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ORIGINAL ARTICLE

Classification of Plant Health (*Capsicum Frutescens*) Normalize Differences Vegetation Index using Image Processing

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ABSTRACT – The evolution of food manufacturer in global contribute in national income of the country. Agriculture has been a part of everyone's life which result in providing food become the building block of every human being. Malaysia is only country experiencing deteriorating development contribute (25.9%) agriculture in Gross Deficient Domestics Product (GDP) while others are fishing (12%), rubber (3.0%) and forestry & logging (6.3%), livestock (15.3%). In line with the development of technology in present century, a lot of methods and technique introduced to upgrowth agriculture sector by focusing to the plant health. The aims of this study are to classify of agriculture plant health through NDVI using image processing. Image processing is a technique representing operations and observation on an image. The images of plant will be captured in this investigation to obtain a photo without (Infra-Red) IR imaging filter. Some of steps must be perform which also include of using multi-function software to gain NDVI values of plant. The main objective in this study is to classify plant health by performing the vegetation index of plant and identify the best machine learning to be applied.

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INTRODUCTION

Normalise Difference Vegetation Index (NDVI) was created in 1973 when a research team at Texas A&M University helped farmers do precision agriculture to allow conservationists to understand ecosystem changes. This technique is very recommended in agricultural global vegetation monitoring. Instead of that, it is also applicable to monitor drought, weather forecasting and fire control. The recent studies of NDVI managed to expand a hundred applications using remote sensing, for instance, Moderate Resolution Imaging Spectroradiometer (MODUS), Advanced Very High-Resolution Radiometer (AVHRR) and System Pour I 'Observation de la Terre (SPOT). The image processing study includes thermal, hyperspectral, fluorescence, Multispectral, and 3D imaging [1]. Nowadays, image processing is primary usage in a traffic light to detect vehicles exit detection zone as video cameras perform traffic monitoring via telecommunication system [2]. Image processing is defined as a form of signal processing using input as an image and the output given either a photo or a set of data such as parameters and characteristics of the image captured.

Normalise Difference Vegetation Index (NDVI) is a method by measuring differences between near Infra-Red (NIR) and Red (R) light from reflection and absorption of light by the plants [3]. NIR refers to the colour of brightness reflected by the sun instead of the temperature, whereas R refers to the colour reflected by plants after photosynthesis. Plants usually absorb sunlight with red, green, and blue (RGB) wavelengths for photosynthesis, the plant produces NIR as the product, and less green wavelength reflects the surroundings. This explains why humans see green as the colour of a plant, but NIR is an invisible spectrum to our eyes [4].

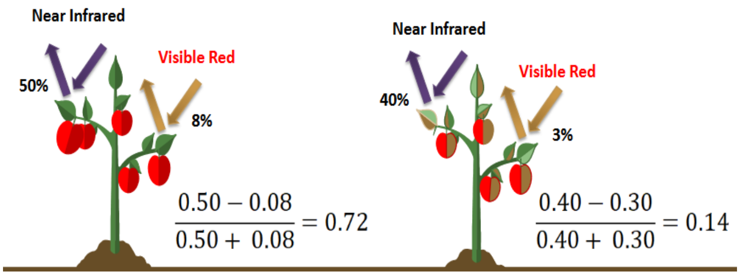

Figure 1. NIR and IR absorb and reflect by healthy and unhealthy plant

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Figure 1 depicts the NIR and IR ratio as expressed in Equation 1 below.

$$NDVI= (NIR – R)/ (NIR + R) \quad (1)$$

The values have a scientific index between -1.0 to 1.0. These represent vegetation density of the plant measured as in Table 1 below:

Table 1. Normalise Difference Vegetation Index (NDVI) index value

Index value	Type of plant
-1 – 0 (clouds, water, snow)	Dead plant or inanimate
0 – 0.33 (rocks, bare soil, sand)	Unhealthy plant
0.33 – 0.66 (shrubs, meadows)	Moderately healthy plant
0.66 – 1 (tropical forest)	Very healthy plant

The device uses infrared (IR) thermal imaging to extract NDVI images from NIR and visible light photos. After the NDVI pictures have been converted from visible light photos, the index NDVI will be computed. The step of converting IR images into RGB colours using MATLAB software may help to reduce the time in separating the RGB images from a single photo to access NDVI data. Moreover, the cameras with IR non-filtering colours performances reduced the cost of the system to gather NDVI as in previous studies, the technique of obtaining NDVI is more focused on data collected by remote sensings such as MODIS NDVI [5], uncontrolled drones [6], the plant detection using imaging techniques include of a multispectral imaging camera and hyperspectral imaging camera [7], which is expensive, heavy and depend to geo-references. Furthermore, the cameras need expert imaging and data processing training.

This paper aims to classify the *Capsicum frutescens* (CF) or chilli plant through NDVI using image processing and identify the best machine learning to classify the plant health. The research scope is limited to the plant in more smaller-scale data set as in this paper chilli plant is selected because of higher production and consumption in Asia. The IR non-filtering photo is captured by Raspberry PI noIR camera v2. This camera comes with many accessories, and one of them is PI noIR without no infrared (noIR) blocking light and is commonly used for different applications.

METHODOLOGY

The research gap and challenges presented by the previous studies advance the future scientifical method to achieve accurate data. By collecting the data features and how it is extracted through analysis and experiment approach, the best result of the method agriculture health classification in references. The previous methodology access more knowledge in plant health monitoring systems with the provision of NDVI techniques.

In general, obtaining NDVI through the image processing method is divided into four main stages: experimental setup, data collection and extraction, getting NDVI value and analysis of performances. This section indicates the research methodology corresponds to the sub-section accordingly.

The studies on CF have been carried out outside the laboratory at University Malaysia Pahang. During the data collection, the chilli plant was allowed to be exposed to sunlight. The Raspberry PI noir camera is prepared to capture noIR photos, which will enable it to measure the amount of the sun reflected across the entire image. The distance between the camera and the plant should becover the whole plant before the photos were trimmed to separate the surroundings from the plant. For every data obtained, the distance between the camera and the plant being monitored should be constant.

Data collection: noIR photo

The device presented in this study is the noIR camera v2, as the specification is given in Table 2, which can produce noIR photos and video once attached to a Raspberry Pi. The Raspberry PI noIR camera is a device that uses thermal imaging techniques to monitor an object's temperature. The wavelength that emits electromagnetic radiation is invisible to the human eye. Most cameras we use nowadays include an IR filter to block sunlight from being received by the lens. By removing IR radiation, an actual photo of the image will be obtained. As stated in table 2, the Raspberry PI noIR camera v2 comes with its features. Chilli plant data will be collected at noon since it requires a lot of sunlight to reach the plant.

Table 2. The specifications of the noIR PI camera

Specifications	noIR PI Camera
Model	Raspberry PI Camera Modules V2
Resolution	3280 x 2464 (8Mp)
Quality	3280 x 2464 - pixel static images 640 x 480p60/90 (1080p30, 720p60) - video.
Lens	4.5 mm
Image storage	8 bits

The image produced by the Raspberry PI camera is known as noIR. Red, green, and blue (RGB) wavelengths were released by the sun. The RGB is involved in photosynthesis by the chlorophyll in plant leaves. The RGB, often known as accurate colour, is a set of wavelengths combined to create additional colours. NoIR photos allow the plant to take an actual image of an object without IR blocking, allowing the quantity of IR accessing the captured surfaces measured of RGB bands.

Data extraction to Visible Red Band (R)

The R image needs to be extracted from the noIR photo. The colour scalar biased on different plant pixels may be easily identified in a single RGB picture represented by Red (R) image or a visible Red band (R). Table 3 shows the range of spectral bands in RGB. The red bar (R) represents the RGB wavelength since it is the longest wavelength compared to blue and green. There are four other colours which are violet, indigo, yellow, and orange. To look at another way, the visible colour is a rainbow spectrum with different frequency wavelengths.

Table 3. visible colour spectrum

colour	Wavelength/nm
Red	620-720
Green	500-570
Blue	460-720

Multispectral Imaging Technique (MIC)

The previous step has discussed the R image, which can be developed automatically from software using appropriate coding, but the NIR cannot be obtained directly. Using multispectral imaging techniques (MIC), the noIR photo is programmed to receive the NIR image as in Figure2. The MIC required some steps in obtaining the value of NIR.

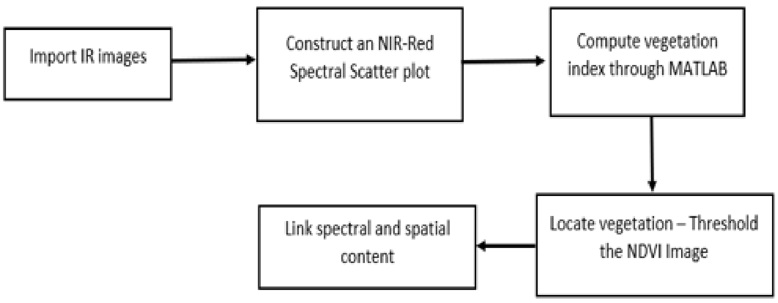


Figure 2. Steps required in MIC

Formation of NDVI

The method to obtain the NDVI images is very crucial in this study. NDVI is calculated by overlapping the Red (R) and near-infrared (NIR) bands. The NDVI image is a remote sensing measurement of vegetation that displays a false colour image. This image shows a wrong colour band representing the degree of vegetation index (VI) to differentiate the plant's existence from the surrounding. When there is no vegetation, the wall, lake, and rocks are usually blue, while the vegetation area like forest, shrubs and meadows will display vegetation colour based on the NDVI colour bar. Based on the NDVI image captured, these colours reflect the level of the plant's health. The value of NDVI can be solved using equation 1. These data will display an index number or VI ranging from -1 to 1, indicating the area that receives the most energy from sunlight. The most excellent NDVI scale colour, 1, suggests that the region has more vegetation, whereas the lowest NDVI scale, -1, indicates that the area has less vegetation

Performances Analysis and Machine Learning (ML)

This section will address the list of deep learning techniques to classify plant health through image analytical tools to organise the chilli plant using image input and image embedded in Orange3-3.29.3. The purpose of machine learning from the specific deep learning process is to identify the chilli plant's condition without going through the data collection process in obtaining the RGB images extraction and multispectral imaging techniques from IR photos. The data set of plants image applied in the process and some of them will be chosen as the validation data to undergo the machine learning process. The absolute result is categorised as healthy or non-healthy plants based on the NDVI index. The accuracy will be recorded for the data which correct classified in healthy or non-healthy conditions. This section is intended to choose which machine learning algorithm should be applied to classify plant health using the application of the VGG-19 architecture in image embedding using 19 layers deep. VGG-19 was selected because of its ability to identify the vegetation region using a deep learning neural network as image identification. The plant can be correctly categorised utilising an algorithm. At least three types of classifiers had classified the datasets. This is an imperative method to find the best performances models with a high classification accuracy

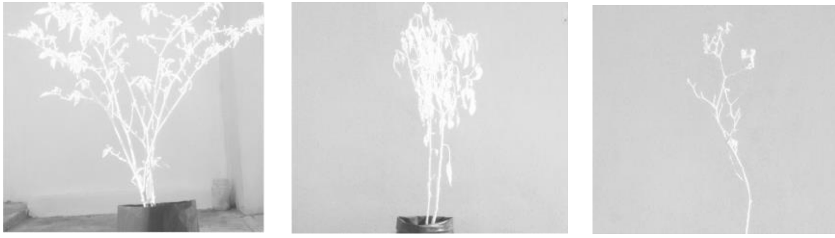
EXPERIMENTAL RESULTS

Figures 3 shows images of different chilli plants A, B, and C took with a Raspberry PI noIR camera. This experiment used three other plants under various conditions classified as healthy, sick, or dead plants based on their appearance. The image on noIR taken appears pink in colour as the picture read the quantity of sunlight reaching the object captured.

a) b) c)

Figure 3. noIR image a) plant A b) plant B c) plant C

Figure 4 illustrates the output of multispectral imaging techniques with the resulting near-infrared (NIR) picture, while Figure 5 shows the automated derivation of the red light (R) image from MATLAB. Usually, these pictures appear to look like a greyscale image with different brightness of input images representing various data in a photo.



