An Efficient Approach for Image Enhancement Based on Image Fusion with Retinex and Gamma Correction

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Abstract—Aiming at problems of poor contrast and blurred edges in degraded images, a novel enhancement algorithm is proposed in present research. Image fusion refers to a technique that combines the information from two or more images of a scene into a single fused image.The Algorithm uses Retinex theory and gamma correction to perform a better enhancement of images. The algorithm can efficiently combine the advantages of Retinex and Gamma correction improving both color constancy and intensity of image.

Key words: Image fusion, Retinex, Gamma Correction, Discrete Wavelet Transformation.

I. INTRODUCTION

Image enhancement is an important technique in the image pre-processing field. In previous research, many enhancement algorithms have been used in various image processing applications. Regrettably, these traditional algorithms tend to only have the ability to solve a single specific problem of degraded images. For instance, histogram equalization can improve an image’s contrast by extending the dynamic range of its grey variation, and sharpening can elevate an image’s sharpness via compensating contours and emphasizing edges. When a degraded image has more than one problem, traditional algorithms cannot provide a satisfactory resultant image to meet the enhancement demand of applications, even after several of these algorithms have been applied successively. Fortunately, image fusion can help to provide a solution to the aforementioned enhancement difficulty. The objective of image fusion exists in combining multiple source images into a fused image that exhibits more useful information than the individual source image. For about two decades, image fusion has emerged as a promising image processing technique in many fields, like remote sensing and medicine. Out of various image fusion techniques, the fusion based on wavelet transform has been proven to be an active research focus in recent years because of its excellent performance [1][2] [3].

Over the years many image enhancement techniques have been reported in the literature. Among several existing image enhancement techniques multi-scale Retinex is the most popular method that works well under most lighting conditions. However, the Retinex based image enhancement method provides acceptable results if the parameters are adjusted. The selection and tuning of Retinex parameter is the most crucial task in a multi-scale Retinex algorithm.

II. IMAGE FUSION

Image fusion means the combining of two images into a single image that has the maximum information content without producing details that are non-existent in the given images[4][5]. With rapid advancements in technology, it is now possible to obtain information from multi-source images to produce a high quality fused image with spatial and spectral information [5] [6]. Image Fusion is a mechanism to improve the quality of information from a set of images. Important applications of the fusion of images include medical imaging, microscopic imaging, remote sensing, computer vision, and robotics.

Image Fusion techniques can be sub divided in three different types of techniques including Simple fusion techniques, Principal Component Analysis (PCA) based Fusion, Pyramid based image fusion methods and Discrete Wavelet Transform (DWT) based fusion as shown in figure 1 as below.

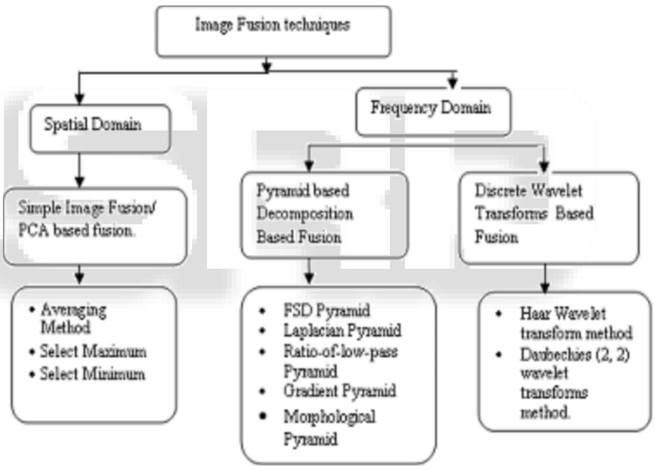

Fig. 1: Different Image Fusion Techniques

III. RETINEX THEORY

The Retinex (retina + cortex) theory was proposed by Land and McCann [7]. The Retinex is a simplified computational model of the human visual system that explains the color constancy phenomenon, and compensates illumination effects in images. The primary goal of Retinex-based algorithms is to decompose an image into a reflectance image and an illumination image to remove the illumination effect. Several Retinex-based image enhancement approaches have been developed.

