ENHANCEMENT OF INDIVIDUAL LEAF SEGMENTATION FROM COMPLEX BACKGROUND USING WATERSHED TECHNIQUE

by

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LIST OF ABBREVIATIONS

ANN	Artificial Neural Network
ASM	Active Shape Models
BPNN	Back Propagation Neural Network
CIVE	Colour Index of Vegetation Extraction
CSS	Curvature Scale Space
ExG	Excess Green Vegetation Index
ExG-ExR	Excess Green minus Excess Red
ExR	Excess Red Vegetation Index
FCM	Fuzzy C-Means
IS	Intelligent Scissors
KNN	K-Nearest Neighbour
LoG	Laplace of Gaussian
MCH	Moving Center Hypersphere
MEGVI	Modified Excess Green Vegetation Index
MLP	Multilayer Perceptron
MMC	Move Median Center
MSE	Mean Squared Error
NDI	Normalised Difference Index
NIR	Near-infrared
PNN	Probalistic Neural Network
PSNR	Peak Signal to Noise Ratio
ROI	Region of interest
SVM	Support Vector Machine

LIST OF SYMBOLS

μ	mean
σ	standard deviation
θ	skewness
γ	kurtosis
$MR_i(f)$	regional minima of a function
CB	catchment basin
$CB(f,MR_i)$	catchment basin associated with the regional minima
$DL(f)$	divide line of a function
$f(m,n)$	original image
$f_b(m,n)$	blurred version of the original image
α	weighting fraction
$f'(m,n)$	enhanced image
$\lvert\Delta f\rvert$	magnitude of vector Δf
Gx	Sobel operator in x direction
Gy	Sobel operator in y direction
$P_1,\ldots,P_9$	pixels' values for input image with 4 x 4 matrix
$f(x,y)$	digital image function
$b(x,y)$	structuring element
$(f \oplus b)(s,t)$	Gray-scale dilation of 3-D function
D_f	domain of f
D_b	domain of b
$(s-x)$ and $(t-y)$	domain of f, and x and y have to be in the domain of b
$(f \oplus b)(s)$	Gray-scale dilation of 3-D function
$(f \ominus b)(s,t)$	Gray-scale erosion of 3-D function
$(f \ominus b)(s)$	Gray-scale erosion of 1-D function
$f \circ b$	Morphological opening
$f \bullet b$	Morphological closing
$(f \oplus b)$	Dilation operation
$(f \ominus b)$	Erosion operation
M_i	set coordinates points in the regional minima
$P(x,y)$	image function

Tn	point in *P(x,y)*
$C(M_i)$	set of points in the catchment basin
C[n]	the union of flooded catchment basin portions at the stage *n*
G	connected component
C(n)	combination of foreground and background markers
MG(n)	foreground marker
M(n)	background marker

Peningkatan Segmentasi Daun Individu dari Latar Belakang Kompleks Menggunakan Teknik 'Watershed'

