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Enhancement of template-based method for overlapping rubber tree leaf identification

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ABSTRACT

The position of rubber tree leaflets is one of the critical features for rubber clone classification. These leaflets exist in three possible positions: overlapping, touching, or separated. This paper proposed a template-based method for overlapping rubber tree leaf identification. Initially, the key point based feature extraction method is adopted. The key features of overlapping and non-overlapping leaf assist in identifying similar shapes through comparison, using the nearest neighbor algorithm. This process is implemented by constructing a directory which consists of various rubber leaf images with different positions. Next, the key points in the input leaf image are compared with the key points of the template image to identify the position of leaflets. The outcome of this study proves that the template-based method is suitable for overlapping and non-overlapping rubber tree leaf identification.

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1. Introduction

Rubber clone inspection and verification is an important process because it must guarantee that recommended rubber clones produce the maximum yield in future (Shigematsu et al., 2011). Plant experts examine rubber tree clones based on physical characteristics of leaves. Currently, researchers are investigating the automation of clone classification based on rubber tree leaflets (Ong et al., 2012). There are several features of rubber tree leaf to differentiate clone types. Leaf tip, leaf base, form of the leaf, and leaf margin are some of the features that differ rubber clone types. Another unique feature is leaflet position that is created by three compound leaflets radiate from one mutual leaf base (palmate leaflets) (Anjomshoae et al., 2015). These leaflets exist in three positions: overlapping, touching or separated. In our previous study (Anjomshoae, 2014), we discussed that these positions can be classified into two categories: overlapping and non-overlapping leaflets, based on the angle ranges of the petioles.

The identification of overlapping object structures is important not only for feature classification, but also for data analysis in general (Silva and Zhao, 2013). The recognition of overlapping objects in an image is challenging due to the inherited complexity of shape and background noises (Saba et al., 2010). It requires to infer the contour of occluded part in certain cases. Several techniques have been used to retrieve the information about overlapping object boundaries by involving Law's texture and Canny's edge detection (Canny, 1986; Kumar Mishra et al., 2012; Caballero and Carmen Aranda, 2012). Other researchers have also used contour-based retrieval methods for overlapping object identification (Zhang et al., 2012; Sun et al., 2013). However, a single contour-based retrieval method or a boundary detection method alone may not be suitable for the overlapping leaf identification because leaves have similar intensity levels.

Several researchers have confirmed the good fit of key point extraction methods for object recognition problems. The key point extraction methods are used for contour-based retrieval methods as well as template-based methods (Ye and Shan, 2014; Yoo et al., 2014; De Araújo adn Kim, 2011). To the best of our knowledge, the template-based recognition is an effective method for rubber tree leaflet position identification. This method is able to extract additional features such as corner, edge, and blob. The key features of overlapping and non-overlapping leaf can be used to identify similar shapes through comparison of the nearest neighbor algorithm based on various similarity measures. Therefore, this study addresses the problem of overlapping leaf identification using a template matching method through comparison of key points.

The common problem with the template matching method is increasing the accuracy of matching results. The wrong matches can be reduced by setting up a larger directory. However, the long iteration throughout the matching process is another consideration

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for the key feature based identification. Therefore, speeding up this process is crucial during the matching process. To increase the accuracy and speed up the process, this research enhanced the template matching result by several factors. First, the decrement of the distance ratio by creating a loop allowed matching more key points. Therefore, a limited number of directory images were used for the leaflet position identification. Second, the contrast adjustment process in the background of rubber tree leaf images increased the accuracy of matching results. The findings of this study indicate that reducing the number of template images decreases the execution time without affecting the template matching result. Based on the ground truth dataset validation process, the results of this study showed that the proposed framework outperforms the previous method.

The paper is organized as follows. The next section presents a general overview of overlapping object recognition, overlapping leaf segmentation and key point extraction methods for template-based recognition. Section 3 introduces the algorithm that adopted in the template matching process. In Section 4, the template-based overlapping rubber tree leaf identification framework is introduced. The experimental results and the performance evaluations are shown in Section 5. Section 6 concludes this paper with the overview of the proposed framework.

2. Related works

There are several research areas where object recognition methods have been applied successfully, such as image segmentation (Li et al., 2012), finger-print classification (Munir et al., 2012), large scale data analysis (Alzate and Suykens, 2011) and medical image analysis (Fabbri et al., 2014) among others. Although, several object recognition algorithms have been proposed in recent years, most of them considered only single objects; not touching or overlapping objects. However, there are some applications such as shape analysis (Clausen et al., 2007), text segmentation (Abella-Pérez and Medina-Pagola, 2010) and medical image analysis (Park et al., 2013), among others, where it is common that one or more objects might be overlapping. For these types of applications, overlapping object recognition is essential.