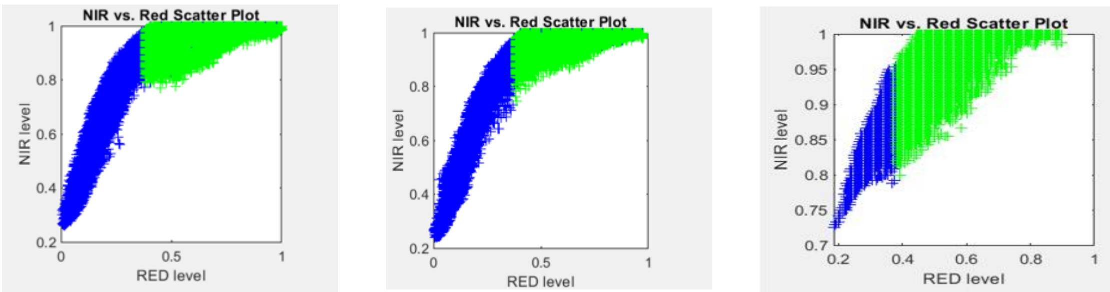
a) b) c)

Figure 4. NIR image a) plant A b) plant B c) plant C

a) b) c)

Figure 5. visible red band (R) a) plant A b) plant B c) plant C

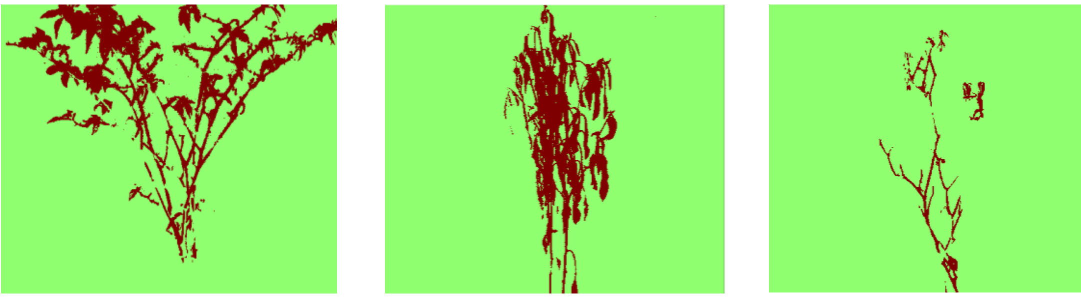
The relationship between NIR and R-value from the original noIR photos can be displayed using visualisation, as shown in Figure 6. The observation has been made from the scatter graph. Plants A and B do not offer a significant change on a scatter plot since they have vegetation area, but plant C has a green area signified value of the Red band that is bigger than the blue area illustrated to NIR produced by the plant. The scatter graph shows that plant C can have a lower NDVI index than plants A and B.



a) b) c)

Figure 6. NIR vs Red scatter plot a) plant A b) plant B c) plant C

The formation of NDVI images of chilli plant images gives the result as in Figure 7, and the mean NDVI for complete images has been solved. Based on the mean NDVI value, the plant can be identified as healthy, non-healthy or dead. Using the colour indication of the NDVI colour bar from -1 to 1, the NDVI picture can distinguish between the vegetation area and its surroundings. The different colours shown in a single image indicates the additional value of NDVI between the plants observed. Plants A and B have a larger red brick region than plants C. The prediction is that plants A and B will have a higher VI than plants C. The red brick colour represented in the picture shows a plant with vegetative, indicating that the plant receives sufficient sunlight to generate food and energy. At the same time, NIR is produced as a product of photosynthesis. Since the wall is not a vegetative area and does not participate in the photosynthesis process, the surrounding region does not receive and absorb sunlight, resulting in a light green colour.

