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RESEARCH ARTICLE

MODIFIED EXCESS GREEN VEGETATION INDEX FOR UNEVEN ILLUMINATION

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ABSTRACT

Analysis of plant leaves image so far been an important and difficult task, especially for leaves with complicated background where some interferents and overlapping phenomena may exist. To extract the plant leaf from complicated background is challenging since we need to remove the soil, residue and etc. In order to obtain the greeness of image, Excess Green Vegetation Index is obtained to ease the segmentation process. But, the problem raise when dealing with uneven illumination. This paper proposed Modified Excess Green Vegetation Index to overcome this problem. The conventional based-auto-threshold method (Otsu's thresholding), ExG (Excess Green Vegetation Index) was compared with Modified Excess Green Vegetation Index to evaluate the performance of them. Experimental results have showed that Modified Excess Green Vegetation Index has superior performance over ExG Otsu's threshold in term of is insensible to illuminant variations.

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INTRODUCTION

Field plants, residue, and soil ecosystems are very complex, but, machine vision technology has the potential to systematically unravel and identify plants using optical properties, shape, and texture of leaves (Meyer *et al*., 1998). The technology is useful in providing imaging-based automatic analysis in various area such as medical, agriculture and many more. Moreover, image analysis is a mathematical process to extract, characterize, and interpret tonal information from digital or pixel elements of a photographic image. The amount of detail available depends on the resolution and tonal content of the image. The process is iterative, starting with large features followed by more detail, as needed. However, shape or textural feature extraction first requires identification of targets or Regions of Interest (ROI). These regions are then simply classified as green plants or background (soil, rocks, and residue). To extract a single leaf with complex background is a very challenging task. The complex background in this context refers to the image of leaf with touching or overlapping with other leaves, soil, branches and etc. In order to extract that leaf, eliminating the non-green background can ease the further process. Unfortunately, we need to face with uneven illumination since the image is captured in outdoor condition. Furthermore, the critical part is dealing with the target leaf usually overlaps other leaves which may create the confusion between the boundaries of adjacent leaves. Since the colour of leaf image is often blue by visualization, the non-green background of image such as soil and residues can be eliminated by using thresholding method firstly (Xiaodong Tang *et al*., 2009). Besides threshold-based segmentation methods, researches have also employed different kinds of indices to separate vegetation from soil such as, color index of vegetation extraction (CIVE) (Kataoka *et al*., 2003), excess green minus excess red (ExG – ExR) (Neto *et al*., 2006), and excess green index (ExG) (Bunting and Lucas, 2006). Another technique that had been introduced by (Liying Zheng *et al*., 2009) is an alternative for segmenting green vegetation. Its involved an algorithm called mean shift. The algorithm mainly consists of two stages – features extraction and image segmentation. At first step, multiple color features, such as hue and saturation in HSI color space were extracted, as well as red, green and blue value in RGB color space. At the second step, with the extracted features, mean-shift segmentation algorithm and a BPNN, the image was classified into two parts: green and non-green vegetation. Unfortunately, this method suffered from long time running, so it is not suitable for real time application (Liying Zheng *et al*., 2009). Separating green vegetation in colour images is a complex task especially when there are noises and shadows in the images (Kataoka *et al*., 2003). Therefore, this paper proposed the method to eliminate the non-green background for outdoor image capturing. The procedure for getting the greeness of the leaf images is presented in Section II, while experimental results and discussion are given in Section III, followed by conclusions in Section IV.

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Colour space

A color space is a mathematical model of defining a color, along with function that allows mapping a color from one space to another. Each color space is designed for a different reason, and each color space is useful for different types of analysis and processing.

The perceptual colour space

The perceptual colour spaces are designed in order to provide a more "intuitive" way of describing colours and lightness. Three quantities are used to define them: hue, saturation and brightness. Brightness embodies the achromatic notion of intensity. Hue is an attribute associated with the dominant wavelength in a mixture of light waves. It represents colour as perceived by an observer (Neto *et al*., 2006). Thus, when we call an object blue, yellow or red, we are specifying its hue. Saturation refers to the relative purity or the amount of white light (or grey of equal intensity) mixed with a hue. Primary colours (pure red, green and blue) are fully saturated, whereas colours such as pink (red and white) and lavender (violet and white) are less saturated. The degree of saturation is inversely proportional to the amount of white light added (Bunting and Lucas, 2006). Basically, there are two distinct perceptual colour spaces: HSL (hue, saturation, lightness); and HSV (hue, saturation, value). Both are defined with polar coordinate systems.In this paper, we focused only on HSV colour space.

