Automatic Plant Health Monitoring Device based on NDVI Analysis using Raspberry Pi for Water Apple Plant

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Abstract: Indonesia is a tropical country with abundant agricultural products. Therefore, the increase of efficiency and productivity of these crops is needed. Normalized Difference Vegetation Index is an index used to monitor plant health. To find out the NDVI value, a special camera is used to capture Near Infrared (NIR) light spectrum. This special camera is usually used by the professional plantation industry and is very expensive. In this study, we used a raspberry pi and a low cost Pi Noir camera to create a system that can predict the NDVI value of plants. The plant used as testing object is a Water Apple Plant (*Syzygium aqueum*). The result was that the system was able to identify the health of plant based on their NDVI value.

1 INTRODUCTION

As a nation that has a tropical nature, Indonesia is provided with tremendous natural resources. One of the natural resources that can be utilized as an energy source is agricultural farm. This comprises of plantations of rubbers, coconuts, oil palm, and so on. This plantation spread in excess of 20 million hectares of land area. From this number of land area dedicated for agriculture, it means should be considered to increase the efficiency and productivity of the plantations.

Precision farming is a method to increase the efficiency and productivity of farms or plantations. Precision farming uses technology to identify plant and manage its variability. As the results, the farmers can determine the use of fertilizers, seeds, waters, or pesticides efficiently. Many precision farming technologies use the camera to identify the health of the plant. The camera used is a special multispectral camera. This multispectral camera can capture non visible light spectrum. This non visible spectrum sometime has information about plant's condition and health. If one can understand plant health precisely, the use of fertilizers, waters, or pesticides can be more efficient. This also will increase the productivity with less capital cost.

There are many vegetation indices used in precision farming. The most popular vegetation index is Normalized Difference Vegetation Index (NDVI). This NDVI can be used to determine the health of plant. The high number of NDVI will indicate the healthier the plant is. NDVI uses information from light that is reflected by the plant leaves. This light information is captured by special camera. The special camera is a normal camera modified to capture special light spectrum. Most of the light spectrum captured is a non-visible light spectrum. So NDVI uses the image processing technology to calculate the index. This index indicates the chlorophyll concentration of leaves, which means it may also indicate the health of plants (Yang et al., 2017).

Normal green leaves in a plant absorbs red light and reflect near infra-red (NIR) light. This Red light has 600 nm to 700 nm of wavelength, and NIR light has 700 nm to 110 nm. Its absorption is the part of photosynthesis process. This absorption process is happened due to the presence of chlorophyll.

The reflected near-infrared light can indicate the health of some type of plant. Equation (1) is the equation to compute NDVI using near-infrared and red captured by camera.

$$NDVI = \frac{NIR - R}{NIR + R} \quad (1)$$

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NIR is the average of color signal in the wavelength of 800 to 1000 nm. R is the average of color signal in the wavelength of 560 nm to 670 nm range. The value of NDVI is in the range of +1 and -1. NDVI value close to zero indicates that the health of the plant is not god, while NDVI value +1 means the plant is in good health condition. Figure 1 shows the NDVI color range and its value.

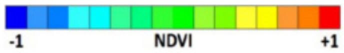

Figure 1: NDVI color range.

Nowadays, the standard normal camera usually is equipped with NIR blocking filter. The reason is that the NIR light can make the photos taken from that camera become unnatural. There are many ways to make the camera can capture NIR light. The first method modifies the lens of camera to unblock the NIR light (Beisel et al., 2018; Rabatel et al., 2011; Variyar et al., 2015). This method is sometime very difficult. In some cameras, the lens is so small and brittle. Modify the lens can make the camera broken and unusable. The second method is to use a specialized camera (Ritz et al., 2020; Vidoni et al., 2017). This camera is made specially for capturing NIR light. This camera is solution for who do not want to modify the lens. However, the price of this camera is so high. This camera is also rarely found on many countries' local market.

Distinct studies demonstrated that NDVI can be measured by using only single camera (Rabetel et al., 2011). The camera used by Rabatel et al. (2011) is a Single Lens Reflect (SLR) Camera which is modified by removing its Near Infrared Blocking Filter. This modification is not easy. One must understand the camera body parts and lenses. One mistake can make the camera unusable. Another research from Glenn et al. (2018), showed the measurement of NDVI by using single Pi Noir Camera. This camera is a special camera built for raspberry pi. This camera does not employ an Infrared Filter, so that the resulting image contains infrared information that is reflected by objects. In spite of that, this camera stiil need a blue filter. The Glenn NDVI measurement is calculated by using NIR value and blue value. This means, Glenn et al. measured blue NDVI in their research. Many researches showed that NDVI calculated using blue spectrum has less good result than using red spectrum.

The development of the mini PC technology has encouraged the use of the mini PC as the main computer in monitoring plants. Wang et al. (2020) have conducted research on the use of raspberry pi and pi noir camera to see the NDVI value of corn plants. At a cost of only 70-85 USD, they managed to capture NDVI values as well as predict nitrogen levels precisely. The Pi Noir camera as a camera to monitor NDVI is also used by Avotins et al. (2020) and Bicans et al. (2019). Avotins et al. (2020) uses the Raspberry Pi Model 3 as the main computer to capture and process the images. The captured data is then sent using an internet connection to the cloud.