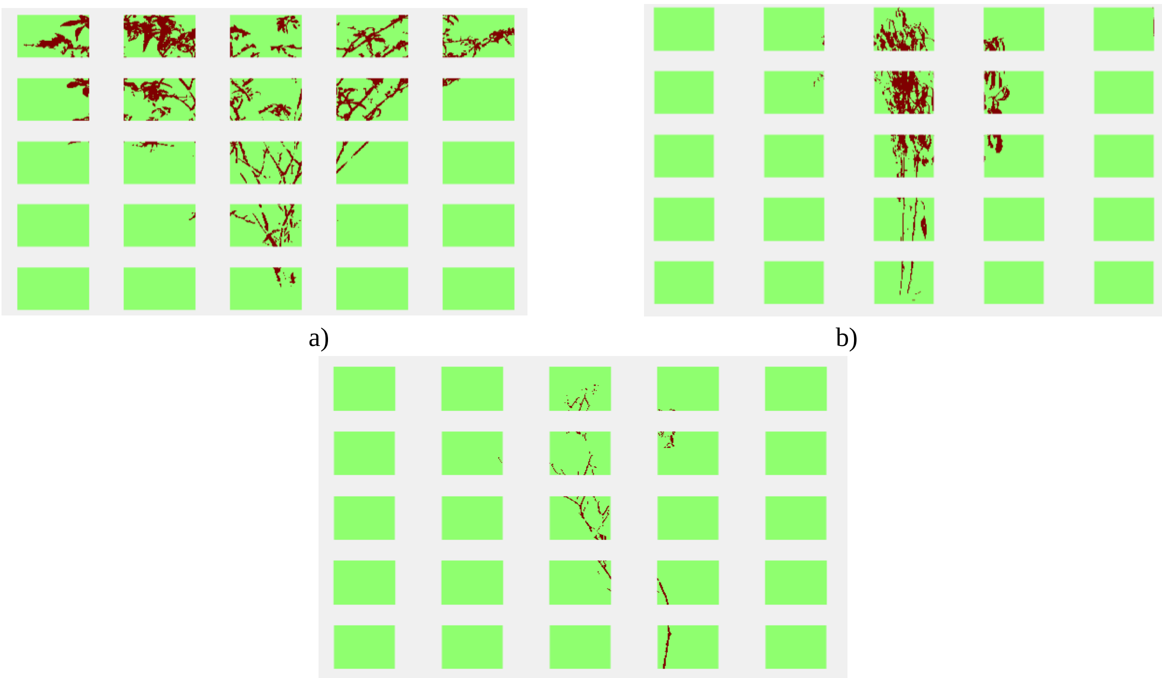


a) b) c)

Figure 7. value of mean NDVI Plant a) A (mean NDVI; 0.2693) b) Plant B (mean NDVI; 0.2488) c) Plant C (mean NDVI; 0.2166)

The mean NDVI for plants A, B, and C are shown in the figures. Plant A has a mean NDVI of 0.3072, indicating a healthy plant, whereas Plant B has a mean NDVI of 0.2488, representing a sick plant. The mean NDVI shown by plant C is 0.0668 perform the plant is ill and seems to be dying. Plant C has fewer leaves, conducting less photosynthesis and producing insufficient food and energy for growth, forcing it to wither and die.

The process is continued by separating the NDVI picture to extract the NDVI value in particular pixels with multiple rows and columns, as shown in figure 8. Each column has a specific Vegetation Index (VI) value. The observation was made based on the NDVI data obtained by each pixel, which region of the plant present a high VI. The area of the abnormal plant that caused the plant to be unhealthy will be determined based on the results.



a) b) c)

Figure 8. separating NDVI images a) plant A b) plant B c) plant C

Classification Accuracy using ML models

This section is intended to choose which machine learning algorithm should be applied to classify plant health. The ratio of test data to train data in the dataset plant picture is 80:20. 75 sets of data from plants A, B, and C were used to train the picture. The application of the VGG-19 architecture in image embedding using 19 layers deep. VGG-19 was selected because of its ability to identify the vegetation region using a deep learning neural network as image identification. The plant can be correctly categorised using an algorithm by three types of classifiers. They were using the machine learning model of kNN, Support Vector Machine (SVM) and Naïve Bayes to train the data, the graphs in Figure 9 shows the outcome of the best model to be selected.

