IMPROVED IMAGE ENHANCEMENT METHOD FOR NON-UNIFORM ILLUMINATION AND LOW CONTRAST IMAGES USING BI-HISTOGRAM MODIFICATION APPROACH

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by

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LIST OF ABBREVIATIONS

AFCFE	Adaptive Fuzzy Contrast Factor Enhancement
AHE	Adaptive Histogram Equalization
AIEBHE	Adaptive Image Enhancement based on Bi-Histogram Equalization
BBHE	Brightness Preserving Bi-histogram Equalization
BE	Bright Enhancer
BG	Bright Gain
BHENM	Bi-Histogram Equalization with Neighbourhood Metrics
BHMIC	Bi-histogram Modification for Illumination Correction
BI	Blurred Image
BPDHE	Brightness Preserving Dynamic Histogram Equalization
BR	Bright Ratio
C	Contrast Improvement Analysis
CDF	Cumulative Distribution Function
CLAHE	Contrast Limited Histogram Equalization
CMBFHE	Cascaded Multistep Binomial Filtering HE
CP	Clipped Pixels
DBLAAIT	Dominant Brightness Level Analysis and Adaptive Intensity Transformation
DE	Dark Enhancer
DG	Dark Gain
DR	Dark Ratio
DRSHE	Dynamic Range Separate Histogram Equalization
DSIHE	Dualistic Sub-image Histogram Equalization

DSR	Dynamic Stochastic Resonance
DT-CWT	Dual-tree Complex Wavelet Transform
DWT	Discrete Wavelet Transform
E	Entropy
EME	Measure of Enhancement
FACE	Fuzzy Adaptive Contrast Enhancement
FHE	Fuzzy Logic based Histogram Equalization
FLHS	Fast Local Histogram Specification
GC-CHE	Gain-Controllable Clipped Histogram Equalization
GG	Global Gain
HAIS	Histogram-Adaptive Image Segmentation
HE	Histogram Equalization
HM	Histogram Modification
HP	Histogram Projection
HSQHE	High-speed Quantile-based Histogram Equalisation
HVSMHE	Human Visual System based Multi-Histogram Equalization
MMBEBHE	Minimum Mean Brightness Error Bi-histogram Equalization
MMLSEMHE	Minimum Middle Level Squared Error Multi Histogram Equalization
MRI	Magnetic Resonance Imaging
MSR	Multi-scale Retinex
MSRCR	Multi-scale Retinex Color restoration
MSRNIE	Multi-scale Retinex Improvement for Night Time Image Enhancement
NICSABMS	Nonlinear Image Contrast Sharpening Approach Based on Munsell's Scale

NIQE	Natural Image Quality Evaluator
NOSHP	Non-Overlapped Sub-blocks and local Histogram Projection
NPEA	Naturalness preserved Enhancement Algorithm
PCP	Percentage Of Clipped Pixels
POSHE	Partial Overlapped Sub-block Histogram Equalization
POSLT	Partially Overlapped Sub-block Logarithmic Transformation
POSLT	Partially Overlapped Sub-block Logarithmic Transformation
PSNR	Peak Signal-to-noise ratio
RMSHE	Recursive Mean Separate Histogram Equalization
RSIHE	Recursive Sub-image Histogram Equalization
RSWHE	Recursively Separated and Weighted Histogram Equalization
SSR	Single-scale Retinex
WAAD	Weighted Average of Absolute colour Difference

KAEDAH PENINGKATAN IMEJ YANG DITAMBAHBAIK UNTUK IMEJ PENCAHAYAAN TIDAK SERAGAM DAN BEZA JELAS RENDAH MENGGUNAKAN PENDEKATAN PENGUBAHSUAIAN BI-HISTOGRAM