Literature [7] proposed the model of how the human vision system adjusts the object color and brightness apperceived - Retinex algorithm. It may achieves the balance in the gradation dynamic range compression, the edge enhancement and the color constancy, thus may be used to the automatic enhancement for different kind of images. But the algorithm is based on the experimental data, and has no unitive mathematical model. Many different improved Retinex algorithms appeared, such as SSR (Single Scale Retinex) algorithm [8-9], MSR (Multi scale Retinex) algorithm [10-12], McCannps Retinex algorithm [13-15] and so on, and obtained widespread application. In essence, all these classics Retinex algorithm is to smooth original image through Gauss model with certain parameters and to extract image's background as far as possible accurate through some suitable ways. In this article, considering the relevance of video's adjacent frame images, we propose an improved multiscale global Retinex algorithm.

A. Single Scale Retinex

In the common processing of traditional HDR image enhance algorithm based on Retinex theory, the image $I(x, y)$ is decomposed into two parts, namely the illumination image $L(x, y)$ and the reflectance image $R(x, y)$:

$$I(x,y) = R(x,y) \times L(x,y) \quad (3.1)$$

where the illumination component L determines the dynamic range of an image, and the reflectance component R depends on the intrinsic properties of the image I. The purpose of using Retinex theory to enhance the image is to accurately extract R from the original image S , i.e., removing the illumination component L to get the original appearance of the image.The current implementation of Retinex algorithm was proposed by Hurlbert which enhances the image using of Gaussian surround function. Retinex theory was briefly described in [7]. The single-scale Retinex (SSR) is given as follows.

$$R(x,y) = \log I(x,y) - \log\left\lfloor F(x,y) * I(x,y) \right\rfloor \quad (3.2)$$

Where, R(x, y) is enhancement output for the Retinex. I(x, y) is an input image, * is convolution operator, F(x, y) denotes surround function which is given by following expression

$$F(x,y) = K_{exp}\left\lfloor -\left(x^2+y^2\right)/\sigma^2 \right\rfloor \quad (3.3)$$

Where σ is Gaussian surround space constant, which is also known as scale parameter, K is coefficient.

Previous Researches Have Proved That SSR Can Achieve Either Dynamic Range Compression or Color Rendition, But Not Both Simultaneously [16].MSR Overcomes This Limitations for Most Scenes.

B. Multi Scale Retinex

The Multi-scale Retinex (MSR) can be given as a weighted combination of SSR. Mathematical expression is given as follows.

$$R_m(x,y) = \sum_{n=1}^{N} W_n \left\{ \log\left[I_m(x,y)\right] - \log\left[I_m(x,y) * F_n(x,y)\right] \right\}$$

$$m=1,...,k \quad (3.4)$$

Where $R_m(x,y)$ is the output of the MSR, m represents the m^{th} spectral band, k is the number of spectral bands, k=1 represents gray-scale image, k=3 represents color image (RGB). W_n represents weight coefficients associated with F_n, n is the number of environmental functions, in which environmental function F_n select different standard deviation σ_n to control the environment function range of the scale. The expression is given as follow

$$F(x,y) = K_{exp}\left\lfloor -\left(x^2+y^2\right)/\sigma^2 \right\rfloor \quad (3.5)$$

Where σ_n is scale parameter for the first n-surround function. Coefficient to be met:

$$\iint K_n exp\left[-\frac{x^2+y^2}{\sigma_n^2}\right] dxdy = 1 \quad (3.6)$$

Better self-adaptability can be achieved for MSR scale through the combination of multi measure, also it can achieve image adjustment under dynamic scope, which produces the enhanced output of the image. MSR was operated to the selected image with specific pixel resolution, which gives satisfactory results for the source images.