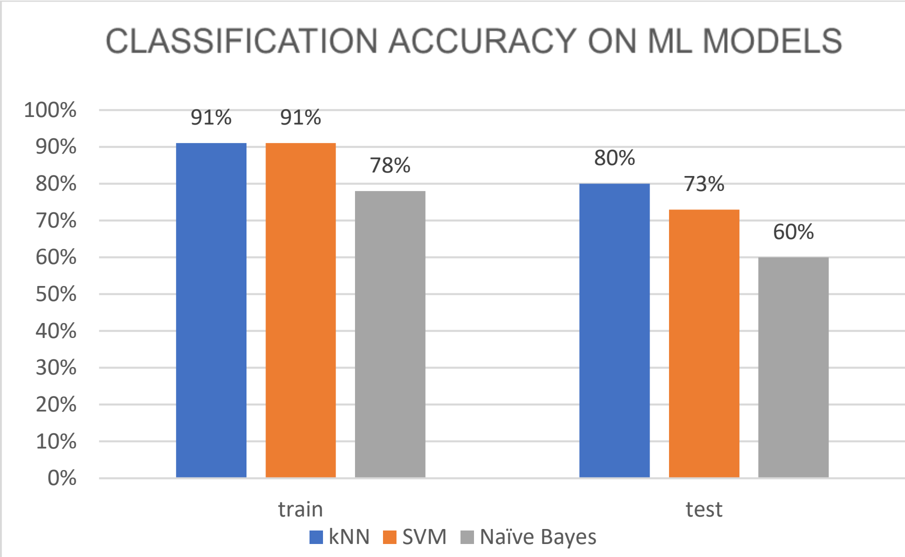


Figure 9. classification accuracy on ML models

From the figure above, the classification accuracy between the two datasets had shown. The chart shows that the highest classification accuracy for both datasets is kNN which is 80% and 90%. In comparison, the lowest classification for both datasets is 60% and 78% on training and test dataset, respectively. The most stable to be used as a classifier for categorising plant health is kNN as the differences for accuracy between train and test is least significant, which is 11%. The overall result shown indicates a satisfactory performance for ML models as all the data shown in the graph were underfitting as the percentage of training and datasets are higher.

CONCLUSION

This paper highlight the studies of NDVI using the image processing method in classifying the chilli plant health. The conclusion of the experimental study can be drawn as where the chilli plant can be classified using image processing techniques based on NDVI index vegetation. The image processing approaches construct a visible Red band (R) image, and the MIC is used to generate an NDVI image. This picture requires a specific index value that may be used to assess the vegetation region and plant health. These procedures will be linked to the second objective, and the index number will be used to classify the pictures into vegetation and non-vegetation areas.

kNN is the best machine learning model to identify the chilli plant. For this study, SVM, kNN and Naïve Bayes use to train 75 images of chili image. The process of data augmentation in data analysis is very imperative since the images will be cropped from surrounding and focused on a specific location to be studied for machine learning as the output is more accurate. In conclusion, the kNN classifiers provide the best classification accuracy among the other two models.

From the findings, there are some suggestions to be improved for future practice. Hence, the recommendations are suggested. Firstly, the performances of the machine learning technique can be increased using a more extensive data set. Since the ML model is easy to train, having many chilli plant pictures will greater accuracy. Meanwhile, a proper methodology of process in collecting data of noIR photos must be improved. Thus, the experiment results can be compared with actual data collected by a specific time range on a particular condition. Lastly, the results of several chilli plants can be captured in the exact location. Different locations may influence the amount of sunlight that reaches the plant. The location of the plant capture must be set as a fixed variable.

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