HSV Colour Space

This conversion is important in computer vision in separating colour components from intensity for various reasons, such as robustness to lighting changes, or removing shadows. HSV is one of many colour spaces that separate colour from intensity. HSV is represented by a hexcone where Hue is the angle around the vertical axis, S is the distance from the central axis and V is the distance along the vertical axis. HSV is often used simply because the code for converting between RGB and HSV is widely available and can also be easily implemented. As HSV is a simple model of color with computational simplicity and is considered to be effective in object detection and segmentation, Hue (H), Saturation (S) and Value (V) components were extracted from the HSV color space.

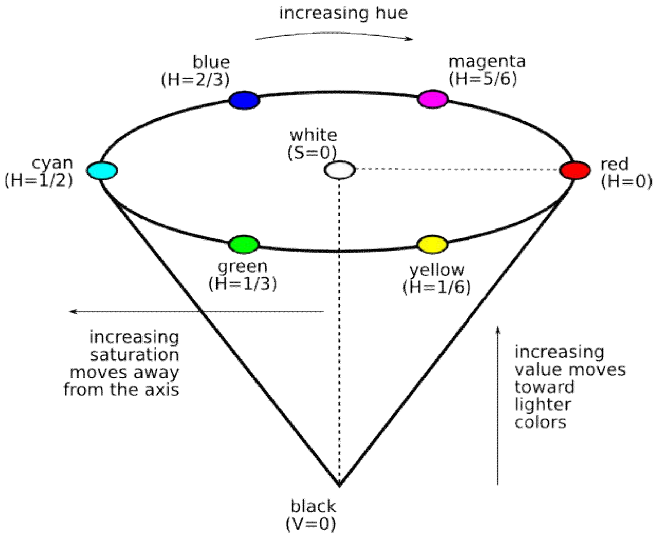


Figure 1. The single-hexcone model of color space

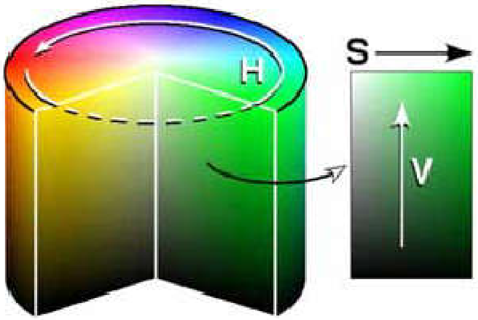


Figure 2. Illustration of HSV channel in colour version

The hue (H) of a colour refers to which pure colour it resembles. All tints, tones and shades of red have the same hue. Hues are described by a number that specifies the position of the corresponding pure colour on the colour wheel, as a fraction between 0 and 1.Value 0 refers to red; 1/6 is yellow; 1/3 is green; and so forth around the colour wheel. The saturation (S) of a colour describes how white the colour is. A pure red is fully saturated, with a saturation of 1; tints of red have saturations less than 1; and white has a saturation of 0. The value (V) of a colour, also called its lightness, describes how dark the colour is. A value of 0 is black, with increasing lightness moving away from black.

Vegetation Index

A **vegetation index (VI)** is an indicator that describes the greenness or the relative density and health of vegetation for each picture element, or pixel, usually used for a satellite image. In addition, VI involves some mathematical combination or transformation of spectral bands that accentuates the spectral properties of green plants so that they appear distinct from other image features. The VI is very important to indicate the amount of vegetation, distinguish between soil and vegetation as well as reducing atmospheric and topographic effects if possible. In other words, vegetation index is used as measures of biomass, amount of vegetative cover, and vegetation condition. The interaction of incident sunlight with green vegetation is strongly controlled by leaf pigments and leaf structure. Chlorophyll, the dominant leaf pigment, strongly absorbs light in the red and blue portions of the visible spectrum while reflecting green wavelengths, resulting in the green leaf color we see. Near-infrared light penetrates the leaf surface and encounters numerous cell walls and air-water boundaries, resulting in strong upward scattering (diffuse reflection) of this energy. Segmenting vegetation in colour images is a complex task, especially when the background and lighting conditions of the environment are uncontrolled. A variety of approaches have been applied to solve this problem in such complex environments, most of which have used image processing to segment only green colour vegetation areas in crop rows. Few researchers start manipulates the original image in order to ease the segmentation process. For example, Excess Green proposed by Woebbecke's while Excess Red proposed by Meyer *et al.* (Xiaodong Tang *et al*., 2009) be the reference to Xiaodong Tang *et al.* (Neto *et al*., 2006) for categorizing the plant leaf based on non green background by using Excess Green (ExG) as (2G) - R - B, Excess Red (ExR) as (1.4R) - G - B and non-green background as ExG - ExR. Another index is Normalized

