackle, brown leaf spot, neck cut or fungal attacks. These diseases can reduce the productivity and quality of rice or cause crop failure. Therefore, farmers must be able to cultivate rice plants optimally so that they grow healthy in order to get good yields.

According to FAO, Indonesia's rice productivity level in 2018 ranked second with 5.19 tons per ha after Vietnam at 5.89 tons per ha. This result shows that the productivity of rice plants is not maximized. The problem on agricultural sector in Indonesia can occur due to low soil fertility, lack of pest control, agricultural methods and so on. The interest of the younger generation to work in the agricultural sector is declining. This adds to the number of problems that occur. Rice is a rice-producing agricultural commodity that plays an important role in the commodity sector that supports food security and builds the country's economy. However, there are obstacles in monitoring the growth of rice plants in order to predict productivity results. Normalized Difference Vegetation Index or NDVI is a method used in comparing the greenness of vegetation of a plant. In the research explains how to analyze the health conditions of rice plants using NDVI values using remote sensing with ASTER satellite image data [1].

Precision agriculture emerged as an agricultural innovation by utilizing technology so that the agricultural commodities produced run optimally. We use an unmanned aerial vehicles (UAVs) for obtaining image information in precision agriculture. Image information in the form of images is processed using computer vision methods to be analyzed. The final result can be used as a reference to decide the action to be taken.

2. Proposed Method

2.1. Computer Vision

Computer Vision is a system that runs automatically to analyze in order to obtain information and understanding from visual images of an object in the form of images or videos [2]. Computer Vision mimics the ability of the human eye to capture, record, analyze or understand an image of an object that is implemented on a computer. Techniques in Computer Vision in processing a visual image are divided into 5 types: Image Classification, Object Detection, Object tracking, Semantic segmentation and Instance Segmentation.

Image Classification is a basic system for understanding images thoroughly by classifying or grouping images into label groups based on certain rules. The rules can be designed using one or more spectral or texture characteristics. Spectral characteristics are variations of the reflectance or radiance of an object. In general, Image Classification is used to analyze an object that is visible in the image [3].

2.2. Image Stitching

Image stitching is the merging of images related to the merging of two or more images of the same scene into one high-resolution image called a panoramic image [4]. In every photo taken, there must be a part that is always overlapping so that each photo can be stitched to make a panorama. A collection of photos that have been taken is then continued in the image stitching process, so that the image becomes one whole part.

Image stitching techniques can be categorized into two general approaches: direct and feature-based techniques. Direct techniques compare all image pixel intensities with each other, whereas feature-based techniques aim to determine the relationship between images through different features extracted from the processed images. Image stitching is the process of combining data from multiple images to form a larger combined image or mosaic. The process of image stitching is shown at Fig. 1.

2.2.1 Feature Extraction

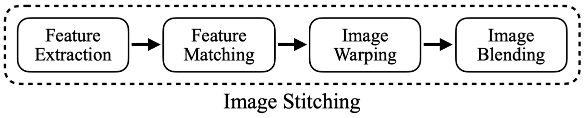


FIGURE 1. Image stitching process

Image data is extracted using the Scale Invariant Features Transform (SIFT) algorithm. Creating a new shape of pixels from the desired image data with several stages so as to get a match between the image data. These new pixels are used as an identity so that the image has a pattern called a feature.

2.2.2. Feature Matching

Upon obtaining the descriptors for images, they pair them by some matching methods [4]. This matching is carried out by comparing descriptors from one image with descriptors from another image. The main goal is to find pairs of descriptors that represent similar features between the images.

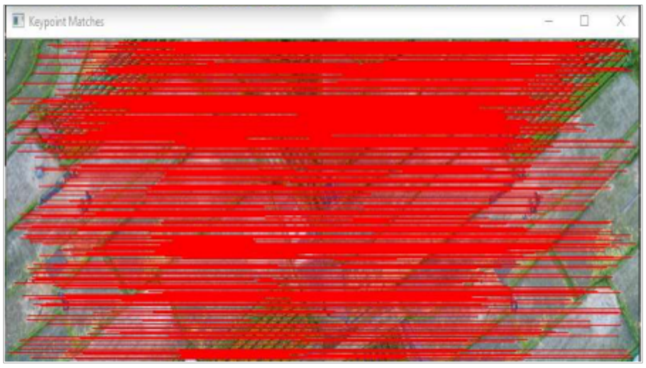


FIGURE 2. Feature matching process

2.2.3. Image Warping

Homography is a geometric transformation that changes the perspective between images to match each other. The next process of the coordinate point is used as a basis calculation to get transformation, on this research is used by Perspective Transformation [5]. RANSAC, or Random Sample Consensus, is an iterative algorithm used to estimate model parameters from a dataset potentially containing outliers. The RANSAC algorithm is used to identify consistent correspondences and ignore false correspondences to compose images with aligned perspectives.

2.2.4. Image Blending

Blending is applied across the stitch so that the stitching would be seamless. There are two popular ways of blending the images [6]. This final stage aims to unify the images produced by the warping transformation into one good image. Image blending involves the process of combining the pixels of the images by considering the relative contribution of each pixel to eliminate seams or breaks between overlapping images.

FIGURE 3. Image merging process

2.3. Unmanned Aerial Vehicle

Unmanned Aerial Vehicle or commonly called UAV is an unmanned flying machine that can be controlled remotely using a remote control or can be controlled automatically without direct control (autonomous) which is designed to resemble a plane when heading to the location but can hover when monitoring the area.

2.4. Workflow System

The UAV vehicle is equipped with an RGB camera to capture images in the air with a height of UAV will be flown at a certain height and take pictures around the farmland area according to a predetermined path. The UAV captures will be processed into image stitching to produce high resolution images.

Data retrieval calculations are required to obtain the actual area value based on the captured images. The equation to determine GSD is as follows:

$$GSD = \frac{H}{FL}PS \tag{1}$$

where: H is flying height zone; FL is focal length of the drone; PS is drone sensor image size.

Data collection planning with a height of 20 meters around the farmland area with UAV drone specifications

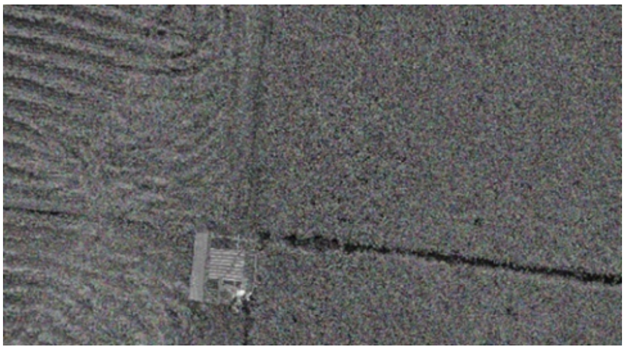


FIGURE 4. The result of keypoint localization detection

found GSD by using Eq. (1) as follows:

$$GSD_x = \frac{20m}{25mm} \times 6.17mm = 4.96m \tag{2}$$

$$GSD_y = \frac{20m}{25mm} \times 4.56mm = 3.64m \tag{3}$$

Based on the calculation of the image resolution taken of 3968 x 2976 from the drone specifications in the image represents 4.96m x 3.64m against the actual size.

2.5. Keypoint Localization

The feature value search process in keypoint localization requires maxima and minima values to provide stability to the feature. After obtaining the DoG in the image, each point maxima will be compared against 9 point minima with one point to 8 other points.

This process creates another distinctive shape that is the shape of the pixels with a type of transformation in the form of features in the image. This process is supported by filters to reduce contrast and make each feature different from other features.

2.6. OpenCV

OpenCV (Open Source Computer Vision Library) is an open source image processing and computer vision library. OpenCV has various features and functions for processing, manipulating, and related digital images. The image stitching diagram is shown in the figure below.

Image data will be extracted from the characteristics of each image using the Scale Invariant Features Transform (SIFT) algorithm. Then the features of each image that have been extracted are searched for feature matches using the Random Sample Consensus (RANSAC) algorithm. Furthermore, the images are merged to become a single overlapping image.

2.7. WebODM

WebODM is an open-source software used for mapping data processing from aerial imagery. In this research, WebODM is used to produce orthophoto. After obtaining image data from drones, the data is processed image stitching using WebODM to produce orthophoto. Orthophoto is a unified aerial photo of several aerial photos that are combined.

2.8. Determining the Vegetation Index Value

Vegetation Index (VI) is a method used to measure the amount and condition of vegetation in an area using satellite imagery or remote sensing data. The vegetation index provides information about the health and density of plants in an area. The vegetation index is calculated by utilizing differences in the absorption and reflection characteristics of light by plants. This is related to the ability of plants to absorb light in a certain spectrum and reflect it back. It is calculated by comparing the difference between reflectance in the near infrared (which is absorbed by chlorophyll in plants) and reflectance in red light (which is relatively more reflected by plants). The Normalized Difference Vegetation Index (NDVI) provides an indication of the amount and density of vegetation, as well as soil fertility conditions. The concept of spectral patterns based on this principle using only red band imagery is as shown in Table 1.

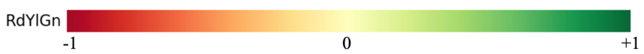


FIGURE 5. NDVI values between -1 and 1.

NDVI values are between -1 and +1, where (-) values indicate a lack of vegetation and (+) values indicate high vegetation. Health classifications based on NDVI values is shown at Fig. 5. Healthy value indication is shown at Table 1, (Source: http://www.symphonygeo.com/blog/18-ndvi-normalized-difference-vegetation-index).

Vegetation Index has many types to describe the greenness of a plant. Some vegetation indices will later be analyzed to determine plant health.

TABLE 1. Healthy value indication

Value	Indication	BGR Range (Lower-Upper)
<0	Non-living things, such as roads, buildings, soil, or dead plants	[0, 0, 100] -[100, 100, 255]
0 - 0.33	Unhealthy plants	[0, 150, 150]-[100, 220, 255]
0.33 - 0.66	Healthy plants	[20, 140, 70]-[90, 255, 180]
>0.66	Very healthy plants	[0, 100, 0]-[80, 200, 100]

Visible Atmospherically Resistant Index (VARI):

$$VARI = \frac{Green - Red}{Green + Red - Blue} \tag{4}$$

Green Leaf Index (GLI):

$$GLI = \frac{2 * Green - Red - Blue}{2 * Green + Red + Blue} \tag{5}$$

Normalized Green Red Difference Index (NGRDI):

$$NGRDI = \frac{Green - Red}{Green + Red} \tag{6}$$

Soil Color Index (SCI):

$$SCI = \frac{Red - Green}{Red + Green} \tag{7}$$

Spectral Slope Saturation Index (SI):

$$SI = \frac{Red - Blue}{Red + Blue} \tag{8}$$

2.9. Min-Max Normalization

Min-max normalization is a normalization method used to transform data values into a specific range. This method is often used on any type of numerical data such as different measurement scales or a wide range of values. In min-max normalization, the minimum and maximum values of the data are identified. Each value is reduced by that minimum value, then divided by the retaining value or the maximum value minus the minimum value. The formula for min-max normalization is as follows:

$$x_{norm} = \frac{x_{old} - x_{min}}{x_{max} - x_{min}} \tag{9}$$

where: x_{norm} is normalized value; x_{old} is the value to be normalized; x_{min} is minimum data value; x_{max} is maximum data value.

2.10. PlantCV

Plant Computer Vision (PlantCV) is a python library developed to analyze plant health. In this final project, PlantCV contains the Naïve Bayes classification method [7].

PlantCV is a collection of modular Python functions, which are reusable units of Python code with defined inputs and output [8]. In this case, Naïve Bayes is used to perform classification on data that has been extracted from plant images. Naïve Bayes classification produces a probability density function (PDF) for each class. Plant leaves in the form of pixel samples are separated into four classes: non-plant background, unaffected leaf tissue, rust pustule, and chlorotic leaf tissue. A Naïve Bayes classifier was then used to group the images into each class together. The health percentage is calculated by the degree to which the plant is infected with the disease, applying the following formula:

$$X = \frac{diseased\ plants}{healthy\ plants\ +\ diseased\ plants} \times 100 \tag{10}$$

where: X is infection percentage; *diseased plants* is pustule + chorosis; *healthy plants* is unaffected leaf.

The VARI algorithm used on RGB sensors only uses a few color correction to minimize reflectance, scattering, and other atmospheric effects to better estimate them fraction of healthy vegetation in an area [9]. There were several formulas introduced by past researchers that identify vegetation information. Our research focused on three of them: VARI, GLI, and VIGreen [10]. Therefore, the calculation of the estimated yield is obtained as follows with the VARI method.

By reference to every $10m^2$ of average area produces 20kg of healthy grain with reference to the height end quality of the same camera resolution produces a calculation of healthy rice as follows:

$$\frac{Grain\ Weight\ Reference * Mapping\ Area}{Healthy\ Area} \tag{11}$$

so that the formula is obtained simple calculation $20kg/m^2$ multiplied by the area.

This area is obtained by mapping the results of the number of color pixels in the stitched image that has been selected according to the classification sector. So the calculation is obtained

$$\frac{HealthyPixels * Harvest\ Forecast}{Harvest\ Area} \tag{12}$$

3. Experimental Results

TABLE 2. Procedure of the experimental results

Aerial Mapping Using Unmanned Aerial Vehicle (UAV)
Image taken from a drone at a height of 50m.
The images produced by the drone are 90-100 images, the overlap between images is 75%.
The resolution per image is 1080p 4K.
Image then one image with another image whose information is continuous will be stitched (stitching process).
Images are uploaded to the Robotani site so they do not require a computing process on the computer.
After stitching the resolution becomes very large.
The next process of this large resolution image is by georeferencing and is inserted into a globe (globe).
Then find out the GPS latitude (LU) and longitude (LS) coordinates.
The image is processed with the Visible Atmospherically Resistant Index (VARI) to identify the types.
From the picture, find which areas of plants are fertile, which are sick, which lack water, which have excess water, etc.
Even with photogrammetry, a 3-dimensional image can be used to determine the height of a tree.