ABSTRAK

Dalam situasi tertentu, imej yang pencahayaan tidak seragam dan beza jelas rendah berkemungkinan akan dirakam. Imej-imej ini dianggap sebagai satu cabaran dalam bidang penglihatan komputer dan pengecaman corak. Teknik-teknik konvensional yang biasa digunakan untuk menyelesaikan masalah ini mempunyai beberapa batasan. Sesetengah teknik memerlukan pelarasan parameter-parameter secara manual. Selain itu, sesetengah teknik hanya tertumpu kepada satu atau dua aspek daripada pengurangan hingar, peningkatan beza jelas, penambahbaikan ketidak seragaman pencahayaan, dan pemeliharaan perincian imej. Oleh itu, penyelidikan ini mencadangkan satu kaedah baharu iaitu " Bi-histogram Modification for Illumination Correction " (BHMIC). Langkah pertama BHMIC ialah membezakan kawasan terang dan gelap dalam sesuatu imej. Kemudian, ia diikuti dengan meningkatkan beza jelas dan keadaan pencahayaan imej tersebut. Pada masa yang sama, proses penyaringan diaplikasi untuk membuang perincian imej (seperti pinggir) dan hingar. Ini dilakukan untuk memelihara perincian tersebut dan menghalang penguatan hingar. Kaedah yang dicadangkan menggunakan anggapan pencahayaan dan pemantulan untuk memisahkan kawasan terang dan gelap imej. Kemudian, kawasan-kawasan tersebut dipertingkatkan dengan menggunakan peningkat terang dan gelap yang diterbitkan secara berasingan. “Clipped Histogram Equalization” yang telah diubahsuaikan kemudiannya digunakan untuk tujuan peningkatan beza jelas.

Akhirnya, perincian imej ditambahkan kembali kepada imej yang pencahayaannya diperbetulkan dan beza jelasnya dipertingkatkan untuk menghasilkan imej keluaran akhir. Analisis kualitatif menunjukkan bahawa BHMIC yang dicadangkan mempunyai prestasi yang bagus dalam pemeliharaan butiran imej, peningkatan beza jelas dan penyeragaman keadaan pencahayaan tanpa memperkuatkan hingar yang tidak dikehendaki. Analisis kuantitatif menunjukkan bahawa BHMIC yang dicadangkan adalah 38% hingga 42.9%, 0.8% hingga 4.7% and 0.7% hingga 2.3% lebih baik daripada kaedah-kaedah lain yang telah diuji masing-masing dari segi EME, NIQE dan entropy. Keputusan yang memberangsangkan ini menunjukkan bahawa BHMIC berkemungkinan mampu digunakan sebagai pra-pemprosesan kepada imej wajah untuk pengecaman wajah, imej perubatan untuk memudahkan diagnosis penyakit dan imej fotografi untuk kegunaan peribadi.

IMPROVED IMAGE ENHANCEMENT METHOD FOR NON-UNIFORM ILLUMINATION AND LOW CONTRAST IMAGES USING BI-HISTOGRAM MODIFICATION APPROACH

ABSTRACT

In certain situations, low contrast and non-uniform illuminated images would be captured. These images are considered as challenge in the field of computer vision and pattern recognition. The conventional techniques that are commonly used to solve this problem have some limitations. Some of these methods require manual parameters tuning. Besides that, some of the methods are only focused on one or two aspects of noise reduction, contrast enhancement, non-uniform illumination enhancement and detail preservation. Hence, this study proposes a new method which is Bi-histogram Modification for Illumination Correction (BHMIC). The proposed BHMIC will first distinguish the bright and dark regions of an image. Then, it is followed by enhancing the contrast and illumination condition of the image. At the same time, filtering process is employed in order to remove the details of the image (i.e. edges) and noises. It is done to preserve the details and avoid the amplification of noises. The proposed method applies the illumination and reflectance assumptions to separate the dark and bright regions of the image. Then, these regions are enhanced using derived dark and bright enhancers separately. The modified clipped histogram equalization is then applied for contrast enhancement purpose. Finally, the details of the image are added to the illumination corrected and contrast enhanced image as an output image. Qualitative analysis shows that the proposed BHMIC has good performance in detail preservation, contrast enhancement and illumination condition enhancement without significantly amplifying unwanted noise. The quantitative analysis shows that the proposed BHMIC is 38% to 42.9%, 0.8% to 4.7% and 0.7% to 2.3% better than other tested methods in EME, NIQE and entropy, respectively. The promising results suggest that the proposed BHMIC could probably be used in pre-processing of face images for face recognition, medical images for easier disease symptoms diagnosis and photography images for personal usage.

