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Research paper



Fusion CLAHE-Based Image Enhancement with fuzzy Set Theory on Field Images

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Abstract

In this paper, a new fusion of Contrast-Limited Adaptive Histogram Equalisation or CLAHE-based method is proposed to enhance field images. The field images, which are low resolution images, were taken using a camera or other devices such as smartphones with lower quality as compared to the lab images with proper setup. The field images had low contrast and were blurred and unsharp due to inconsistent setting or environment exposures. Image enhancement helps to enrich the perception of images for better quality, reduce impulsive noise, and sharpen the edges with the help of different image enhancement techniques. The main attraction towards the enhancement of this research area is due to the additional knowledge and hidden information provided by the results of this procedure, which will further be used for many different useful purposes. This research proposes a fusion of CLAHE-based with Fuzzy set theory. An optimisation technique was applied to increase the enhancement ratio. The result of the proposed fusion method was compared with the standard method as a benchmark. The obtained value is compared by using image quality measurement techniques. The proposed fusion method produces better quality and enhanced images and required minimum processing time than the other methods.

Keywords: *Image Enhancement; CLAHE; Fuzzy;USM.*

1. Introduction

This study used various leaves images from an online repository, Leafsnap. Images were obtained from the random leaves collection on Leafsnap. Leafsnap contains beautiful high-resolution images of leaves, flowers, fruits, petioles, seeds, and bark. The lab images were captured by a professional photographer at the lab with proper setup and equipment. Besides that, these low quality images are known as field images were taken by mobile devices in the outdoor environment. In this study, a preliminary experiment has been conducted to run different enhancement methods from previous research and to come out with a new proposed fusion method.

The low quality images contain noise, shadows, varying amounts of blurriness, and illumination patterns [1]. This problem becomes a limitation in many fields such as face recognition. High resolution images are required to detect and tag persons in the photographs for the purposes of criminal investigation, diseases detection, and many applications that can be found in smart cities. Additionally, digital images are used in the medical field, such as x-ray and scanners [2] [3]. The accuracy of these applications depends on the quality of the image obtained [5]. A good camera is expensive, and the image produced depends on external factors such as light. To make these applications work properly, image enhancement is as important as, for example, a good disease detection algorithm [6]. Furthermore, image enhancement can be used for pictures taken in bad light conditions or to improve the contrast of an image in normal photographs [4].

The main goal of the proposed work is to obtain a better quality of images by a fusion of certain methods. The enhanced field image quality values have been compared with other images with different enhancement methods applied. This research presents the image enhancement techniques, which are Contrast-Limited Adaptive Histogram Equalisation (CLAHE), Unsharp Masking (USM), and Fuzzy. There are various image enhancement techniques that exist in the digital domain, among them is the CLAHE-based image enhancement technique, which provides good picture quality and is widely used as compared to other techniques [7], [6], [8]–[11]. A pixel-based fusion algorithm is employed to effectively improve the visibility of field images of the leaves.

2. Overview

Low quality image can be identified as a field image that consists of typical images taken by mobile devices in the outdoor environment. In agriculture, field image is required in order to obtain fast result in identifying the disease of a leaf for treatment purposes. Having good visual quality of leaf images, captured in the lab or in controlled environments (i.e., limited to leaf images with side views only, clean background, good illumination, and containing just one leaf in an image) may lead to an accurate result in identifying the disease; however, it will consume time and incur cost.

As a result, image enhancement is significant to improve visual quality in field images. Image enhancement basically improves the interpretability or perception of information in images for human viewers and provides `better' input for other automated image processing techniques. CLAHE is the most popular enhancement method for low quality image due to its performance and simplicity. Nevertheless, applying CLAHE alone in image enhancement will not remove noise completely, especially in contrast stretching and it is very limited in local-based images in tile presentation. On

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the other hand, the Fuzzy set theory can improve brightness of both local and global-based images as it can brighten the surrounding, by having uniform density and dark boundaries.
Therefore, in this proposal, the fusion approach of CLAHE with the Fuzzy set theory will be proposed. This process is inclusive of an enhanced CLAHE method to perform contrast stretching and adaptive histogram equalisation of field images. Meanwhile, the Fuzzy method will improve the brightness and enhance the edge of the images. The result of field image enhancement from this fusion approach will be measured and compared for each image.