ABSTRAK

Dalam penglihatan komputer, kesukaran dalam segmentasi daun dari latar belakang yang kompleks masih memerlukan penyelidikan yang luas. Latar belakang kompleks ini terhasil apabila imej daun ditangkap dalam persekitaran semula jadi. Keadaan sinar matahari yang tidak terkawal menjadikannya sukar untuk mengesan kawasan hijau pada gambar. Walaupun terdapat banyak teknik yang berjaya digunakan untuk segmentasi daun tetapi masalah timbul apabila berhadapan dengan daun yang menyentuh dan bertindih. Oleh kerana daun sasaran dan daun yang tidak dikehendaki mempunyai nilai intensiti yang hampir sama, bahagian kritikal adalah untuk memisahkan daun sasaran yang biasanya menyentuh / bertindih dengan daun lain yang boleh menyebabkan kekeliruan antara sempadan daun bersebelahan. Walaupun teknik 'watershed' adalah teknik yang berupaya untuk memisahkan objek menyentuh atau bertindih, malangnya, teknik 'watershed' ini bersendirian untuk memisahkan daun individu dari latar belakang yang kompleks membawa kepada 'over / under segmentation'. Tujuan kajian ini adalah untuk menghapuskan latar belakang kompleks bukan hijau, untuk menambahbaik bahagian tepi di antara objek dalam gambar (tepi yang kabur) di antara daun tunggal dan daun bukan sasaran dan untuk meningkatkan kecekapan 'watershed marker control' bagi segmentasi daun tunggal dari latar belakang yang kompleks. Dalam kajian ini, tiga algoritma diperkenalkan untuk membantu dalam memisahkan daun dari latar belakang yang kompleks. Pada peringkat pertama, 'Modified Excess Green Vegetation Index' (MEGVI) diperkenalkan untuk mengatasi masalah cahaya yang tidak terkawal dalam menghadkan kawasan bukan hijau. Proses segmentasi daun individu dilakukan dengan proses yang disebut sebagai 'marker-controlled watershed transform'. 'Watershed transform' sebenarnya mempunyai keburukan di mana 'over / under segmentation' sering berlaku. Untuk mengatasi masalah 'over / under segmentation', dua lagi algoritma telah diperkenalkan dan dapat membantu menyelesaikan masalah tersebut. Oleh kerana daun yang ditangkap di luar biasanya menyentuh / bertindih dengan daun lain, tepi di antara objek dalam imej dipertingkatkan untuk membantu proses segmentasi. Proses segmentasi akan lebih berkesan sekiranya penanda dihasilkan dengan tepat. Dengan menjalankan ketiga-tiga algoritma ini, daun individu yang dikehendaki boleh dibahagikan dengan sempurna tanpa 'over /under segmentation'. Teknik yang dicadangkan memberikan kejayaan sebanyak 74.1% dari latar belakang kompleks berbanding dengan segmentasi klasik iaitu 0%, normal 'marker-controlled watershed transform' sebanyak 13.8% dan segmentasi menggunakan kaedah yang diperkenalkan oleh Xiaodong Tang sebanyak 9.5%. Hasil dari ujikaji ini, MEGVI yang dicadangkan mampu menghapuskan latar belakang bukan hijau dalam pencahayaan yang tidak sekata. Sementara itu, algoritma untuk penambahbaikkan tepi di antara objek dalam imej yang dicadangkan memberi hasil yang terbaik untuk meningkatkan tepi di antara objek dalam imej yang menyentuh dan menimpa. Pendekatan ini juga memberi manfaat dalam mewujudkan penanda hadapan untuk objek yang mempunyai bentuk yang tidak teratur. Teknik yang dicadangkan juga dapat mengurangkan 'over/under segmentation' apabila 'watershed transform' digunakan.

Enhancement of Individual Leaf Segmentation from Complex Background Using Watershed Technique

ABSTRACT

In computer vision, difficulty in leaf segmentation from complex backgrounds 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 picture. Even though there are many successful techniques used for leaf segmentation but the problem arise when we face with touching and overlapping leaves. Since both the target leaf and unwanted leaves have almost the same intensity values, the critical part is to segment the target leaf which usually touches/overlaps with other leaves which may create the confusion between the boundaries of adjacent leaves. Even though watershed technique is a powerful tool for separating touching or overlapping objects unfortunately, watershed transform itself for separating individual leaf from complex background leads to over/under-segmentation. The aims of this study is to eliminate non-green complex background, to enhance gradient of touching and overlapping edges (blur edges) between single leaf and non-target leaf and to improve the efficiency of watershed marker control for single leaf segmentation from complex background. In this study, three algorithms were introduced to assist in the segmentation of leaves from complex backgrounds. At first stage, Modified Excess Green Vegetation Index' (MEGVI) was introduced to overcome the uncontrolled light problems in limiting non-green areas. Individual leaf segmentation process is done by the proses called marker-controlled watershed transformation. Watershed transforms actually have disadvantages where over/under-segmentation often happens. In order to overcome over/under-segmentation problem, the other two algorithms were introduced and could help to solve the problem. Since leaf captured outside are usually touching/overlapping with other leaves, the edges between the objects in the image are enhanced to aid the segmentation process. The process of segmentation could be more effective if the accurate marker is created. By running these three algorithms, the desired individual leaves can be segmented perfectly without over/under-segmentation. The proposed technique gave 74.1% successful rate of leaf segmentation from complex background as compared to classical watershed segmentation of 0%, normal marker-controlled watershed segmentation, 13.8% and Xiaodong Tang watershed segmentation of 9.5%. From the experimental results, MEGVI is capable to eliminate non-green background in uneven illumination. While, the proposed gradient enhancement gave the best result in order to enhance the gradient image for touching and overlapping objects. A new algorithm to automatically obtain the foreground and background markers was proposed to improve the efficiency of the watershed marker control for single leaf segmentation from complex background. This approach is also benefits in creating foreground marker for irregular objects. The proposed technique also could reduced over-segmentation/under-segmentation when applying watershed transform.

CHAPTER 1: INTRODUCTION

1.1 Overview

Plants are very important organisms in the universe. This is because plants become dependent on other living things. They are plants which boast a remarkable ability to produce their own food through photosynthesis from carbon dioxide in the atmosphere. Furthermore, they provide the basis for the food web. Other living things cannot exist without the existence of plants.

