Techniques used in Eliminating Non-Green Background for Leaf with Complex Background- A Review

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Abstract

In computer vision, difficulty in leaf segmentation from complex background still requires extensive research. This complex background is produced when the leaf image is captured in a natural environment. The uncontrolled sunlight conditions make it difficult to detect the green area of the image. First, before the leaf could be segmented for the purpose of leaf identification, the unnecessary background need to be eliminated. The process is called greenness identification. This paper review the methods used to eliminate non-green background for leaf with complex background in order to ease the process of leaf identification.

Keywords: Leaf segmentation, complex background, index based method

Introduction

Now a day, the technology has grown rapidly. A computer vision technology is used in order to identify plant species or quality inspection (Razali, 2011). The visualization and the cost is effective as a result of the development of computer technology, processing and analysis (Abdullah et al., 2007). The traditional identification or quality checking in is very inefficient (Kiratiratanapruk & Sinthupinyo, 2011). In addition, it extremely depends on human skill and experience which usually contribute to errors.

Plants identification is the technique used to match a sample plant to a recognized group of one or more populations of an organisms. Since most types of plants have unique leaves which are different from each other based on a number of characteristics hence, to identify the plant species, leaf recognition is the best and easiest way compared to other criteria. Leaf recognition is a process of identifying plants by using the images of its leaves.

Thus, leaf segmentation is an essential step for automatic leaf recognition and plant identification. However, it is still a very challenging task to extract a single leaf from images with complicated background such as with some interference and overlaps between two adjacent leaves (Rong et al., 2014; Wijethunga et al., 2008). The complex background in this context refers to an image captured outdoor in natural scene. The image of the target leaf, with complex background, may be touching or overlapping with other leaves. Due to that, the problem arises when dealing with objects of uniform intensity (Kazanov, 2004). The complex background may also consist of soil, residue, branches etc. (Guru & Mallikarjuna, 2010). Therefore, the process of target leaf segmentation could be a difficult and challenging task (Pahikkala et al., 2015; Anjomshoae et al., 2014).

In reality, the brightness and contrast of outdoor captured image are extremely affected by uncontrolled illumination condition. Furthermore, the background of the plant image captured in outdoor environment is more complex than that of in greenhouse. Hence, it is impossible to completely separate the vegetation from the background under naturally changing outdoor lighting condition since all these methods are threshold-based, Therefore, a more robust and practical method for greenness identification is highly needed (Yang et al., 2015).

Techniques Used for Eliminating Non-Green Background

Previous studies have reported that leaf images captured in the outdoor environment are not the ideal images as they may be affected by uncontrolled illumination condition (Anantrasirichai, N., Hannuna, S. & Canagarajah, N., n.d.). The uncontrolled illumination condition may be influenced by whether condition and time the images are captured. The images may also contain complex background. Soil, residues, other overlapping/touching leaves and etc. are considered as complex background. Therefore, Anantrasirichai et al. (n.d.) highlighted the needs of eliminating the non-green objects or background contained in the images in order to ease the process of leaf extraction. The process mentioned above is called greenness identification. The process is essential step for leaf segmentation where the leaf images are captured outdoors. It is because greenness identification could influenced the successful of the leaf extraction process.

Visible Vegetation Index

Many researchers have been struggling to develop methods to identify the greenness. Traditionally, the methods used for greenness identification are based on visible vegetation index (Yang et al., 2015). The Visible Vegetation Index provides a measure of the amount of vegetation or greenness of an image using only information from the visible spectrum. It is well known that information in the near infrared is necessary to distinguish and separate vegetation from soil or ice surfaces in satellites imagery.

Index-Based Method

However, other researchers (Meyer & Neto, 2008) who had looked at index-based method have investigated the performance of the other methods. There were excess green index (ExG), the excess green-minus excess red index (ExG-ExR) and ExG-ExR with Otsu thresholding. Tang et al. (2009) carried out a few steps to eliminate non-green background from leaf images captured outdoor. The authors applied ExG – ExR (Meyer & Neto, 2008) to eliminate leaf from non-green background. Since the author believed that the common colour of leaf is always blue by visualization, hence the Otsu thresholding was applied to ExG-ExR to decrease the non-green background. Then, morphological operation was used to refine the small holes.

As a result of the reading, it is found that many researchers are keen to use the index based method in separating plants from complex background. Tang et al. (2009) and Anantrasirichai et al. (n.d.) used the same approach in separating leaf images from the background. Similarly, Anantrasirichai et al., (n.d.)) have also applied the index-based method in order to extract leaf from the background. The authors applied the ExG – ExR in their steps. The difference between these vegetation indexes are used to separate the region into two groups. The groups were created based on Otsu threshold. The threshold was set at one standard deviation below the mean value if there exist more than one peak. The authors have also added the extra state to classify the region as background when the blue value is higher than the green value.

Zheng et al. reported a novel and practical steps to extract greenness from complex background (Zheng, Zhan & Wang, 2009). HSV colour space was used together with the RGB image. Hence the goal was to extract the leaf image from the background. The authors came out with six features which were G – R, G – B, H, S, x and y where x and y represent the position of pixels. Mean shift image segmentation algorithm was employed to further segment the image (Zheng et al., 2009). The process was continued with Back Propagation Neural Network (BPNN) to identify whether the image belongs to green object. Even though the performance of the proposed method is better than ExG and Colour Index of Vegetation Extraction (CIVE), but it is not suitable for real time application since it took long time to run.

Moorthy, Boigelot & Mercatoris, (2015) proposed the Bayesian model to segment the green vegetation in real filed. They conducted experiments to evaluate the greenness of sugar beet and maize plants. The process involved both colour space which were RGB and HSV colour spaces. The features obtained from normalized RGB values, HSV components and G-R. A naïve Bayesian model was trained with these features to segment the images. The detail steps can be found in (Moorthy et al., 2015). The efficiency of the proposed method was compared to three others index based methods which were ExG, ExG-ExR and CIVE. The author claims that the proposed algorithm performed better compared to the rest.

Based On HSV Colour Space

Yang et al. (2015) proposed a technique called HSV decision tree to identify the greenness of plant images. The goal of the proposed method is to improve the robustness of the greenness identification method. The proposed method has successfully extracted the crop images from the background in various environmental conditions. The effectiveness of the technique has been tested and compared with the existing techniques. The process started by converting the RGB colour space image to HSV colour space. Yang et al. (2015) claim that illumination effect could be avoided by converting the RGB image to HSV colour space. By representing channels in HSV colour space, majority of the background pixels were excluded according to their hue values as compared with the ones of green plants. Next, a combined condition of H, S and V channels was set to remove the pixels of wheat straws. Therefore, all remaining pixels were green plants. The proposed method effective in distinguishing green plants but inefficient in uneven illumination.

There are also researchers who do not use the index based method for the purpose of reducing non-green background from the plant images. Many of them used the adaption of RGB or HSV image in their proposed method (Hamuda, E. et al., 2016; Su et al., 2014; Xia et al., 2013; Lin Kaiyan, L. et al., 2013; Wang et al., 2005).

Hamuda, E. et al. (2016) also used HSV colour space to automatically detect crop under natural illumination. The HSV colour space was used to differentiate crop, weeds and soil. The process involved five pre-processing steps in order to extract crop from the background. The process begun by resizing the original image so that computational time would be reduced. Gaussian filter was used to enhance image quality simultaneously reduced the noise. The process continued by converting the RGB image to HSV colour space. Then the region of interest (ROI) is obtained by filtering the HSV channels between the minimum and maximum values. The details of minimum and maximum values as well as the thresholding can be found in (Hamuda et al., 2016). Then, the morphological operations were employed to deal with overlapping region. The morphological erosion operation of the structuring element 3 x 3 was used to eliminate the remaining isolated white pixels while dilation of the 7 x 7 structuring element was performed in order to retrieve the desired objects. Although the proposed method had given better results as compared to HSV decision tree proposed in (Yang et al., 2015), a drawback accompanying with the approach was its dependence on colour.

In 2014, the author (Su et al., 2014) said that HSV colour space gave better performance than grey scale image. According to Su et al. (2014) leaf marker was created in order to eliminate the targeted leaf from background. The process of creating leaf marker was done in the HSV channel. The range for green was defined in order to create the leaf marker, while the value outside the range were addressed to background (Su et al., 2014).

Other Methods

Xia et al. (2013) used Mahalanobis distance in order to remove the background of leaf image. The proposed algorithm only employed the RGB colour space. An additional refinement of the algorithm was created to improve the performance of leaf extraction especially in complex situations such as field condition and overlapping or occluded leaves since the experiments were conducted in greenhouse condition.

Kaiyan et al. (2013) proposed a new fuzzy C-means (FCM) algorithm for the same purpose as Xia et al. (2013). The FCM algorithm was based on colour quantization. The process started by adjusting the contrast and used the decorellation stretch transform to make the distribution of RGB space more uniform. Furthermore, the process could improve the dynamic range of the image. Then, the FCM was employed to extract the greenness from the background. The detail approach can be found in (Kaiyan et al., 2013). The segmented region than is converted to binary image hence reducing noise by employing the morphological operation. Connected components in a binary image than was labelled using Blob filtering. After that, the small holes in the object were filled. The author proved that the proposed method performed significantly in extracting the crop leaves from complicated background.

Another technique that did not use index based method to differentiate leaf from the background can be found in (Wang et al., 2005). Wang et al., (2005) conducted a series of experiments to classify leaf images from complex background. In this article, the pre-segmentation involves Otsu thresholding. Since Otsu thresholding itself was not efficient when dealing with complex background, therefore the erosion operation was combined with Otsu thresholding in order to obtain the marker in order to get the target leaf. Since the morphological operation involved erosion operation, hence the challenging part is to obtain a size of structuring element for the whole leaf images. However, the article was not explained in detail about the structuring element size used in the erosion operation.

Normalised Difference Index

Since the early 90's, studies had been conducted in order to produce a method for separating plants from the soil background for the purpose of detecting plant species. In 2000, Perez et al. (Meyer & Neto, 2008) introduced the Normalised Difference Index (NDI) that used only the R and G channels to form the NDI formula as expressed in Equation (1).

$$NDI = (G - R) / (G + R) \tag{1}$$

Excess Green Index

The excess green index (ExG) was proposed by Woebbecke in 1995. The author investigated various colour vegetation indices that were originally used chromatic coordinates and the modification of hue channel to differentiate green plant from the background. The colour vegetation indexes used in the article is expressed in Equation (2).

$$ExG = 2g - r - b \tag{2}$$

where r, g and b are the normalized colour in RGB colour space and R, G and B are the colour components of the input image. The *r*, *g* and *b* can be derived from Equation (3) to Equation (5), respectively.

$$r = \frac{R}{R+G+B} \tag{3}$$

$$g = \frac{G}{R+G+B} \tag{4}$$

$$b = \frac{B}{R+G+B} \tag{5}$$

Form the experimental results, it is proved that ExG yielded the best result in separating the green plants from their background. This technique has been widely used and cited in recent studies (Moorthy et al., 2015; Yang et al., 2015; Meyer. & Neto, 2008).

Excess Red Index

Excess Red Index (ExR) was originally introduced by Meyer in 1998 (Hamuda et al., 2016). Due to the fact that there are 64% of red cones in the human eye retina, 4% blue and 32% green have prompted Meyer et al. to introduce ExR which is then compared to ExG. Although ExR can separate green plants from the background, but it is not as good as ExG. The formula used for ExR is expressed in Equation (6).

$$ExR = 1.4g - b - r \tag{6}$$

Colour Index of Vegetation Extraction

Colour Index of Vegetation Extraction (CIVE) was originally proposed by Kataoka in 2003 (Hamuda et al., 2016). The R, G and B channels were used in the formula in order to differentiate plants from soil background. The formula for CIVE is expressed in Equation (7).

$$CIVE = 0.441r - 0.881g + 0.385b + 18.78745 \tag{7}$$

From the comparison made by Kataoka between the CIVE and Near-infrared (NIR) methods, it is proved that the CIVE has better performance than NIR (Hamuda et al., 2016).

Excess Green Minus Excess Red Index

Since the ExR introduced by Meyer in 1998 showed poor results compared to ExG, this has led Meyer once again to produce a combination of two colour indices, Excess Green minus Excess Red Index (ExG-ExR) in 2004. ExG is used to extract plants region while ExR is used to eliminate background noise. Equation (8) expresses the formula for ExG-ExR.

$$ExG - ExR = (2g - r - b) - (1.4r - g - b) \tag{8}$$

A comparative study revealed by Hamuda et al. (2016) that the colour index-based approach is simple to implement and very effective in real-time performance, however the accuracy decreases if the light is strong or poor. On the other hand, the threshold-based approach is fairly simple and quite effective in real-time processing. Even though the accuracy is fairly good but the requirement of threshold adjustment is needed for most cases.

Conclusion

Xiaodong Tang et al. (2009) and Nantheera Anantrasirichai et al. (2017) totally used vegetation index based method to obtained greenness from complex background in their studies. Zheng et al. (2009); S. Moorthy et al. (2015), Yang et al. (2015) and Xia et al. (2013) have also proposed their methods to eliminate non-green background. However, majority of the proposed methods were faced with the problem of uneven illumination in complex background. The non-green parts failed to be eliminated due to this problem. The uneven illumination could be raised from brighter/darker light, cloudy day, shadow, reflection and many more factors. In reality, the brightness and contrast of outdoor captured image are extremely affected by uncontrolled illumination condition. Furthermore, the background of the plant image captured in outdoor environment is more complex than that of in greenhouse. Hence, it is difficult to completely separate the vegetation from the background under naturally changing outdoor lighting condition since all these methods are threshold-based, Therefore, a more robust and practical method for greenness identification in uneven illumination is highly needed.

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