CHAPTER ONE

INTRODUCTION

1.1 Background

Recently, digital images can be seen everywhere in our daily lives. Due to the rather widespread of mobile phones and social media platforms (e.g. Facebook, Instagram and etc.), the personal usage of digital images has significantly increased. In addition to personal usage, digital images are also widely applied in professional applications. For example, digital images are applied in medical images (i.e. X-ray, MRI and etc.) which can assist doctors to diagnose health status of patients (Dougherty, 2009; Aach et al., 1999), as well as in forensic imaging (e.g. fingerprints, faces, irises and etc.) which can help police to identify criminals (Gloe et al., 2007; Swaminathan et al., 2008) and also in industrial imaging applications which can assist in the quality assurance of products (Kang et al., 1999; Zeng et al., 2013; Sridhar, 2011).

Image enhancement is one of the major topics in the field of digital image processing. Image enhancement process consists of a collection of techniques that seek to improve the visual appearance of an image or to convert the image to a form which is better suited for analysis by a human or a machine (Pratt, 2007). The concept of image quality should be defined prior to conducting image enhancement. Although there are many factors that will affect the quality of image but several factors such as contrast, brightness, spatial resolution and noise have been identified as the dominant ones (Sridhar, 2011). Contrast refers to the magnitude of the intensity differences of an object's surface which is recorded in an image (Sridhar, 2011). Brightness refers to the average pixel intensity of an image (Sridhar, 2011).

Spatial resolution is usually defined as the number of pixels per inch of an image (Sridhar, 2011). Noise is an unwanted disturbance that causes fluctuation in the pixel value (Sridhar, 2011). Besides that, the uniformity of image illumination is also a factor that would affect the quality of image. It is determined by the lighting condition during the image acquisition process. Limited lighting sources would lead to a variation of image illumination which would resulting an image with non-uniform illumination as shown in Figure 1.1. From Figure 1.1, it can be observed that the man's face and the door at the center of the image are over brighten but the background at the left and right sides of the image are very dim. Besides that, the shelf and the water dispenser are barely observed due to limited light.

Image enhancement process can be roughly categorized into five categories which are contrast enhancement, noise reduction, edge crispening, colour image enhancement and multispectral image enhancement (Pratt, 2007). Besides these stated processes, the non-uniform illumination image enhancement also plays an important role in image enhancement process especially in microscopic images (Hasikin and Isa, 2012).

Figure 1.1: Non-uniform illuminated image (Weber, 1999)

1.2 Current Trends in Image Enhancement of Non-uniform Illumination Images

Images are powerful tools to convey messages as compared to text (Sridhar, 2011). After the invention of cameras, photography has become a tool of communication. With the reduction in the cost of digital cameras and digital computers, digital image processing is becoming part of our everyday lives. Currently, image processing is widely applied in areas of medicine, forensics, entertainment, corporate presentation and industrial applications. The main objective of image processing in these areas is to acquire images that are suitable for further analysis (Sridhar, 2011). For example, image processing is applied to X-ray, MRI etc., which allow doctors to detect the disease symptoms easily. Another example is in the electronic manufacturing industry, computer vision is applied for inspection of printed circuit board to ensure the quality of products (Leung et al., 2005).

In non-controlled situations, most of the recorded images are low in contrast with non-uniform illumination effects. These conditions occur due to the insufficient lighting sources and improper focus during image acquisition process (Hasikin and Isa, 2013). Low contrast images with the weak edges (i.e. low-intensity differences) are a challenge in the field of computer vision and pattern recognition. Besides that, non-uniform illumination will cause difficulties to obtain the information in the images. Thus, it may affect the accuracy of the consequences analyses such as character recognition (Leung et al., 2005), bridge painting rust defects recognition (Lee and Chang, 2005) and 2D barcode recognitions (Lee and Kim, 2009).

