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A Novel Approach of Using Laplacian Image Enhancement

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Abstract**—** Contrast enhancement based on multiscale decomposition of images has been proven to be a far versatile and efficient method than other regular techniques. We present here contrast image enhancement by using Laplacian Pyramid. Proposed method enhances the brightness and contrast of an input image by decomposing it into band pass image to improve both local and global contrast of an image. Laplacian Pyramid allows smooth enhancement of large images so that visible artifacts can be avoided that are seen when we apply histogram equalization (HE) technique alone.

Index Terms— contrast enhancement, histogram equalization, image enhancement, Laplacian pyramid.

I. Introduction

Contrast enhancement plays a crucial role in image processing applications such as digital photography, medical image analysis, remote sensing. Due to various multimedia devices such as digital cameras, the need for enhancing images has been increased tremendously. There are many enhancement techniques used widely, among which histogram equalization (HE) [1] is appreciated most. The popular enhancement techniques based on HE are Contrast Limited Adaptive Histogram Equalization (CLAHE) [7], Bright preserving bi-histogram equalization (BBHE) [2], HE with bin underflow and bin overflow (BUBO) [4], to name a few.

HE is an effective technique to transform a narrow histogram by spreading the gray-level clusters in the histogram and it is adaptive since it is based on histogram of an image. The classic HE provides the best visual performance in certain conditions compared to other state-of-the-art techniques but has disadvantage of over enhancement.

The CLAHE technique however inspired some post HE methods separating an image into tiles, equalizes them and interpolates their boundaries resulting into successful improvisation of contrast but giving it an artificial look. BBHE individually equalizes two sub histograms based on the mean value of the image. The BUBO method uses the clipped histogram of an image, thus preventing excess stretching. Even with the clipping histogram of the BUBO method, however, suffers from when there is gradual change.

There are also some other contrast enhancement techniques allowing decomposition of an image. One such decomposition scheme is Laplacian pyramid.

In this paper, we propose a color image enhancement method adopting merits of techniques like histogram equalization and Laplacian pyramid so as to obtain an output image persisting its naturalness with an improved local and global contrast.

II. Proposed work

Laplacian pyramid is used for separating the brightness and contrast components of an image. The brightness component is characterized by slow spatial variations and contrast components tend to vary abruptly. Therefore, the brightness component has low frequency while the contrast component tends to have a relatively high frequency. Each band of Laplacian pyramid [8-9] is the difference between two adjacent low-pass images of the Gaussian pyramid [I_0, I_1, …, I_N].

For the given input image as RGB, we will separate images according to its components as R image, G image and B image. We need to perform contrast as well as detail enhancement on each of these images. When the individual images are enhanced in contrast and detail manner, we combine them together and get the enhanced output image.

Fig 1: Input RGB image

A. Image Enhancement

Image enhancement is an important step in almost every image processing application. The objective of image enhancement is to increase the visual perception of the image so that they are more suitable for human viewers or machine vision applications. It is well known in the image processing society that there is no unifying or general theory for image enhancement algorithms. Thus an enhancement algorithm that is suitable for some application may not work in other applications. In image processing technology, image

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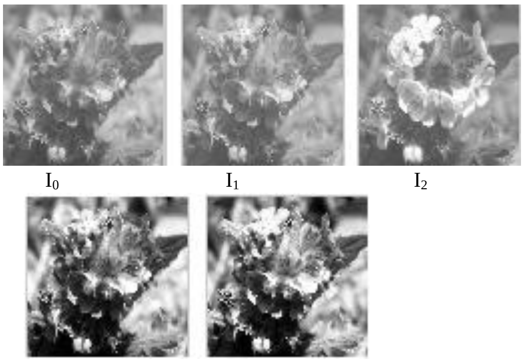
enhancement means improving image quality through a broad range of techniques such as contrast enhancement, color enhancement, dynamic range expansion, edge emphasis, and so on.

Generate the Laplacian pyramid for the given image, for *n* particular levels.



I_0 I_1 I_2

$D_0=I_1-I_0$ $D_1=I_2-I_1$

Fig 2: Image pyramid decomposition

So following is the reconstruction equation

$$I_0 = I_N + \sum_{n=1}^{N} Dn \qquad (1)$$

Where N is the decomposition layer.

This phase involves pyramid expansion and then its reduction. Pyramid expansion for an image of size m by n will create a result of size (2*m-1) by (2*n-1). Pyramid reduction would cause an image of size m by n to produce a result of size ceil(m/2) by ceil(n/2).

B. