# Image Contrast Enhancement Techniques

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## RESEARCH PAPER CONSULTED

1. Contrast Enhancement Algorithm for Colour Images by Ojo J.A, Solomon I.D, and Adeniran S.A. (View)

2. Image Contrast Enhancement Using Singular Value Decomposition for Gray Level Images by P. Sivakumar, K. Maguesway, and M. Rajaram (View)

3. A New Contrast Enhancement Technique by Adaptively Increasing the Value of Histogram by Ching-Hsi Lu, Hong-Yang Hsu, and Lei Wang (View)

## ABSTRACT

In this report, the modern image contrast enhancement techniques discussed in above mentioned research papers have been analyzed. Conventional contrast enhancement techniques often fail to produce satisfactory results for low-contrast images, and cannot be automatically applied to different images because processing parameters must be specified manually to produce satisfactory results for a given image. The experimental results has shown the superiority of the proposed methods over conventional methods.

# INTRODUCTION

Image enhancement techniques have been widely used in many applications of image processing where the subjective quality of images is important for human interpretation. Contrast is an important factor in any subjective evaluation of image quality. Contrast is created by the difference in luminance reflected from two adjacent surfaces. In other words, contrast is the difference in visual properties that makes an object distinguishable from other objects and the background.

In visual perception, contrast is determined by the difference in the colour and brightness of the object with other objects. Our visual system is more sensitive to contrast than absolute luminance; therefore, we can perceive the world similarly regardless of the considerable changes in illumination conditions. Many algorithms for accomplishing contrast enhancement have been developed and applied to problems in image processing.

In many applications such as geosciences studies, astronomy, and geographical information systems the satellite images are used. One of the most important quality factors in satellite images comes from its contrast. Contrast enhancement is frequently referred to as one of the most important issues in image processing. Contrast is created by the difference in luminance reflected from two adjacent surfaces. In visual perception, contrast is determined by the difference in the color and brightness of an object with other objects.

Our visual system is more sensitive to contrast than absolute luminance; therefore, we can perceive the world similarly regardless of the considerable changes in illumination conditions. If the contrast of an image is highly concentrated on a specific range, the information may be lost in those areas which are excessively and uniformly concentrated. The problem is to optimize the contrast of an image in order to represent all the information in the input image.

# PROPOSED METHODS

## METHOD 1

Many algorithms for achieving contrast enhancement have been developed; among them is histogram equalization technique that is attractive due to its simplicity. Histogram equalization generates a grey map that changes the histogram of an image and redistribute pixel values to be as close as possible to a user-specified histogram [1, 2].

An adaptation of histogram equalization is the contrast limited adaptive histogram equalization (CLAHE). CLAHE divides input image into a number of equal size blocks and then performs contrast limited histogram equalization on each block. The contrast limiting is done by clipping the histogram before histogram equalization [1]. Other colour enhancement methods have been proposed based on histogram equalization [3,4], these also include multiscale approaches [5-10] and other hue preservation contrast enhancement schemes [11-14].

Earlier works have also shown that the performance of HSV colour space is good in colour improvement [2]. Therefore, this work proposes a Hue preserving algorithm, which uses a derived mapping function to modify the Saturation, and CLAHE Luminance components.

The complete algorithm for the image enhancement method is presented in the flowchart.

Processing Flow/Algorithm:

1) Load a colour image

2) Convert from RGB to HSV colour space

3) Apply Discrete Wavelet Transform (DWT) to saturation (S) component

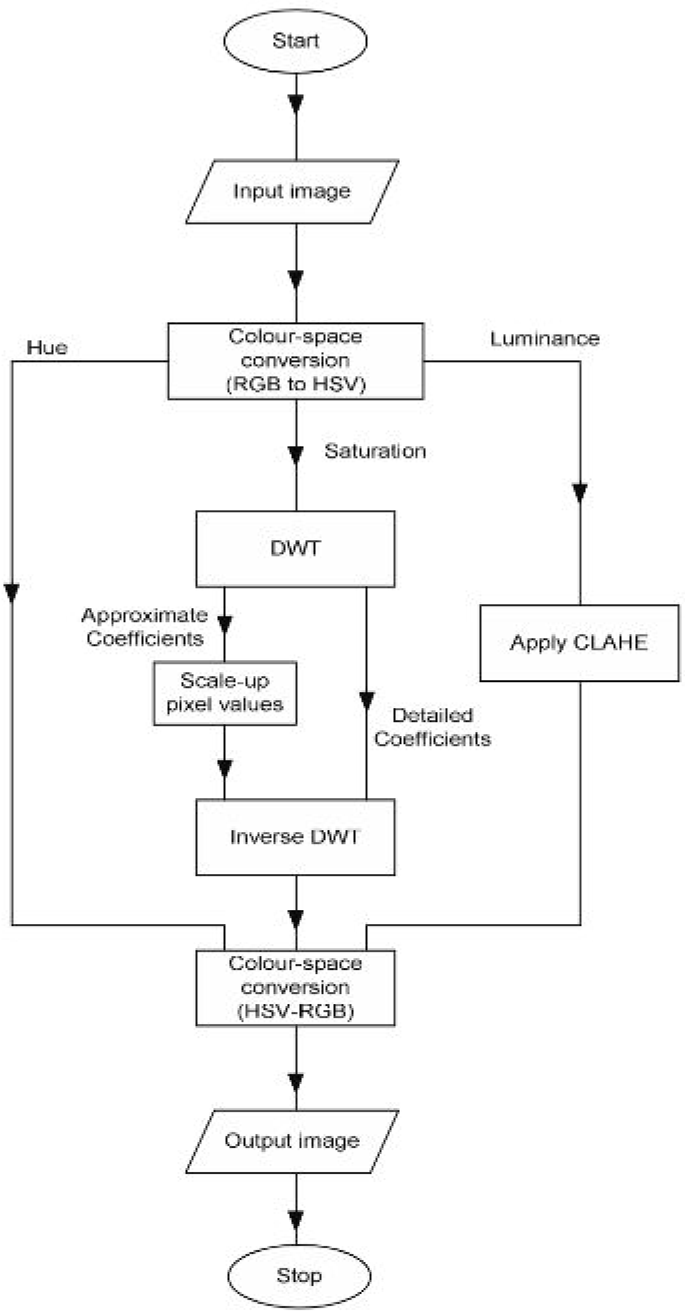
4) Use a derived mapping function to modify approximate coefficients from the equation.

5) Reconstruct S using Inverse Discrete Wavelet Transform

6) Enhance luminance (V) component using CLAHE

7) Combine H, new S component, and V components to get the enhanced HSV image

8) Convert from HSV to RGB colour space



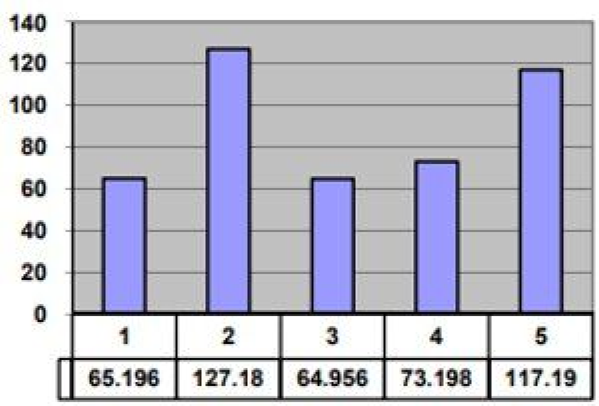

Block Diagram of Image Enhancement algorithm

METHOD 2

There are two significant parts of the proposed method. The first one is the use of SVD. As it was mentioned, the singular value matrix obtained by SVD contains the illumination information. Therefore, changing the singular values will directly affect the illumination of the image; hence, the other information in the image will not be changed. The second important aspect of this work is the application of DWT. As it was mentioned in Section I, the illumination information is embedded in the LL sub band. The edges are concentrated in the other sub bands (i.e., LH, HL, and HH). Hence, separating the high-frequency sub band and applying the illumination enhancement in the LL sub-band only will protect the edge information from possible degradation. After reconstructing the final image by using IDWT, the resultant image will not only be enhanced w.r.t. illumination but also will be sharper.

