Contrast Enhancement Based on Fusion Method: A Review

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Abstract. Image enhancement is a fundamental step and plays an important role in image processing, pattern recognition, and computer vision. Image enhancement can sharpen the edges of objects in an image, making it easier to extract objects and attain more information from the enhanced image. In this paper, a few popular image enhancement methods based Fusion Method 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

Image enhancement can be considered as one of the fundamental processes in image analyses. 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, a few popular enhancement approaches such as histogram equalization and fusion method was reviewed. The advantages and drawback of the method were elaborated deeply and systematic. This paper is organized in the following sections: Section 2 describes the method using fusion techniques and Section 3 gives the conclusion of the work.

2. Fusion Method

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 [1], [2]. The area of image enhancement is very appealing, where many fundamental image enhancement techniques are developed based on a very simple concept [3]–[6]. In the recent decades, image enhancement based on contrast and luminosity correction has been focused [7]–[12].

In 2010, Al-amri et al. [13] published a paper that reviewed two types of contrast enhancement techniques, namely linear contrast and non-linear contrast. The linear type represented by three methods such as Max-Min contrast, Percentage contrast, and Piecewise contrast. Four methods of the non-linear technique namely Histogram equalization, Adaptive histogram equalization, Homomorphic Filter, and Unsharp Mask. After evaluation, the Piecewise contrast and the Homomorphic Filter technique produced the best result compared to the other methods. According to Vu and Caplier [14], they found that the
combination of two non-linear functions and the difference of Gaussians filter were efficient to solve the contrast and illumination problem. In this experiment, this approach obtained a very high recognition rate even for the challenging illumination conditions. The proposed algorithm also has a low computational complexity. In contrast to [14], a study by Cheng et al. [15] argued that 2D Gaussian Filtering technique is more effective. This technique focuses on contrast stretching between dark and bright areas. The proposed method was effective to eliminate the luminosity and enhance the contrast compared to the method by [14]. This view is supported by Cheng et al. [16] that discovered a combination of quotient image and different smoothing filter knows as Different Smoothing filters Quotient Image (DSFQI). The Gaussian distribution in 2D was performed in order to smooth the contrast variation image. This technique was more effective for illumination normalization, compared to Self-Quotient Image (SQI) [17] and Dynamic Morphological Quotient Image (DMQI). The finding based on the smoothing filter is consistent with the research by Ambule et al. [18] which introduced an adaptive smoothing filter. However, this method focuses on the median filter. The adaptive median filter able to eliminate the noise and enhance the image quality. Furthermore, this technique is simple and has fast processing time. An et al. [17] proposed pre-processing techniques by using a combination of Lambertian reflectance model and Self-Quotient Image (SQI) to enhance the contrast variation images under changing lighting conditions. This paper used the TV_L model for finding the low frequency and high frequency component. The approach is very effective and suitable for a real-time application. The research study by Wang et al. [19] also found the Lambertian reflectance function for contrast enhancement. They performed experimental investigations on face images by applying Weber’s law method in order to eliminate the unwanted light and automatically enhanced the contrast variation. This technique consists of two steps: (1) by using the Laplace operator to measure the intensity variation; (2) by applying an algorithm from Lambertian reflectance as a way to produce the final result.

In recent years, there has been an increasing amount of literature on image enhancement method and the main purpose is to improve the quality of the image by performing an adjustment on bright or dark intensity [20], [21]. Rivera et al. [22] proposed a new image enhancement algorithm known as Content-Aware Algorithm. Normally. The images were captured in abnormal lighting (dark conditions) and producing an image with low levels of brightness. The aim of this method was to preserve the flat region's information by smoothing and gradient (edge) sharpening. This method enhanced the image by adaptively creating the mapping functions and produced the ad hoc transformation for every individual image. The ad hoc transformation comes from the contrast in the boundaries and the texture regions. The finding is consistent with the finding by Jha et al. [23], which proposed a new method known as Non-linear Non-Dynamic Stochastic Resonance. The proposed method is able to enhance the dark original image. Generally, images are degraded due to noise, blurring, and occlusion. Besides that, the artefacts have the ability to produce a degradation in the abnormal lighting conditions. By using the low contrast information, the sub-threshold was obtained and applied to enhance the contrast. The result of the experiment was better compared to the existing spatial domain techniques. In 2011, Fang et al. [24] suggested a new technique using image fusion. A fusion explained as changing the properties of one entity according to the properties of another entity. Fusion plays a very important role in evaluating the information from more than one image by fusing it, especially in the satellite image processing and medical image processing where analysing the information is crucial. For example, when the doctor does not understand the condition of a patient by using one medical image, then they fuse the two images to get the accurate information. In this work, different fusion techniques along with different enhancement techniques are compared based on standard deviation, contrast level, and average gradient. In 2012, the above finding supported the study by Saleem et al. [25], which reported that contrast enhancement based on image fusion. In this technique, a multi-channel property was determined using the Laplacian pyramid. A simple model was developed to represent saturation, contrast variation, and image brightness. The main advantage of this approach is, it is effective to enhance local and global contrast image without affecting the colour balance. Based on the result performance, this method is successfully compared to HE and
CLAHE. Figure 1 illustrates the comparison result between a few methods. However, this method is not suitable and less efficient for a real-time system.