IV. GAMMA CORRECTION

In general, the enhancement techniques can be divided into two main categories: direct enhancement methods and indirect enhancement methods. In direct enhancement methods, the image contrast can be directly defined by a specific contrast term. Where in indirect enhancement methods attempt to enhance image contrast by redistributing the probability density. In other words, intensity of the image can be redistributed within the dynamic range without defining a specific contrast term. Histogram modification (HM) is the most widely used indirect enhancement techniques due to their easy and fast implementation.[17]

Gamma correction technique [17] which make up a family of general HM techniques obtained simply by using a varying adaptive parameter γ. The simple form of the gamma correction is given by as follows.

$$T(l) = l_{max}\left(l / l_{max}\right)^{\gamma} \quad (3.7)$$

where l_{max} is the maximum intensity of the input image. The intensity l of each pixel in the input image is transformed as $T(l)$ after performing the equation 4.6. As expected, the gamma curves illustrated with $\gamma > 1$ have exactly the opposite effect as those generated with $\gamma < 1$, as shown in Fig. 4.1(a). It is important to note that gamma correction reduces toward the identity curve when $\gamma = 1$.

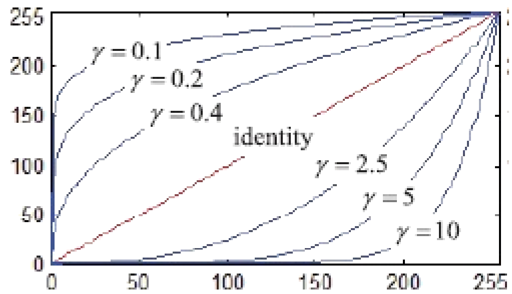

Fig. 2: Transformation Curves

However, when the contrast is directly modified by gamma correction, different images will exhibit the same changes in intensity as a result of the fixed parameter. Fortunately, the probability density of each intensity level in a digital image can be calculated to solve this problem. The probability density function (pdf) can be given as follows.[18]

$$pdf(l) = n_l / (MN) \quad (3.8)$$

Where, n_l is the number of pixels that have intensity l and MN is the total number of pixels in the image.

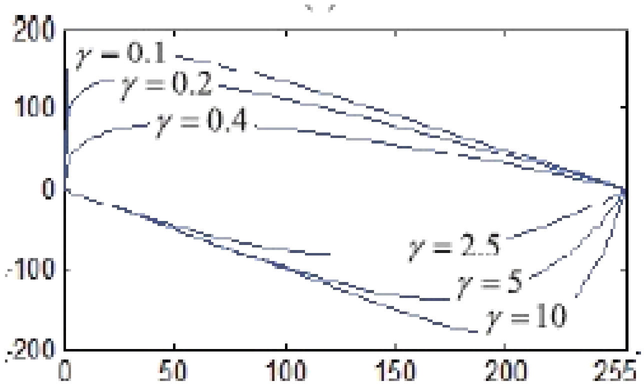

Fig. 3:Gamma Correction

Fig 3 shows the modified values of each intensity by using the corresponding curves illustrated in Fig 2. The x-coordinate is the input intensity and the y-coordinate is the decrement or increment of each intensity level. As shown in Fig 3, unvaried modification is produced by the use of the gamma correction.

V. DISCRETE WAVELET TRANSFORM (DWT)

The Discrete Wavelet Transform (DWT) is obtained by filtering the signal through a series of digital filters at different scales. The scaling operation is done by changing the resolution of the signal by the process of subsampling. The DWT can be computed using either convolution-based or lifting-based procedures. In both methods, the input sequence is decomposed into low-pass sub-bands, each consisting of half the number of samples in the original sequence.