In general, image enhancement of non-uniform illumination images can be categorized into three categories which are histogram modification (HM) based (Rubin et al., 2006; Wharton et al., 2007), fuzzy logic based (Hasikin and Isa, 2014;

Magudeeswaran and Ravichandran, 2013) and other algorithms (Jiao et al., 2009; Wang et al., 2013). The conventional HM based algorithms for non-uniform illumination image enhancement are Histogram-Adaptive Image Segmentation (Rubin et al., 2006) and Human Visual System based Multi-Histogram Equalization (HVSMHE) (Wharton et al., 2007). Histogram Adaptive Image Segmentation is employed to widen the dynamic range of segmented low contrast areas which results in a better contrast and brightness resultant image. On the other hand, HVSMHE separates the image into different regions of illumination instead of the threshold by pixel intensity to solve non-uniform illumination problem.

The examples of fuzzy logic based algorithms which focus on solving non-uniform illumination problem are Fuzzy Logic based Histogram Equalization (FHE) (Magudeeswaran and Ravichandran, 2013) and Adaptive Fuzzy Contrast Factor Enhancement (AFCFE) (Hasikin and Isa, 2014). FHE firstly computes the fuzzy histogram using fuzzy set theory before separates it based on the median value of the original image. Finally, the separated fuzzy histogram is equalized independently using Histogram Equalization (HE) approach. Whereas, AFCFE fuzzifies an image and separates it into two regions by using threshold value derived from the contrast factor. The separated regions are then modified using sigmoid function and defuzzified to obtain the enhanced image.

In addition to the abovementioned algorithms, Partially Overlapped Sub-block Logarithmic Transformation (POSLT) (Jiao et al., 2009) and Naturalness Preserved Enhancement Algorithm (NPEA) (Wang et al., 2013) are also proposed to improve the contrast of non-uniform illumination images. POSLT divides the input image into many partially overlapped sub-images and then applies a logarithmic transformation to each sub-image. The pixels are probably transformed more than one time due to the partially overlapped of several sub-images. Their results will be summed up and divided by transformation frequency. NPEA, on the other hand, proposes a bright pass filter to decompose the illumination and reflectance from the input image. Next, the illumination is processed using bi-log transformation and is then synthesized with the reflectance to obtain the enhanced image.

1.3 Problem Statement

Although there are numerous state-of-the-art techniques proposed to solve the non-uniform illumination issue, it needs to be pointed out that most of these techniques are not robust. It is because these techniques are specifically designed to solve a specific problem or to enhance certain characteristic of an image. A robust technique should able to enhance the images with various illumination conditions. These techniques have a trade off in some aspects in order to maximize the enhancement or to solve the problems. For example, NPEA and POSLT perform well in illumination correction but have a drawback of noise amplification. AFCFE also performs well in illumination correction but it has a weakness in terms of insignificant contrast enhancement. FHE provides good illumination correction but would results in the loss of some image details due to the remapping process using HE. Therefore, it is necessary to find a balance between illumination correction, contrast enhancement, image details preservation and noise suppression.

Moreover, some state-of-the-art techniques employ control parameters to fine-tune their performances. For example, HVSMHE employs 3 tuning parameters, while MSRNIE employs 1 tuning parameter. These parameters require manual adjustment of user, which is a subjective process. This would become a problem in the automated application. The above-stated problems faced by the non-uniform illumination and low contrast images become the motivation to develop a better image enhancement algorithm for the non-uniform illumination and low contrast images.

1.4 Research Objectives

The main objective of this study is to propose a robust framework for image enhancement of non-uniform illumination and low contrast image which consists of:

i. To formulate significant concept and equations to distinguish between dark and bright regions in addressing non-uniform illumination and low contrast issues.
ii. To formulate a histogram based concept for non-uniform illumination images in order to propose a new histogram based enhancement technique for the non-uniform illumination and low contrast images.

1.5 Scope of the Research

The scope of this research focuses on the development of an image enhancement algorithm for non-uniform illumination and low contrast images. Only grey scale images are selected to evaluate the performance of the proposed algorithms. This is because the main focus of the proposed algorithm is contrast improvement and linearization of the non-uniform illumination of the images without considering the colour factor which may cause the analysis to become more complex. Beside of the contrast improvement and linearization of the non-uniform illumination, the noise reduction and naturalness of the resultant images are also considered during the development of the image enhancement algorithm.

The proposed algorithm is developed and implemented on an Intel i7 2.5GHz computer using Matlab R2014a. The test images for the evaluation of the proposed algorithm are collected from public images library namely Computational Vision at