The output results of this research produce data consistently every week by observing the development of agriculture with the same mapping location as well. Table 2 shows the procedure of the experimental results.

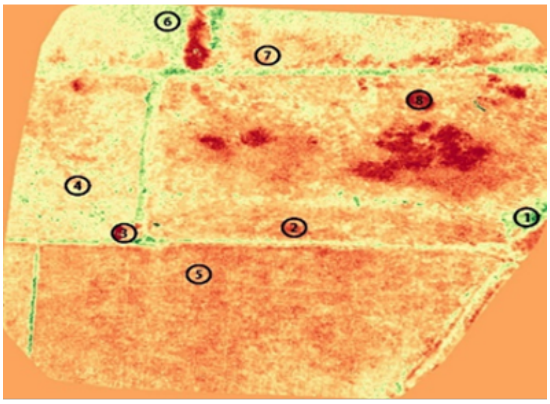
We would like to show one of our experiments using that procedure as shown at Fig. 6 (a). Figure 6 (a) is resulted from the procedure in Table 2. And then by using the proposed method, Figure 6 (b) can be found. index of the results of the percentage of health conditions of leaves on rice plants is as the following table (Table 2).

In the section, from the Figure 6 (b), shown in No. 8, we can conclude that it is an area that has many unhealthy rice plants. Therefore, it is indicated by a bright red pixel. The index of the results of the percentage of health conditions of leaves on rice plants is as the following table (Table 2).

Table 3 is found from the testing. Testing begins by creating a mask that has been obtained from previous training data. Masks are useful as a tool for segmenting images based on class: non-plant background, unaffected leaf tissue, rust pustule, and chlorotic leaf tissue. Unaffected leaf tissue is displayed in green, rust pustule is displayed in red, chlorotic leaf tissue is displayed in golden yellow. After that, the Naive Bayes classifier is useful for grouping images into each class simultaneously.

After conducting testing using Naive Bayes, it can be

(a) Result of image stitching



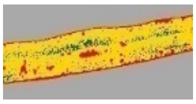
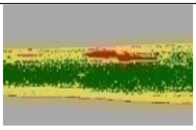
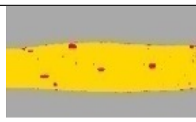
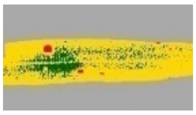
(b) Result of VARI method with analysis results of 8-point

FIGURE 6. The result of image stitching and analysis results of 8-point VARI method.

concluded that plant health analysis taken from the rice leaf section can provide a better understanding of the condition of the plant and the type of disease. This can help identify actions needed to maintain and improve plant health.

Table 4 shows from the research data above (Table 3), it produces output in the form of data on the level of estimated rice yields which will be observed periodically with the same intensity.

TABLE 3. Naive Bayes classification testing

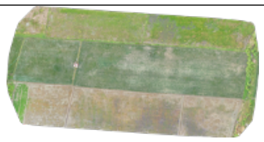
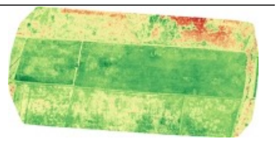
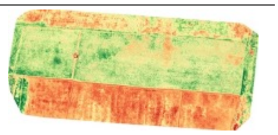
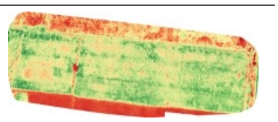
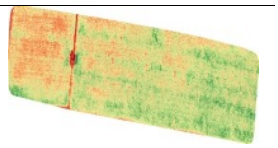
No	Dataset	Output	Disease percentage (%)
1			92.6
2			49.3
3			100
4			84.2
5			99.6
6			88.3

4. Conclusions

After testing the conditions based on mapping on rice plants periodically by applying the same rules to each monitoring, it can be concluded as follows:

- Vegetation Index VARI can be used to measure the greenness of plants. VARI can be applied to analyze a state of plants in an area using remote sensing image data. In this book, testing using VARI can be concluded if the growth of rice plants is uneven. This can be caused by bumpy land surfaces, uneven fertilizer application, and soil conditions that are too humid.
- The use of normalization of min and max values applied to the VARI vegetation index needs to be formulated to obtain good image visualization of the level of vegetation or lack of vegetation. Naive Bayes testing can be used to analyze plant health taken from rice leaves. This is useful to provide a better understanding of the state of the plant and the type of disease.
- Testing using the vegetation index VARI and Naive Bayes can be used to help identify actions needed to main-

TABLE 4. Comparison of leaf conditions on rice plants (mapping week)

Week	Mapping Week	Result
I		
II		
III		
IV		

tain plant health or effectively address plant related problems.

Acknowledgements

This research is funded by Directorate General of Vocational Education, Ministry of Education, Culture, Research and Technology, Republic of Indonesia, Date 11 June 2022, No: 0746/D4/AK.04/2022, FY 2022.

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