| | Methods | Mean value |
|---|---|---|
| 1 | Original image | 65.1961 |
| 2 | GHE | 127.186 |
| 3 | LHE | 64.956 |
| 4 | BPDHE | 73.1989 |
| 5 | The proposed technique | 117.195 |

The general procedure of the proposed technique is as follows. The input image A is first processed by using GHE to generate Â. Then, both of these images are transformed by DWT into four sub band images. The correction coefficient for the singular value matrix is calculated by using the following equations:



The comparison chart

$$\zeta = \frac{\max(\Sigma_{LL\hat{A}})}{\max(\Sigma_{LLA})}$$

where $\Sigma_{LLA}$ is the LL singular value matrix of the input image and $\Sigma_{LL\hat{A}}$ is the LL singular value matrix of the output of the GHE. The new LL image is composed by

$$\overline{\Sigma}_{LLA} = \zeta \Sigma_{LLA}$$
$$\overline{LL}_A = U_{LLA}\overline{\Sigma}_{LLA}V_{LLA} \qquad \overline{A} = IDWT\left(\overline{LL}_A, LH_A, HL_A, HH_A\right)$$

Now, the $LL_A$, $LH_A$, $HL_A$, and $HH_A$ sub band images of the original image are recombined by applying IDWT to generate the resultant equalized image A.

METHOD 3

In this section, we review two popular techniques about image contrast enhancement as the basis of this research. They are traditional Histogram Equalization method [3], and BUBO method [4].

A. Traditional HE Method

HE [3] obtains input-output transfer function by means of the histogram of input images.

$$P(k) = \frac{n_k}{N}, \qquad \text{for } k = 0,1,\ldots,L-1$$

For the digital image input f(x, y) in an active area of gray level [0, L-1] with N pixels. The probability density function (PDF) P(k) of the image is defined as (1), where L is the maximum gray level of image.

In the equation, nk is the total number of pixels in the image with gray level k. By means of the cumulative density function (CDF) defined below, the input-output transfer function is then defined as the f(x), where $X_0$ and $X_{L-1}$ are minimum and maximum luminance values.

$$C(k) = \sum_{i=0}^{k} P(i), \qquad \text{for } k = 0,1,\ldots,L-1$$

$$f(x) = X_0 + (X_{L-1} - X_0)C(x)$$

Although the transfer function can derive enhanced images by contrast enhancement, HE can not control the effect of enhancement. Moreover, while histogram is centralized in a narrow area, the method tends to produce undesirable artifacts.

B. BUBO Method

To improve the undesirable artifacts caused by traditional HE method, the BUBO method [10] puts constraints to avoid over enhancement by the equation on the left, where $C_{BU}$ and $C_{BO}$ are bin underflow and bin overflow thresholds as defined below: $C_{BU}$ = (1-α)/N and $C_{BO}$ =(1+α)/N

$$P_{BUBO}(k) = \begin{cases} C_{BO} & ,\text{if } P(k) > C_{BO} \\ P(k) & ,\text{if } C_{BU} \le P(k) \le C_{BO} \\ C_{BU} & ,\text{if } P(k) < C_{BU} \end{cases}$$

BUBO is an effective technique for contrast enhancement; but in some cases the method still can not expand gray level distribution to expand dynamic range of input image. Although we can add the function of adjusting parameter into BUBO to expand image for more dynamic range; the method still need to adjust different parameter for input images.