3. Related Works

In the agriculture field, it is important to protect plants and to catalogue the various types of plant, diseases, and also the treatment needed for the plants to remove the disease. Conventionally, lab images are used to catalogue the plants. Lab image can be defined as a good visual quality of leaf image, captured in the lab or in controlled environments (i.e., limited to leaf images with side views only, clean background, good illumination, and containing just one leaf in an image), which lead to an accurate result of identifying the disease. However, taking lab images is very time consuming and could increase cost [1, 3]. Another option is to catalogue the field images, which consists of a "typical" image taken by mobile devices in an outdoor environment. This type of image can easily and quickly capture any plant and leaf in any environment with a low amount of storage memory. Nevertheless, these images contain varying amounts of blurriness, noise, and have low or high contrast both in the edge and image areas [2, 5].
Image enhancement is required to remove noise, edge or boundary enhancement, automatic edge detection, and automatic contrast adjustment [3, 4, 5] since multiple noises may affect the quality of nature images. Most field images have low contrast as their features have a low range of reflectance in any waveband. Image enhancement techniques are used to highlight certain features such as: (i) increasing the contrast, and (ii) changing the brightness level of an image, so that the image looks better [5, 6].
CLAHE is the most popular enhancement method in improving the contrast of the image. Applying CLAHE on the field image will result in a better image by stretching the histogram of the image so that the full dynamic range of the image is filled. The basic idea behind contrast stretching [7] is to linearly increase or decrease the contrast of the given image. However, CLAHE works on small areas in an image, called tiles, as opposed to the whole image, which can be restricted to abstain from increasing any noise that may be available in the image [8].
Most image features such as brightness, darkness, boundary, and region are fuzzy in nature. Since CLAHE focuses on contrast in small areas of the image, Fuzzy set however focuses on fuzzy event on the sample space [9]. Fuzzy event can be defined as a sample space that contains the most information when its associated entropy is at the maximum. Therefore, using the Fuzzy set theory can improve the brightness of the whole image as it can brighten the surrounding, by having uniform density and dark boundaries [10]. The Fuzzy set theory can provide both local and global information to ensure that the fine details of the degraded image are enhanced in terms of preserving brightness and details without amplifying existing noises [11].
The proposed image enhancement method of fusing CLAHE with the Fuzzy set theory may improve contrast and brightness, and enhance the edge of the whole image as in small areas or the whole image in field images. All these characteristics are important in contributing to a more effective plant recognition system. This research can assist many scientists and professionals in solving problems in environmental biology. This proposed method is more flexible compared to previous research study using algorithm based on CLAHE and USM only.

4. Objectives

The main objectives of this research is to identify the features needed to be improved in the field images. The CLAHE method has been used by stretching the histogram. This research aims to determine the maximum entropy value in the Fuzzy set theory for brightness of grey levels in field images. Besides, the research focuses on evaluating the fusion approach of CLAHE-based image enhancement method with Fuzzy set theory so that it can increase the contrast and brightness in field images. In this research, the most important factor to acquire is an improved brightness of an image. The combination of both methods will improve the quality of contrast and brightness for field images and enhance the quality of the images.

5. Proposed Framework

This section provides the proposed technique for enhancing the field image and achieving an enhanced field image for image value comparison. The proposed method is divided into two (2) phases of processing once the image is loaded into the system. These phases are CLAHE-based enhancement procedure and Fuzzy set theory enhancement procedure. Fig. 1 illustrates the processes involved in the fusion of CLAHE-based images to enhance the quality of field images. The proposed framework is shown as follows:

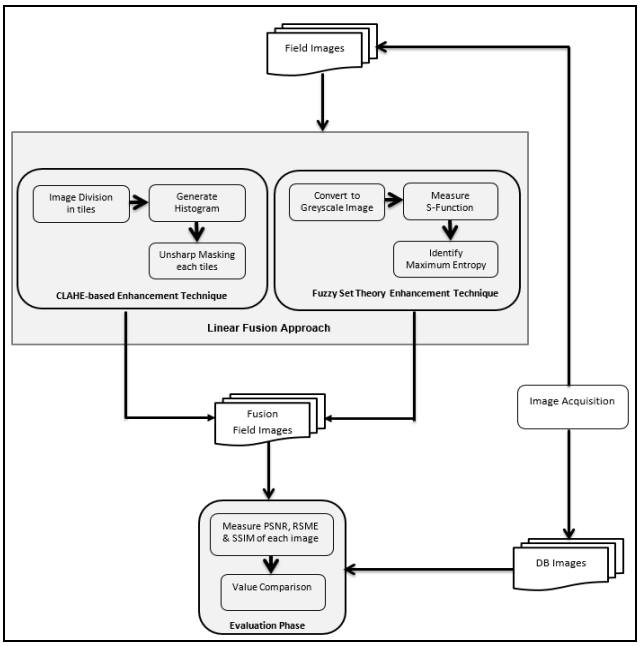


Fig. 1: Proposed Framework for Field Image Enhancement.

5.1 Image acquisition

Leaf images of various plants sourced from Leafsnap were used for this research. Another set of leaf images was acquired by taking pictures of leaves using a smartphone camera, which are known as field images. The series of field images have been enhanced and the values of Peak Signal to Noise Ratio (PSNR) and Structural Similarity Index Measurement (SSIM) have been collected to perform value comparison.

5.2 Linear Fusion Approach

i) CLAHE

Contrast-Limited Adaptive Histogram Equalisation (CLAHE) is an improved version of AHE, or Adaptive Histogram Equalisation.

Both overcome the limitations of standard histogram equalisation. CLAHE was originally developed for medical imaging and has proven to be successful for the enhancement of low contrast images such as portal films. CLAHE image enhancement has been applied to every field image to reduce the noise implication in the field images. CLAHE applies contrast reduction to each point within a region in an image. The process is followed by unsharp masking to enhance the high frequency elements in the image and to enhance the leaf veins. The unsharp mask is a method to sharpen and give effect to contrast enhancement. The effects of contrast enhancement are wider and less limited to sharp edges of the original image.

ii) Fuzzy set theory

The Fuzzy set theory has been applied to the same field images to determine the brightness membership function for grey levels in the images.

iii) Image Fusion

This process combines both result images from CLAHE and Fuzzy for evaluation. The final result is the enhanced field image with a new information value.

5.3 Evaluation

As previously mentioned, the field images quality value has been measured by different enhancement processes. Therefore, the different results that can be obtained from these methods can be compared against the parameters like Peak Signal to Noise Ratio (PSNR), and Structural Similarity Index (SSIM).

6. Experimental Setup

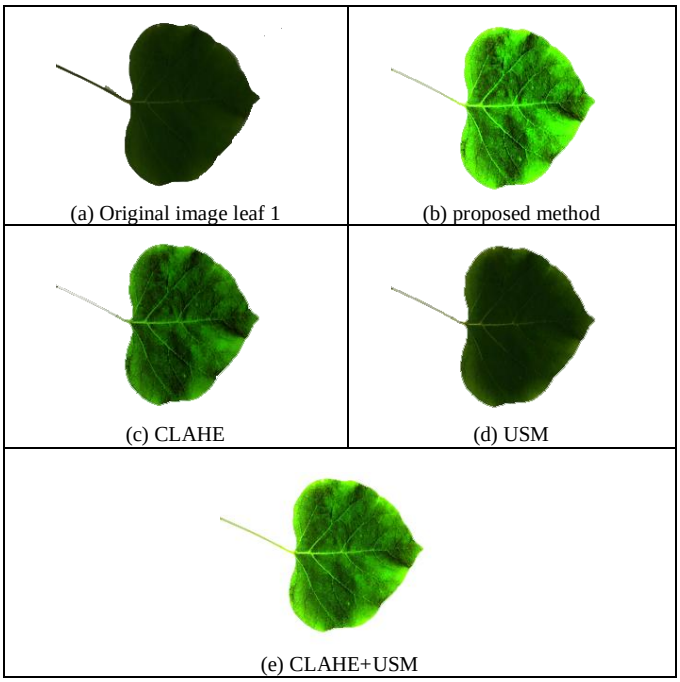
This section describes the experiments conducted to process image enhancement and compares the value of field images. Different measurement techniques were used to measure image quality values. The experiment was conducted using MATLAB software on a 32-bit Windows 7 Professional machine. The processor used was Intel Pentium, 2.20 GHz, and 4.00 GB. A total of four different experiments were conducted to enhance different field images from the online source.

