A Review of Histogram Equalization Techniques in Image Enhancement Application

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Abstract. Image enhancement can be considered as one of the fundamental processes in image analysis. The goal of contrast enhancement is to improve the quality of an image to become more suitable for a particular application. Till today, numerous image enhancement methods have been proposed for various applications and efforts have been directed to further increase the quality of the enhancement results and minimize the computational complexity and memory usage. In this paper, an image enhancement methods based on Histogram Equalization (HE) was studied. This paper presents an exhaustive review of these studies and suggests a direction for future developments of image enhancement methods. Each method shows the owned advantages and drawbacks. In future, this work will give the direction to other researchers in order to propose new advanced enhancement techniques.

1. Introduction
The image enhancement technique is to make the digital picture more appealing to our eyes, for example, making the images smooth or sharp. This is an important topic in digital image processing. It can help humans and computer vision algorithms obtaining accurate information from the enhanced images. The visual quality and certain image properties, such as brightness, contrast, signal-to-noise ratio, resolution, edge sharpness, and color accuracy were improved through the enhancement process [1], [2]. Recently, many image enhancement methods have been developed based on various digital image processing techniques and applications. They can be developed in the spatial domain or spatial-frequency domain. The enhanced image will provide useful information for post-processing, especially in segmentation stage. This paper is organized in the following sections: Section 2 describes the related work of the studied using HE and Section 3 gives the conclusion of the work.

2. Histogram Equalization
A large and growing body of literature has investigated about enhancement methods. Image enhancement deals with improving the quality of images, where the objective is to emphasize wanted features and make them less obscured [3], [4]. The area of image enhancement is very appealing, where many fundamental image enhancement techniques are developed based on a very simple concept [5]–[8]. In the recent decades, image enhancement based on contrast enhancement has been focused [9]–[14].
Many researchers argued that Histogram equalization (HE) is a simple and an easy method to enhance the contrast and improve the image quality [15]–[17]. Since 1997, Yeong Kim [18] raised several concerns about contrast problem and suggested Brightness preserving Bi-Histogram Equalization (BBHE) in order to enhance the contrast. The average intensity value was applied as a separating point to differentiate between a dark area and bright area. The above finding contradicts the study by Wang et al. [19]. The author presented that a median intensity value is more accurate as the separating point compared to the average intensity. These results were contradicted that suggested the minimum mean brightness between original and output image as the separating point is more specific and accurate compared to the BBHE and Dualistic Sub Image Histogram Equalization (DSIHE) [20]. Research conducted by Ooi and Isa [21] proposed a new improvement in histogram equalization known as Quadrant Dynamic Histogram Equalization (QDHE). The first step in this technique was to divide the histogram into four sub-quadrant histograms based on the median value of the original image. After normalizing each sub-histogram, finally, the image was equalized. A major advantage of QDHE is that it's enhanced the image without any intensity saturation, noise amplification, and over-enhancement. In 2010, Ooi et al. [22] presented a new method based on Plateau level equation, namely Bi-Histogram Equalization with a Plateau Level (BHEPL). The main objective of this paper is to improve the BBHE technique in term of processing time. The process of this method also involved mean brightness preserving histogram equalization method with a clipped histogram equalization method. However, interestingly, this is contrary to a study conducted by Sengee et al. [23]. They suggest an extension method of BBHE based on the Neighbourhood Metric. This method involved a few steps: First, a large histogram was divided into the sub-region using Neighbourhood Metric. Second, based on mean, the histogram of the original image was separated into two sub-regions and process independently. The results enhanced the local contrast and preserved the brightness of the original image. The comparison of result performance is illustrated in Figure 1.
Figure 1. The comparison of enhancement result based on histogram modification: (a) Original image, (b) HE, (c) BBHE [23], (d) BHEPL [22], and (e) QDHE [21].

In a different study, Salah et al. [24] explained a new approach to solving the illumination problem on the face images using Histogram Equalization (HE). The technique is based on the combination of gamma correction and the Retinal filter’s compression function namely GAMMA-HM-COMP. The Retinal filter is a new enhancement method, and the result was effective compared to the three conventional enhancement methods which are histogram equalization [1], gamma correction [25] and log transformation [1]. In another study, Tan et al. [26] proposed a Background Brightness Preserving Histogram Equalization (BBPHE) method based on non-linear Histogram equalization (HE). Based on the background and non-background level techniques, the original image was separated into three interval histograms: (1) low grey level, (2) medium grey level, and (3) high grey level. The objective of this method is to enhance the object contrast and maintaining the background brightness. Similarly, Moniruzzaman et al. [27] proposed a modification of Brightness Preserving Bi-Histogram Equalization (BPBHE) using the edge pixels data. In order to prove the effectiveness, the Average Mean Brightness Error (AMBE) was calculated and the result was presented in table 1. The lowest of AMBE shows the high quality image and good performance technique.

