ADAPTIVE K-MEANS METHOD FOR SEGMENTING IMAGES UNDER NATURAL ENVIRONMENT

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ABSTRACT. This paper evaluates the performance of two conventional clustering-based segmentation methods and proposes an improved method for segmenting images captured under natural environment. Image segmentation refers to a process that separate area of interest from the background with the aim to extracts object of interest only for further image analysis. However, the segmentation process is very challenging for experiment conducted in outdoor environment due to the non-uniform illumination. Different illuminations produce different colour intensity for the object surface which leads to inaccurate segmented images. The widely used clustering-based segmentation methods are K-means and Fuzzy c-means (FCM). However, both methods have several limitations in producing good quality segmented images of objects that are exposed to the natural illumination. Therefore, this paper proposes an improved clustering-based segmentation method (Adaptive K-means) that is able to partition natural images accurately. The performance of three segmentation methods are evaluated on fruit images and compared quantitatively using similarity index (SI) and Tanimoto Coefficient (TC). The results show that Adaptive K-means has the ability to produce more accurate and perfect segmented images compared to the conventional K-means and FCM.

Keywords: segmentation, clustering, K-means, Fuzzy c-means

INTRODUCTION

Over the past several years, image segmentation technique is gaining importance in agriculture areas especially for fruit grading. Image segmentation is a process of dividing an image into distinct regions with the aim to extracts object of interest from the background. Segmentation was known as one of the critical tasks in image processing technique because the quality of segmented images influenced the results of the remaining processes (Karasulu & Korukoglu, 2011; Sathya & Manavalan, 2011). The main purpose of the segmentation process is to ensure that only the object of interest will be processed during the object analysis phase. However, the process of segmenting images has become more difficult for the images captured under natural environment due to the complex background and changeable illumination on these images. Low quality of segmented images often leads to degradation of the object measurement and classification processes.

Therefore it is important to have an effective segmentation technique that is able to divide an image into foreground and background, accurately and effectively. In this study, aninnovation to the current methods was developed to increase the segmentation accuracy and thus enable better classification of images in inconsistent illumination conditions.

CLUSTERING-BASED SEGMENTATION ALGORITHMS

A clustering technique is an unsupervised classification of objects into meaningful groups or clusters based on their similarity. Recent years, variety of extended clustering-based segmentation techniques has been explored in the literature. The advantage of clustering technique is its ability to classify either foreground or background without prior knowledge about the distribution of the pixels.

There are two types of clustering techniques: crisp and fuzzy techniques. The crisp clustering is applied when a data point is assigned to only one cluster while fuzzy is suitable for data point which is assigned to more than one cluster. In this study, the data point refers to each pixel in the investigated image. Nevertheless both crisp and fuzzy clustering techniques have different capabilities in segmenting images. Therefore the following section discusses the most well-known methods for clustering images which are K-means and Fuzzy c-means (FCM) methods.

K-means Method

The most well-known and recognized crisp clustering method is K-means (MacQueen, 1967). K-means method was used in this study because this method has the ability to classify images quickly and efficiently (Bharati & Subashini, 2013; Halder & Dasgupta, 2012; Ahmed & Ashour, 2011). This method is also simple because it can easily classify a given data set or pixels through a certain number of clusters. However, K-means method does not guarantee the best clustering result if the initial centroids are randomly chosen. It was reported that K-means produces good result only when the centroids are correctly initialized. Nevertheless, choosing the correct initial centroids is challenging because the initial centroids were highly dependent on the condition of the entire original image. The selection of the proper centroids becomes more difficult for images which are captured under natural environment.

For this study, FCM was also studied because previous researches have shown that FCM is better than K-means in segmenting some investigated images.

Fuzzy C-means Method (FCM)

For fuzzy technique, FCM is the mostly used method because it is able to classify data into several clusters. FCM (Liu & Xu, 2008) allows data point to be assigned to one or more clusters. The degree of being assigned to a certain cluster is indicated by the membership values. The larger the membership values, the higher the confidence in assigning data to the particular cluster. This method is efficient and easy to implement (Dante et al., 2013; Aghajari & Gharpure, 2012). However, FCM is not extensively applied for classifying images captured under natural environment because of its difficulties in segmenting images with the existence of non-uniform illumination.

K-means and FCM methods are very sensitive to the initial cluster values where different initial cluster centre may produce different segmentation results. Determining the best initial cluster is a challenging and difficult task for images which captured under natural environment. Another limitation of K-means and FCM is that both methods classify an image into clusters based on single global intensity value which is only appropriate if all the pixels of the investigated area have sufficient different intensity from the pixels of the background. Therefore determining the best single value for the entire image is very difficult if the area being investigated has similar colour to the background.

In order to overcome this limitation, an improved segmentation method is required to segment the investigated objects perfectly and correctly. In this study, an improved clustering-based method which integrates few processes to K-means was developed. The discussion on this new segmentation method is presented in the following section.

An Adaptive K-means Method

A new segmentation method was developed using an approach that separates an image into sub-images and then these sub-images are further segmented individually based on local intensity values. The local intensity value is very significant for segmenting images under natural environment because it is able to judge the variations of illumination in sub-images and therefore able to automatically adjust the local value based on illumination condition of the corresponding sub image. For individual segmentation, K-means method is used to segment all the sub-images sequentially. Although K-means is sensitive to the initial cluster center, this method is chosen because of its ability to segment each image without any priori information on the image. The new segmentation method is named Adaptive K-means and consists of five main steps.