Based on PDF shaping HE methods, this study proposes a new contrast enhancement method, abbreviated as AIVHE. The method reshapes the original PDF to obtain new PDF to prevent a significant change in the gray levels.

# RESULTS

In the first paper, the performance of the system was evaluated using AMBE, MSE and PSNR. The proposed method also gave the highest PSNR values, which shows that it produces the best reconstructed image of the three methods.

In the second paper, the quality of the visual results indicates that the proposed equalization technique is sharper and brighter than the one achieved by GHE, LHE, and BPDHE. Experiments have been performed on over 100 randomly selected images from various sources which confirmed the qualitative results. In order to support the qualitative conclusions on the superiority of the proposed method, a quantitative analysis is required.

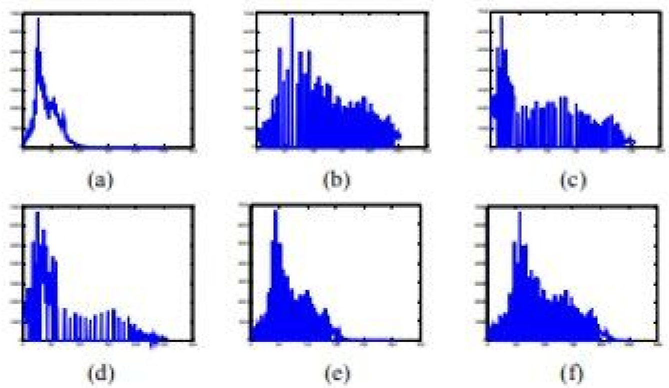



Figure Histogram of Fig. (a) input image, (b) Enhanced by HE (c) Enhanced by BBHE (d) Enhanced by RMSHE (e) Enhanced by BUBO (f) Enhanced by AIVHE

However, when the ground truth that represents the original image is missing, a quantitative error analysis on the enhanced image is not possible. In an attempt to estimate the quantitative performance, we propose to analyze the estimated Gaussian distribution of the enhanced images which are modeled by using the calculated mean (μ) and standard deviation (σ) of the output images.

In the third paper, the study tested the proposed AIVHE method on different images. Some other contrast enhancement methods, such as HE [3], BBHE [5], RMSHE [6] and BUBO [4], are simulated for comparison, too. To observe the effects of contrast enhancement achieved by these methods, the process of luminance component is done but the process of chrominance component is omitted for the completion of the image contrast enhancement processing.

# CONCLUSION

In the first Paper, an algorithm for colour image enhancement was presented. Modification was performed in HSV colour space, while enhancement achieved in the frequency domain. The Hue component is preserved (unchanged), luminance modified using CLAHE, while Saturation components were up-scaled using a derived mapping function on the approximate components of its discrete wavelet transform.

The method performed best when compared with outputs of HE and CLAHE methods, through preservation of image quality and increased dynamic range of image brightness. The method produced images with the lowest MSE AMBE, and highest PSNR. In our future work, we hope to introduce adaptive noise removal, which is expected to give a better result.

In the second paper, the above table shows the corresponding mean values of original image, GHE, LHE, BPDHE and the proposed method and the chart is drawn. It is clear from these distributions that the estimated Gaussian functions of the GHE and the proposed method have means which are close to the ideal mean ($\mu$=128) for the gray level range with $\mu$ = 127.19 and 117.19 respectively. However, the estimated Gaussian distribution of the proposed method covers a wider gray level range; that is why it has better illumination.

In the third paper, an important feature of AIVHE is that the functions proposed in the study are all designed under the consideration of hardware implementation, and then use the mechanism of adjustable contrast enhancement effect. It might be suitable to be applied for consumer electronics such as mobile phone, digital camera, LCD, TV, etc. Thus, this analysis supports the qualitative observation that the proposed method over performs the conventional techniques.

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