Table 1. The AMBE result on different histogram technique.

| Image | HE   | BBHE | BPBHE |
|-------|------|------|-------|
| A     | 24.3350 | 29.7404 | 3.4737 |
| B     | 42.0428 | 35.4111 | 2.5079 |
| C     | 53.9887 | 13.6073 | 13.6073 |
| D     | 11.386 | 8.5763 | 3.3188 |

Hashemi et al. [28] proposed a novel enhancement method based on Genetic Algorithm using a simple chromosome structure and corresponding operator. The method was tested on the image that has a low dynamic range. In 2013, research finding by Chaudhary and Patil [29] also suggested a simple method based on Genetic Algorithm. The advantages of both methods are fast processing time, efficient, and produce a high-quality image. Besides that, they also produced a comprehensive comparison between a BBHE, DSIHE, MMBBHE, MPHE, and RMSHE. The analyses were done based on PSNR and contrast ratio.

In another study, Shome et al. [30] examined a method using Contrast Limited Adaptive Histogram Equalization (CLAHE) in order to normalize the contrast variation in the retinal image. CLAHE is an adaptive extension of Histogram Equalization followed by thresholding, which helps in the dynamic preservation of the local contrast features of an image. This proposed method used a non-mean based approach to improve the quality of the Diabetic Retinopathy (DR) image while preserving the sharpness and minutes of the details. The method also increased the local contrast pixels. The above view was supported studied by Sundaram et al. [31] where a CLAHE technique with a slight modification was suggested in order to enhance the mammogram images. The method was known Histogram Modified...
Contrast Limited Adaptive Histogram Equalization (HM-CLAHE). The optimization technique was used to adjust the level of strong contrast and the local details for more relevant interpretation. Based on Enhancement Measure (EME) result, this method was better compared to the HE, Unsharp masking (USM), and CLAHE. Tan et al. [26] introduced a modification of HE based on non-linear technique. The aim is to enhance the image contrast, while preserving the background brightness for images with well-defined background brightness. The original image was divided into three sub-images by using the proposed algorithm. Finally, only the problem region was normalized. The correction process based on sub-images technique also was supported by Shanmugavadivu and Balasubramanian [32]. They proposed a new method called as Thresholded and Optimized Histogram Equalization (TOHE). The main process has divided the histogram using the Otsu thresholding. Based on the result performance, this approaches is successful compared to the HE, BBHE, Range-Limited Bi-Histogram Equalization (RLBHE). Figure 2 shows the comparison result between TOHE and a few histogram methods. Circle in figure 2 represent the improvement and drawback of each method.

Figure 2. Comparison of the result performance after applying a different histogram process.

On the other side, Lin et al. [33] suggested a new HE method was applied to the colour image known as Averaging Histogram Equalization (AVHEQ). The technique also separates the original image into sub-images and equalized independently. A new mathematical algorithm in order to determine the optimal averaging threshold was proposed. The result is better compared to the conventional methods such as BBHE, DSIHE, and BHEPL.

Summary, the Histogram Equalization (HE) technique popular because is easy to implement and fast processing [34][23][35]. However, this technique produces many drawbacks such as it adds noise to the output image, increasing the contrast of its background and the signal gets distorted [15]. The HE may produce over enhancement result and saturation artefacts due to the stretching of the grey levels over the
full grey level range. In addition, many types of HE are based on the global technique. However, these global processing techniques of image processing are found to be insufficient to overcome variations due to illumination changes [36]. In non-uniform illumination, variation is still difficult to deal with using these global processing techniques [37], [38].

3. Conclusion
One major area of digital image processing is image enhancement. The main objective of image enhancement is to improve the quality of images emphasize wanted features and make them less obscured. This study has discussed an overview of the background and related work in the area of image enhancement using HE. The HE technique is simple and easy to apply. Recently, many modifications on HE was presented in order to find the best normalization technique. In future, research on the mathematical algorithm in HE should be explored.

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