Step 1 refers to a process of separating an original image into sub-images in order to produce a local intensity value for each sub-image. Step 2 refers to a conversion process of each sub-image into LAB colour format to allow easy separation. The LAB format was chosen because it can distinguish colours in the images easily and correctly. Step 3 refers to the segmentation process using K-means method. The output of this process is a binary image which is either classified as interest area or background area.

Step 4 is a process which implemented for the images which are wrongly classified. In this stage, the pixel in the centre of each sub-image is firstly identified. Step 5 refers to merging process of all segmented sub-image to produce a complete segmented image

MATERIALS AND METHODS

The segmentation process consists of three major steps; image acquisition, image pre-processing and image segmentation.

Image Acquisition

In this study, 40 images of jatropha fruit were captured under natural environment to get realistic data. A charge coupled device (CCD) digital camera was used to capture jatropha fruit in a jatropha orchard in Universiti Teknologi Mara (UiTM), Perlis. The samples of these images which are in RGB colour format are shown in Figure 1.

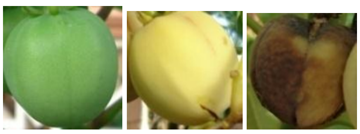


Figure 1. Sample of Jatropha Images

Image Pre-processing

All the RGB images were then resized into 474 x 474 pixels in order to reduce the computational processing time and to have standard pixel intensity values for all images.

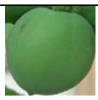
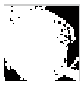
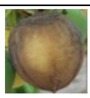
Image Segmentation

Segmentation is process to separate the interest area from its background. The segmented image is a binary image where '1' (white) and '0' (black) pixels represent area of interest and background, respectively. In order to evaluate the effectiveness of the conventional methods, the first segmentation process was conducted by using K-means and FCM methods. Next, Adaptive K-means method was used to determine the capability of this new method over both conventional methods.

RESULTS AND DISCUSSION

This section evaluates the performance of K-means, FCM and Adaptive K-means. The evaluation was made based on the degree of similarity between segmented images and ground truth. Ground truth is a series of binary images which are created manually and used as reference images for the evaluation. For the binary images, pixels with value '1' denote the area of interest and pixels with value '0' denote the background area. The degree of similarity between the segmented images and ground truth is measured using SI and TC values. The SI and TC values measure the number of common pixels in foreground and background areas that are shared by both segmented and ground truth images. The results of SI and TC for FCM, K-means and Adaptive K-means methods are presented in Table 1.

Table 1. Similarity Index (SI) and Tanimoto Coefficient (TC) for Different Segmentation Methods

			Segmented Images		
Original images	Ground Truth		FCM	K-means	Adaptive K-means
		SI TC	 0.941 0.888	 0.927 0.863	 0.962 0.928
		SI TC	 0.045 0.023	 0.896 0.812	 0.936 0.879
		SI TC	 0.702 0.541	 0.871 0.772	 0.954 0.912
		SI TC	 0.529 0.360	 0.664 0.497	 0.899 0.817
		SI TC	 0.288 0.168	 0.914 0.814	 0.952 0.908
		SI TC	 0.144 0.078	 0.789 0.652	 0.886 0.795

From the results, it was discovered that Adaptive K-means method has the ability to produce segmented images that are very similar to ground truth images. The similarity of these images is shown by the SI and TC values. For all images, the SI values for Adaptive K-means are higher than the SI for FCM and K-means. The results show that the segmented images produced by Adaptive K-means are more similar to the ground truth. Moreover, Adaptive K-means has consistently produced the SI with the values more than 0.81. According to Viera & Garrett (Viera & Garrett, 2005), the segmented image with the SI value more than 0.81 is defined as almost perfect segmented image. Even though FCM and K-means are able to achieve this level of similarity for several images, Adaptive K-means is able to achieve this level of similarity for 100% of images.

The TC values for Adaptive K-means are also higher than those values for FCM and K-means. This measurement also proves that the segmented images for Adaptive K-means are nearer to the ground truth. Therefore, Adaptive K-means has the ability to improve the segmented images even though the objects were exposed to natural illumination.

CONCLUSION

Segmentation is an essential process used for analyzing images in computer vision because digital images must be partitioned into different regions. However, segmenting the images captured under natural environment is difficult because the images are exposed to the natural illumination. Segmenting these images using FCM and K-means only is not enough to isolate the area of interest from its background. This is because FCM and K-means are very sensitive to the initial centroids where the inappropriate initial centroid resulting in low quality segmented images. Therefore, a new improved segmentation method is needed to produce appropriate initial centroids in order to improve the accuracy of segmented images. The new method is named Adaptive K-means and has the capability to isolate the area of interest from its background accurately and correctly.

The first strength of Adaptive K-means is its ability to separate an original image into several sub-images which enable it to automatically produce the best initial centroid for each sub-image. The second strength is the addition of inverse process which is used to reverse the pixel of binary image. These two processes allow Adaptive K-means to segment images more accurate even though the images are exposed to the natural illumination.

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