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. Identification is a process to recognize an object with its appropriate name based on the similarities or differences between two or more elements. Plants identification is the technique used to match a sample plant to a recognized group of one or more populations of an organisms. The practice of identifying plants based on certain characteristics has occurred thousands years ago. The practice has led to the introduction of variety of methods which have been adopted for identification.

The ability to identify plants is very important for some reasons. From the perspective of plant management, this identification helps us to know the identity of the plants. This is because, knowing the identity of plants can determine that the plant is not weeds. In addition, it is also useful for early detection of undesirable new weeds and taking further action to redress the matter or problem. Furthermore, the identification of plant identities also ensures that the plant could only be eaten by us since some of the plants could be poisonous.

A plant can be identified using many features that are available on it. In addition, the features can be used to distinguish between plants, such as flower size, flower colour, flower period, seeds, odor, etc. Among them, leaves are the most popular characteristics for plant species identification since leaves can be found easily almost throughout the year. Furthermore, leaves are easy to capture as image that makes the potential identification commonly through their shape (Cerutti et al., 2013). The other characteristics may be more apparent. Due to that reason, leaves are often the popular characteristic since they are so easily observed.

In Computer Vision, many researches have been produced since the past decade. The research based on leaves features have are produced in order to help botanists and non-experts in plants identification. The technology is useful in providing imaging-based automatic analysis in various areas such as medical, agriculture and many more. Besides the leaf features such as leaf shape and leaf margin, the plants have a variety of other botanic features. Therefore, the identification of plant can be performed from several characteristics including flower colour, flower size, their odor, venation pattern, inflorescence and others. Since leaves of various types of plants are unique which are

different from each other based on a number of characteristics, therefore leaves can be popular features in order to perform plant identification. Therefore, to identify the plant species, leaf recognition is the best and easiest way compared to other criteria.

Thus, leaf segmentation is an essential step for automatic leaf recognition and plant identification. One-dimensional gray image histogram is not enough in order to select the threshold value in traditional approach (Han & Huang, 2010). According to the previous studies, the process of leaf segmentation are limited to plant leaf images in plain/ideal background. 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).

The watershed transform is a powerful technique for image segmentation (GurvinderKaur & LakhwinderKaur, 2013; Hsieh et al., 2006). The technique has been widely used in many fields since it is simple, intuitive technique. It is fast and can be parallelized (Grau et al., 2004). But, this technique itself has brought over a very bad segmentation (Acharjya, Santra & Ghoshal, 2013; Acharjya et al., 2013; Zghal & Masmoudi, 2010; Salman, 2006; Smolka, 2005; Noor et al., 1999). The controversy over

the drawback of classical watershed has raged for many years. Therefore Meyer proposed marker-controlled watershed transform in order to overcome the problem of over-segmentation. However, for segmenting individual leaf from complex background, this technique still produces over/under-segmentation. Recent developments in leaf segmentation from complex background using marker-controlled watershed segmentation have shown the need for improvement. Most studies of leaf segmentation still require post-processing to improve the condition of the extracted image. This makes the time to segment the leaves longer and the need of extra features or information. Therefore, it motivates the author to extract the leaves from complex background without going through post-processing or refinement stage.

1.2 Problem Statement

Leaf segmentation is an important step for automatic leaf classification and plant identification. But it is still a very challenging task to extract a single leaf from images with complicated background. The single leaf to be segmented is referred to the biggest/perfect leaf captured from outdoor. The existence of the soil, residues and most challenging problem which is touching/overlapping with other leaves could be considered as the complex background. Even though there are many successful techniques used for leaf segmentation but the problem arises when we face touching and overlapping leaves. Since both the target leaf and unwanted leaves have almost the same intensity values, the critical part is to segment the target leaf which usually touches/overlaps with other leaves which may create the confusion between the boundaries of adjacent leaves. However, the

previous research involved combination of two or more methods to successfully segment individual leaf from complex background. Even though watershed transform is a powerful technique to separate touching or overlapping objects (Singh, & Bawa, 2013; Xu et al., 2011; Gonzalez et al., 2008), but watershed transform itself in order to segment target leaf from complex background leads to over-segmentation. (Andrade et al., 1997)

1.3 Objectives

The main objective of the study is to segment individual leaf from complex background. These are tasks to be carried to achieve the main objective.

a) To eliminate non-green complex background.
b) To enhance gradient of touching and overlapping edges (blur edges) between single leaf and non-target leaf.
c) To improve the efficiency of watershed marker control for single leaf segmentation from complex background.