Difference Index (NDI) which have been proposed by Perez (verification vegetation index) to separate plants from soil and residue background images. The technique used only green and red channels and is given as

$$NDI = \frac{G-R}{G+R} \tag{1}$$

1)Excess Green Vegetation Index

According to Woebbecke's indices without row and column indices of each pixel included:

Colour indices: (r - g, g - b, $\frac{g-b}{r-g}$ and 2g - r -) (2)

where r, g and b were the chromatic coordinates.

$$r = \frac{R'}{R'+G'+B'},\ g = \frac{G'}{R'+G'+B'} \text{ and } b = \frac{B'}{R'+G'+B'} \tag{3}$$

and R', G' and B' are the normalized RGB values (0-1) defined as:

$$R' = \frac{R}{R_m},\ G' = \frac{G}{G_m} \text{ and } B' = \frac{B}{B_m} \tag{4}$$

where R, G and B are the actual pixel values from the images based on each RGB channel and a sample of at least 100 pixels from each area of interest (plant, soil or residue) (Bunting and Lucas, 2006). Excess Red is obtained using equation while Excess Green is obtained using equation (5) and (6).

ExG = 2*g - r - b (5)

where r, g and b as shown in Equation 3

ExR = 1.4* r - g-b (6)

where r, g and b as shown in Equation 3.

In this paper a new method called Modified Excess Green Vegetation Index is proposed to improve the vegetation segmentation rate in images with uncontrolled background by manipulating the colour image in HSV channel in order to apply the equation (7) to obtain the greeness. Modified Excess Green Vegetation Index was compared with Excess Green Vegetation Index and the conventional based-auto-threshold method (Otsu's thresholdingto evaluate the performance of them.

ExG - ExR (7)

Methodology

Algorithm for Modified Excess Green Vegetation Index

The initial goal in the image analysis process was to divide the different pixels of the scene into two classes: soil (background) and leaves. For accomplishing that, differences in spectral reflectance between vegetation and soil were primarily used. In this process, the modification of HSV channel is needed to obtain sufficient images. This is because the images are captured in daylight at random times. Therefore, the images are exposed to direct sunlight. This will result in some part of the image is brighter than the other part and some part is darker than other part. In order to eliminate the effect of the sunlight and to reduce the parts with brighter and darker effect, the image is modified in term of S and V channels. The S and V channel are adjusted to modify the brightness of the image since the image is taken under uncontrolled illumination. The pixel values between 0.1 and 0.5 of S channel were forced to 0.7. By increasing the S value will eliminated the darkness of the image which cause by the shadow or uneven illumination. The pixel values greater than 0.6 in V channel were forced to 0.4 to reduce the brightness. The value of S and V channels are selected based on try and error of adjusting the range of both channels mentioned so that the result obtained after Excess Green Vegetation Index is acceptable. The modified HSV image then needs to be sharpen using a filter. The filter referred as unsharp masking which is one of the techniques used typically in edge enhancement. In this approach, a smoothened version of the image is subtracted from the original image, hence tipping the image balance towards the sharper contents of the image (Bunting and Lucas, 2006). The procedure to perform unsharp masking is explained in the next paragraph. First, the image needs to be blurred using blur filter. Then, substract the result obtained from the first step from the original image. After that, the result obtained is multiplying by some weighting fraction. Lastly, the result obtained is adding to the original image. Mathematically, the unsharp masking operation is written as Equation (10).

$$f'(m,n) = f(m,n) + \alpha\left[f(m,n) - f(m,n)\right] \tag{8}$$

where

$f(m,n)$ is the original image

$f(m,n)$ is the blurred version of the original image

α is the weighting fraction

$f'(m,n)$ is the sharpened result

Then, a normalised difference index using green and red channels was selected to improve the contrast in the image while the amount of information was significantly reduced. Table 1 shows the flow chart of the algorithm mentioned.