There are two major steps in the overlapping object recognition method: (1) segment the extracted contour into clusters; (2) group the segmented clusters which belong to the same class. However, there is no perfect method for segmentation due to different purposes (Melen and Ozanian, 1993). The contour segmentation mainly consists of two methods of geometrical features: Hough transformation method and curvature based method. Hough transform can project the contour pixels on a 2D image plane onto the parameter plane to find object segments (Ballard, 1981; Pei and Horng, 1995). Though, the randomized Hough transform method (Xu et al., 1990) could reduce the computational complexity, a random selection of contour pixels might cause a detection of false shapes when the objects are overlapped.

On the other hand, several researchers have developed various methods of overlapping leaf segmentation. Valliammal proposed an approach to extract the leaf edges through a combination of thresholding method and H-maxima transformation (Valliammal and Geethalakshmi, 2011). The morphological filters like the h-maxima transform belong to the class of connected operators. They preserve contour information, however, whether this is an advantage or disadvantage depends on the application. Furthermore, Valliammal and Geethalakshmi (2012) worked on non-linear k-means algorithm to improve the segmentation results for high resolution images. At the first level of segmentation K-means clustering is carried out to distinguish the structure of the leaf. The process continued with Sobel edge detector to eliminate the unwanted segments and extract the exact part of the leaf shape. However, this method does not separate touching objects well, specifically, if the overlapping objects have a similar level of intensity. Jie-Yun and Hong (2011) used color features for segmentation purpose. The traditional transformation from RGB model to HSI model is improved, at the same time the leaf color information is extracted using the similarity distance between pixels. It has a high degree of accuracy in 24-bit true color images, on the other hand, the algorithm is not producing rapid result. The active contour model is another method for image segmentation that Cerutti et al. (2011) used in their project with a particular enhancement of the method proposed by Guillaume et al. (2011). He presented a system for leaf segmentation in natural images that combines basic segmentation steps with an estimation of descriptors shows the general shape of a simple leaf. The algorithm has promising results compare to standard active contour; however, the algorithm is not suitable for overlapping objects.

Although, several clustering algorithms have been reported in the literature addressing the problem of overlapping clusters, they have some limitations in practical problems. For this reason, we have considered addressing the problem of overlapping clustering through a template-based method using SIFT features. SIFT is the shortened form of "Scale-invariant feature transformation". The dominant proponent of SIFT is Lowe, who in 1999, proposed SIFT to address feature matching challenges that arise due to scaling, rotation, and transformation. The SIFT descriptor is robust to moderate perspective transformations and illumination variations. The standard SIFT algorithm firstly detects interest points by searching for the scale-space extrema of differences-of-Gaussians (DoG) within a difference-of-Gaussians. Next, the position-dependent histograms of local gradient directions around the interest points are statistically accumulated as the SIFT descriptor. In the end, the SIFT descriptor is utilized to match the corresponding interest points between different images. Experimentally, the SIFT algorithm has been proven to be useful in practice for image matching and object recognition, including image copy detection (Ling et al., 2013), multi-object recognition (Kim et al., 2012), image stitching (Brown and Lowe, 2007), neurosurgery (Qian et al., 2013), human action recognition (Liu et al., 2013), video tracking (Saeedi et al., 2006).

Recently, several SIFT-based template matching methods were proposed. De Araújo adn Kim (2011) presented a grayscale template matching algorithm for matching colored objects. However, the execution time is the main drawback of this method. Gurjal and Kunnur (2012) used the template matching algorithm for the hand gesture recognition. This algorithm compares the given data with a data set to determine whether or not it can be classified as a member of the stored data set. This method is computationally appropriate and can be quite accurate for a fewer number of gestures. The algorithm loses its efficiency, however, for a larger data set.

3. Methodology

In this work, SIFT key point detection method was used to detect the main features of the rubber tree leaves, such as occluded region of the leaflets and edges. If the region is occluded, SIFT is not only extract the edge and corner key points of that region, it extracts the blob and ridge features as well. If the leaves are separated, the region between leaflets remains blank and no feature will be detected as demonstrated in Fig. 1.

SIFT algorithm is defined through four main phases: finding the scale space extreme, key point localization, orientation assignment, and key point descriptor.

Finding Scale-space extreme: This phase involves examinations on all scales and image locations that are implemented by a difference-of-Gaussian (DoG) function. In the region of 3×3, the greatest or the smallest value between them can be found by

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