7. Result and Discussion

In this section, some experimental results for image enhancement comparison of various enhancement methods are presented. Source images are taken from different leaf varieties of field image. The image quality measurement values are compared based on the value comparison. The result in Fig. 2 indicates that the proposed method improved the image quality value, which is better than the normal image quality value for CLAHE+USM and other methods. The comparison of the discussed method revealed that the fusion method improved image enhancement, which has significantly improved the image quality value.

The original field images captured using a mobile device were not suitable to be used in the plant recognition system. The enhanced CLAHE method can improve the features in field images by stretching the histogram of an image so that the full dynamic range of the image is filled. Then, the Fuzzy set approach can effectively determine the brightness in field images. Finally, the fusion approach of CLAHE and Fuzzy set will significantly enhance the quality of field images as compared to the CLAHE-based method.

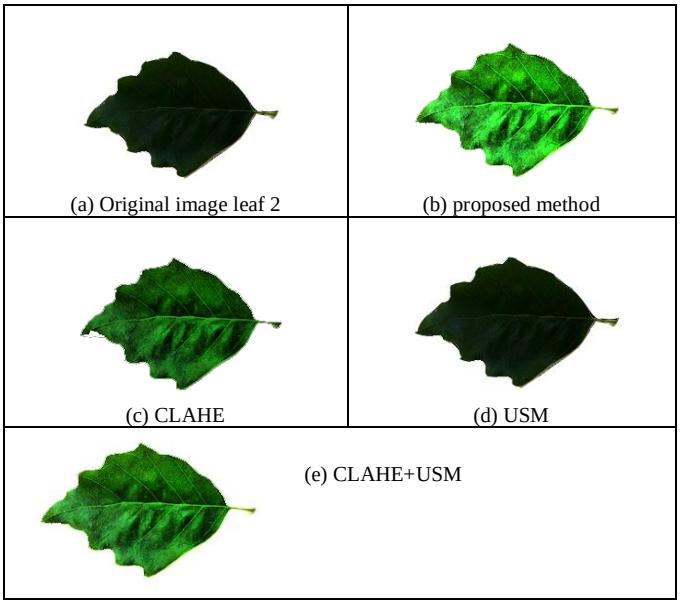
After the CLAHE-based fusion method is applied on the same images with other methods, it is clear that the CLAHE-based fusion method does not only give better equalisation but also improves the contrast and vein of leaf images.