RESULT, ANALYSIS AND DISCUSSION

This method was proposed to overcome the problem of uneven illumination which caused the unsuccessful of extraction of leaves from non-green background. The initial steps begin for green leaves detection by removing the image backgrounds. The first step was resized the image to 256 x 256 pixels.

Step 1: Resize the original RGB image to 256 rows and 256 columns.

Step 2: Convert the RGB channel to HSV using

$$H = \cos^{-1}\left\{\frac{\frac{1}{2}[(R-G)+(R-B)]}{\sqrt{(R-G)^2+(R-B)(G-B)}}\right\} \tag{9}$$

$$S = 1 - \frac{3}{R+G+B}[\min(R,G,B)] \tag{10}$$

$$V = \frac{1}{3}(R+G+B) \tag{11}$$

Step 3: Smooth the image.

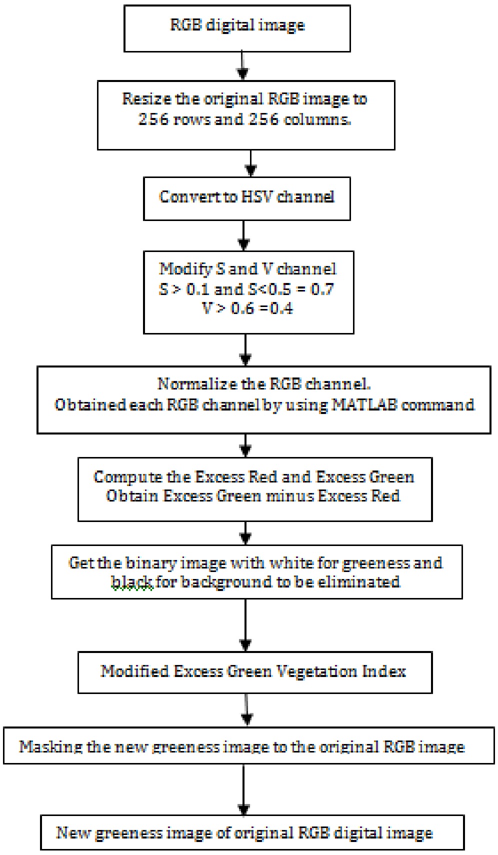


Table 1. Flow Chart of Modified Excess Green Vegetation Index

The result after image smoothing in HSV channel is illustrated in Figure 3.

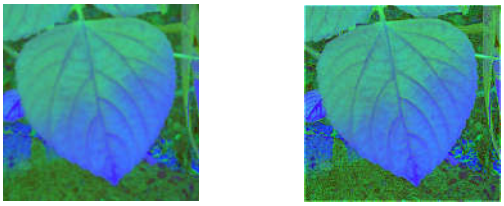

HSV Channel Image
Filtered HSV Channel Image

Figure 3. Image obtained after image smoothing in HSV channel

Step 4: Do the modification to:

S channel

Pixel values between 0.1 and 0.5 were forced to 0.7.

V channel

Pixel values greater than 0.6 were forced to 0.4.

The result after HSV modification is illustrated in Figure 4.

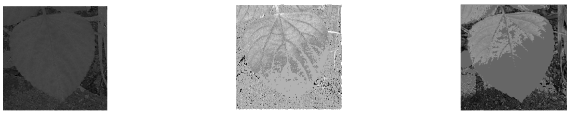

H Channel Image
Modified S Channel Image
Modified V Channel Image

Figure 4. Results obtained after modification of S and V channel

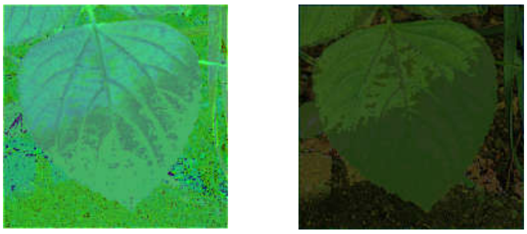
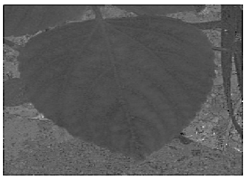

Modified HSV Channel Image
Modified RGB Channel Image

Figure 5. Results obtained for HSV channel and RGB channel after modification of S and V channel

Step 5: Normalize each RGB channel using Equation 4.