A number of the study examined the relationship between global and local effect. The global and local method has their own advantages and drawbacks. In order to remain the advantages and at the same time minimize the drawbacks, a method based on a combination of the global and the local technique was proposed by Garvert and Gollisch [26] and Celik [27]. The objectives of both studies are to enhance the contrast and improved the quality images without any distortions and noise. Garvert and Gollisch [26] proposed a method based on contrast adaptation, while a method presented by Celik [27] is known as Spatial Entropy-based Contrast Enhancement in DCT (SECEDCT). Another algorithm for illumination correction was proposed by Glaister et al. [28] which calculated the underlying illumination through Multi-stage Illumination Modelling. This paper was divided into three parts. The first part deals with estimating the illumination map using non-parametric, second, by determining the quadratic surface reflectance through parametric modelling, and finally, calculating the final illumination estimation and used it to remove illumination variation.

Figure 1. Comparison of classical enhancement algorithm: (a) the original image, (b) CLAHE, (c) imadjust, (d) HE, and (e) Saleem method [25].
As highlighted by Wu et al. [29], a novel algorithm using tone mapping was presented. This technique is based on brightness adjustment to improve the contrast image without increasing the noise. The advantages of this approach are, it can reduce the computational complexity and easily implemented in the hardware. In 2012, the findings by Hasikin and Mat Isa [30] contradicted the study by Wu et al. [29], where they found that tone mapping correction of low contrast images was not successful in producing better enhanced images. According to an investigation by Hasikin and Mat Isa [30] and Zhou et al. [31], they set local and global adaptive information as the main parameters in order to enhance the low brightness and low contrast in the non-uniform images. Hasikin and Mat Isa [30] studied the effect of low contrast images and they proposed a new effective enhancement method based on fuzzy set theory. The proposed work used the fuzzy set theory by maximizing the fuzzy measurements in the image. The fuzzy set offers low complexity and high performance while enhancing the image even in the bad contrast conditions. The finding is consistent with findings by Zhou et al. [31], which focuses on local and global details. They proposed a novel method namely Overall Brightness and Local Contrast Adaptive Enhancement (OBLCAE) and experimented with colour images. Unfortunately, the proposed algorithm by Zhou et al. [31] is not suitable for very low illumination image enhancement because of inherent defects caused by the brightness non-linear mapping function. Besides, the finding by Hasikin and Mat Isa [30] supported by the finding Vlachos and Dermatas [32] investigated a method based on Fuzzy C-Means (FCM). However, this technique focuses on the modification of FCM algorithm that able to reduce the non-uniform illumination effects significantly and does not introduce brightness variations if the background is uniform. However, the weakness of this technique is the random selection of the prototypes of classes in the first step of the modified FCM algorithm.

Recently, image processing and computer vision approach are growing progressively in all areas of medical imaging, especially in modern ophthalmology. The high quality of retinal images is important for precise detection and diagnosis either manually or automatically. The aim of the pre-processing stage is to improve the diagnostic in fundus images for visual assessment and also for the computer-aided segmentation. Based on the previous study, many researchers agreed that retrospective correction techniques were effective to enhance the illumination in medical images, especially, retinal image [33], [34]. This view is supported by H. Lee and Kim [35] who agreed that retrospective correction is a better way in order to improve image quality. They suggested a new approach for bi-level images based on penalized non-linear least squares to measure the roughness of illumination. Major advantages of this approach are, it does not require tuning of design parameters, not suffering from a trivial minimizer, and effective optimization.

In 2010, Kubecka et al. [33] presented a B-spline shading model for non-uniform illumination modification following Shannon’s entropy. It applied two models which were a parametric local bias model for the formulation of criterion function and its derivatives and multiplicative model of non-uniform illumination. The example of the resulting images is shown in Figure 2.

![Figure 2](image-url)
However, based on the same application, Zheng et al. [34] proposed a method based on Gradient Distribution Sparsity to solve the bias field problem in retinal fundus images. The illumination inhomogeneity was automatically calculated using Parametric Model of Bias Field and Gradient Distribution Sparsity. The experiment result showed that this technique was efficient to eliminate the bias effect and automatically improved the blood vessel segmentation. In the same years, an easy technique for illumination normalization was proposed by Leahy et al. [36]. The approach was developed by obtaining the illumination profile using multiplicative image formation models and Laplace interpolation. The proposed method was applied to the retinal image. The latest research by Rasta et al. [37] produced comprehensive reviews on contrast and illumination enhancement on retinal image. The main objective of all techniques is to enhance the contrast and improve the segmentation result for retinal vasculature. This review involved eight pre-processing techniques in order to correct uneven illumination and low contrast which appeared in the retinal images. Based on the analyses, the quotient based and homomorphic filtering was an effective technique to reduce the variation of illumination. However, this technique eliminated some features such as the macula.

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. In this paper, we present an overview of the background and related work in the area of image enhancement that focuses on Fusion method. The most obvious finding to emerge from this study is that Fusion method technique is popular because it is easy to implement and fast processing. In addition, many types of Fusion method are based on the global technique. However, these global processing techniques are found to be insufficient to overcome variations due to illumination changes. Therefore, the fusion method is effective compared to the histogram equalization, however, a few methods show the complicated algorithm and slow process. This study was done to find the gaps in the existing research and possible solutions to overcome these gaps in the future.

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