(a) Original image leaf 1 (b) proposed method

(c) CLAHE (d) USM

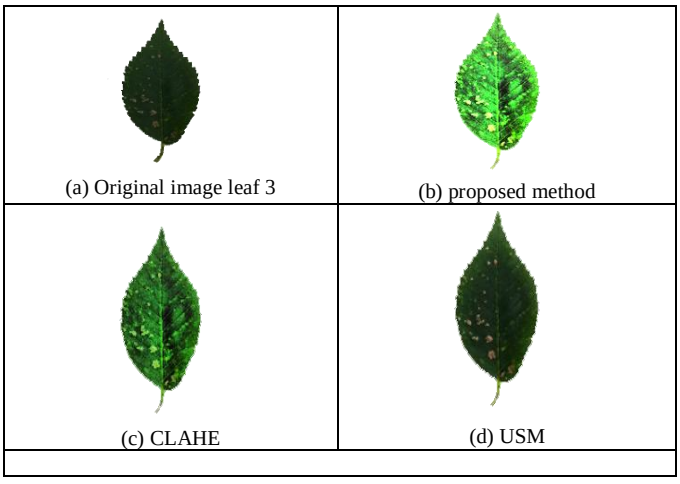
(e) CLAHE+USM



(a) Original image leaf 2 (b) proposed method

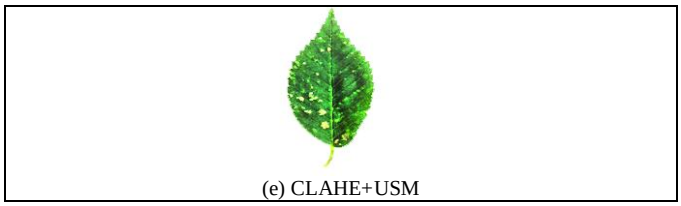
(c) CLAHE (d) USM

(e) CLAHE+USM



(a) Original image leaf 3 (b) proposed method

(c) CLAHE (d) USM



(e) CLAHE+USM

Fig. 2: Comparison of Different Enhancement Method.

Table 1: Comparison of PSNR

S.N.	Images	Proposed method	CLAHE	USM	CLAHE +USM
1	Leaf 1	17.62	21.81	23.21	18.70
2	Leaf 2	17.73	20.79	22.12	19.78
3	Leaf 3	18.68	23.89	25.86	19.72

Table 2: Comparison of SSIM

S.N.	Images	Proposed method	CLAHE	USM	CLAHE +USM
1	Leaf 1	0.7850	0.8740	0.9498	0.8141
2	Leaf 2	0.7835	0.8399	0.9455	0.8101
3	Leaf 3	0.8943	0.9256	0.9682	0.9021

Enhanced images that were produced by the proposed and other methods are presented in Fig. 2. Different samples from various types of leaves have been processed using the image enhancement method. For the subjective qualitative analysis of the processed image appearance, the test images, namely 'Leaf 1', 'Leaf 2', and 'Leaf 3', are shown in this Fig. The original field images have poor brightness in the underexposed regions and brightness is higher in the overexposed regions. CLAHE (Fig. 2 Leaves 1, 2, and 3 (c)) enhanced the original images and resulted in brighter images as compared to the original. USM (Figs 2 Leaves 1, 2, and 3 (d)) enhanced the original images and resulted in darker images as compared to the original, which did not contribute to any valuable information. The images processed by the fusion of both methods tend to enhance the region at the centre of the image. The quantitative and subjective quality enhancement of the proposed method is evaluated using well-known parameters like PSNR, and SSIM [13] as shown in Table 1 and 2.

The enhanced images (Figs 2 Leaves 1, 2, and 3 (b)) obtained by the proposed fusion method are more pleasant and the brightness of the images has been improved accordingly to the respective regions. With this proposed method, the intensity of the underexposed regions has increased and the images are brighter than the original. The enhanced images produced by the proposed method are quite similar to the enhanced images by using CLAHE+USM. However, the proposed method seems to be able to adjust the level of brightness and the field image enhancement shows better image quality as compared to the other enhancement methods in this experiment. Figs 2 Leaves 1, 2, and 3 (e)) are using a combination of CLAHE and USM. The result is acceptable as it has enhanced the original images in terms of brightness. However, the proposed fusion method has helped in brightening the enhanced images and enhancing the leaf veins.

8. Conclusion

The research introduced a linear fusion approach that combined CLAHE-based image enhancement and Fuzzy set theory. Combining both methods will improve the contrast and brightness quality of the field images and enhance the quality of the images.

The fusion method was aimed to improve the quality of contrast and brightness of field images that can be used significantly in agricultural image processing research during the image acquisition stage. This method will reduce the cost and time in preparing the research dataset.

This linear fusion approach in image enhancement methodology will support the procedure of field image dataset acquisition in any agricultural research. It will ease researchers in collecting images using portable devices such as smartphones, directly process the field images, and enhance the image quality equivalent to the lab image standard in order to obtain the same high quality image characteristics that will ease image recognition and retrieval processes.

For future reseach, field image enhancement can be compared with lab images or be enhanced to be of the same quality as the lab images, or even better.

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