Normalized Red Channel Image



Normalized Green Channel Image

Normalized Blue Channel Image

Figure 6. Results obtained after normalization

Step 6: Obtained each RGB channel by using Equation 3.


Red Channel Image
Green Channel Image
Blue Channel Image

Figure 7. Results obtained for each RGB channel

Step 7: Compute the Excess Red representation using Equation

Excess Red Image

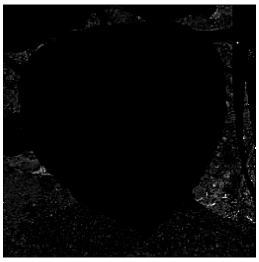


Figure 8. Results obtained for Excess Red

Step 8: Compute the Excess Green representation using Equation 6

Excess Green Image

Figure 9. Results obtained for Excess Green

Step 9: Obtain Excess Green minus Excess Red using Equation 7. After this, the image will be mentioned as new greeness image.

Excess Green Vegetation Index Image

Figure 10. Results obtained using Excess Green Vegetation Index

The new greeness image was masked on to original image as shown in Figure 3 and Figure 7. The new masking image was the image without non-green background. In other words, the leaves with black background.

Step 10: Creating 3 channel mask
repmat(d, (1, 1, 3));

Step 11: Apply mask to the original RGB image to eliminate the complex background

z(mask_three_chan) = 0

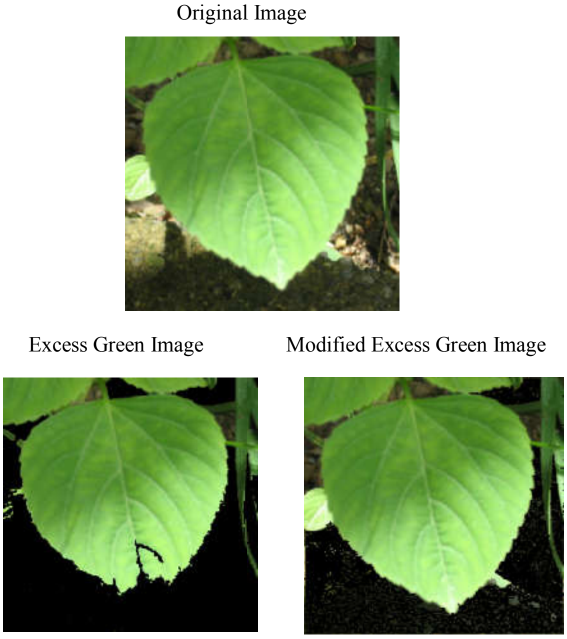
Original Image

Modified Green Image Only

Figure 11. Results obtained after masking to original image

In order to eliminate the non-green background to ease the further segmentation process, a few experiments were done to compare the performance of those methods in reducing the non-green background without effected the object to be extracted. The methods mentioned included Otsu's thesholding, Excess Green Vegetation Index and Modified Excess Green Vegetation Index. Since in certain condition the previous method mentioned above fail to extract complete greeness in such situation, we believed that, this modified method could overcome almost 80% of this problem. The main modification focused on HSV channel. The S and V channel were modified such that the main area of object of interest or foreground could be extracted successfully. In other words, the extraction of greeness was not influence by the uneven illumination.

Figure 12 - 14 show the result after comparing the three methods for the same input images.



Original Image

Excess Green Image

Modified Excess Green Image

Figure 12. Comparison between Excess Green Vegetation Index and Modified Excess Green Vegetation Index

Original Image

Excess Green Image Modified Excess Green Image

Figure 13. Comparison between Excess Green Vegetation Index and Modified Excess Green Vegetation Index

Original Image

Excess Green Image Modified Excess Green Image

Figure 14. Comparison between Excess Green Vegetation Index and Modified Excess Green Vegetation Index

Conclusion

This method was proposed to overcome the problem of uneven illumination which caused the unsuccessful of extraction of leaves from non-green background. Since in certain condition the previous method mentioned above fail to extract complete greeness in such situation, we believed that, this modified method could overcome almost 80% of this problem.

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