In the discrete wavelet transform, an image signal can be analysed by passing it through an analysis filter bank followed by decimation operation. The analysis filter bank consists of a low-pass and high-pass filter at each decomposition stage. When the signal passes through these filters, it splits into two bands. The low-pass filter, which corresponds to a differencing operation, extracts the detail information of the signal. The output of the filtering operation is then decimated by two. A two-dimensional transform is accomplished by performing two separate one-dimensional transforms. First, the image is filtered along the row and decimated by two. It is then followed by filtering the sub-image along the column and decimated by two. This operation splits the image into four bands, namely, LL, LH, HL and HH respectively as shown in below figure.

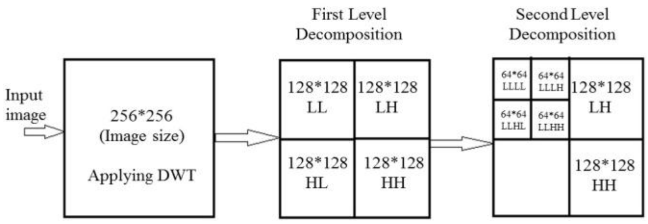

Fig. 4: DWT Decomposition of the Input Image

VI. PROPOSED ALGORITHM

Degraded image often appear poor in contrast and blurred in edges. As a useful method, conventional methods can improve the contrast of the degraded images by stretching the grey histogram of them. However this method cannot effectively enhance the edges and the change of the grey histogram may cause excessive brightness in some high grey areas in enhanced images[17][20].

The main idea here developed here is to use image fusion to combine the useful properties and suppress the disadvantages of the various local and global contrast enhancement techniques. The proposed algorithm based on the image fusion is summarized in Figure 5, and the processing flow is demonstrated as follows:

- Perform the Multi-Scale Retinex operation and Gamma Correction on the original poor contrast image to get two different output images.
- Perform the Discrete Wavelet Transform (DWT) decomposition on two output images of the previous operations. DWT decompose the input image into a set of band-limited components, called HH, HL, LH, and LL subbands.
- All these subbands are fused using the fusion rules which were specified in previous section.
- Finally, perform Inverse Discrete Wavelet Transform (IDWT) to achieve final enhanced output image.

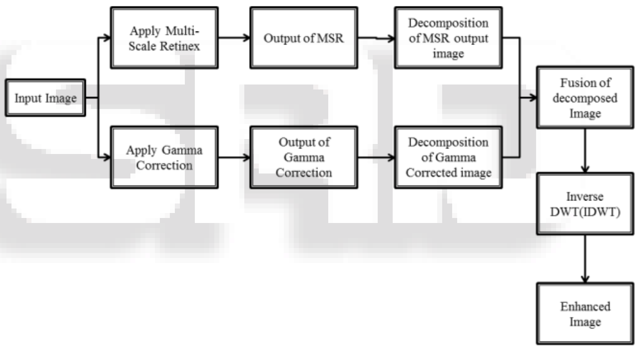

Fig. 5: Block Diagram of Proposed Method

VII. CONCLUSION

In the proposed approach, wavelet-based image fusion is utilized to enhance degraded images by combining the performance of multi scale Retinex and gamma correction. First, multi scales Retinex and gamma correction are respectively applied to the same degraded image in order to obtain source images. Then these two source images are fused through special rules in the wavelet domain to get the enhanced image. Only luminance component is processed by using a Retinex function with different parameters, and then the processed results are fused by a gamma corrected image. We will test the proposed method for different types of images and will compare it with other algorithms.

ACKNOWLEDGMENT

The satisfaction and euphoria that accompany the successful completion of any task would be incomplete without the mention of the people who made it possible, whose consistent guidance and encouragement crowned my efforts with success. Jaydeep Tadhani highly thankful to my guide Avanish Patel and Mohit Bhadla without whose guidance the work would not have been materialized and he helps me to solve my difficulties arising during this report preparation. Also J.R. Tadhani would like to acknowledge all other faculty member of Computer Department and my classmates who have come forward to help me in every way at any time. With all this assistance little for remains for which I can take credit.

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