NDVI values, which are numbers, sometimes cause the reader to have difficulty understanding them. Therefore, Wijitdechakul et al. (2017) grouped plant index values such as NDVI, NDWI, and SAVI into semantic keyword groups. So that it can be concluded directly by the system whether the plant is drought, or the soil moisture of the plant is not good.

In this research, we propose NDVI calculation by using two cameras. The first camera is standard webcam camera, and the second is Pi NoIR Camera. We use raspberry pi as a main image processor. From the first camera, the red pixel information obtained and from the second camera, The NIR pixel information is obtained. The tests are carried out on several conditions of leaf. The results are grouped in several keywords such as "Healthy", "Unhealthy", and "Dead". These keywords are then showed to the user via web applications.

2 METHODOLOGY

In this project, two cameras are used. The first camera is standard RGB camera and the second one is Pi NoIR camera. Figure 2 shows the system used in this project. As an image data processor, Raspberry pi type B is used. Rapsberry pi captures image from two cameras. These two cameras have different resolution and different view angle. Before image being processed, the two images (stereo image) need to be matched. After these images matched, the red pixel information is extracted from first RGB camera. Then, the NIR pixel information is extracted from second camera.

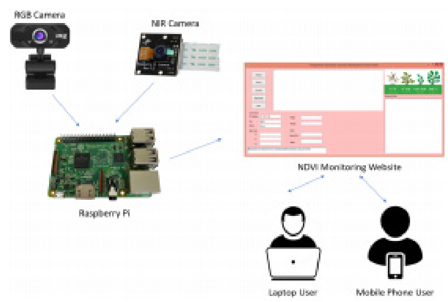

Figure 2: Raspberry Pi system.

The NDVI is calculated using equation (1). Then, the result, is colormaped by using information shown in Figure 1. The resulting NDVI image and NDVI number are shown on the web application. This web application is served by web server in the Raspberry Pi. This application can be accessed by user from everywhere. For the testing purpose, a leaf is placed in front of the cameras. We used Water Apple (*Syzygium aqueum*) leaves as testing object. The leaves used for the test are shown in Figure 3.

Figure 3: Water apple leaves as testing object.

3 RESULT AND DISCUSSION

In the first test, the green healthy water apple leaf is placed in front of the cameras. The resulting image is shown in figure 4. As we can see in figure 4, the red pixel dominates the image color. This red color is a representation of the chlorophyll intensity in the leaf. From the results of the NDVI calculation, the value was 0.479, which means that the leaf is in good health.

In the second experiment, an object of water apple leaf that is torn and slightly yellow is placed in front of the camera. The result captured by the system is shown in figure 5. In contrast to the previous healthy leaf, this leaf has more dominant blue color. Only a few red pixels are visible. Many red pixels are clustered on the outer side of the leaf. From the results of NDVI calculations, the value is 0.142 which means the plant is in an unhealthy state.

In the third experiment, the water apple leaf object which looked dry was used as the test object. The results of the received image is shown in figure 6. From the observations, it can be seen that almost all leaf colors show blue. This means that the leaf is dry, there is no indication of chlorophyll at all. From the NDVI calculation, the value of -0.9 is obtained, which means that the leaf is in a dead condition.

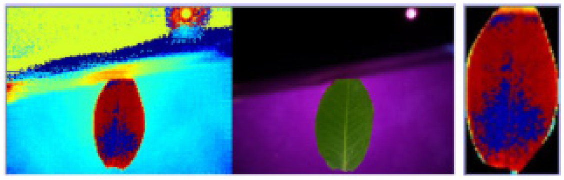

Figure 4: NDVI image of healthy green water apple leave.

Figure 5: NDVI image of not healthy green water apple leave.

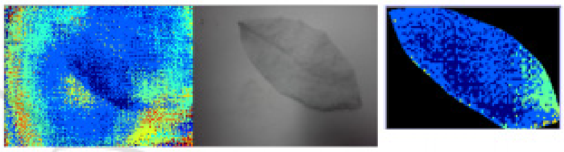

Figure 6: NDVI image of death green water apple leave.

In the fourth and final experiment, dummy plant is used as testing object. The resulting image is shown in figure 7. It can be seen that the image result shows an all blue color. No red pixel is detected. This is because in dummy plants, there is no chlorophyll intensity. The result is the plant in dead condition.

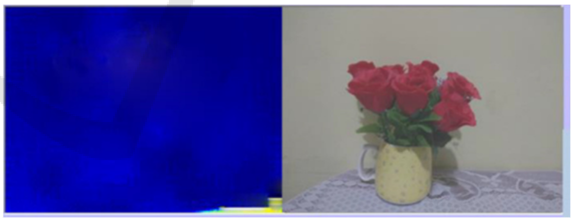

Figure 7: NDVI image of dummy plant.

4 CONCLUSIONS

Nowadays, there are many NDVI measurement solutions on the market, they are usually very expensive and need very skilful personnel to operate. The proposed system described in this paper presents an affordable alternative to one who needs to know the health of the plants from NDVI measurement perspective. From the experimental results, this system has succeeded in identifying the health of water apple leaves and predicting the average NDVI value of the leaf. Furthermore, further research will be carried out on the effect of NDVI values on crop yields and water requirements of plants.

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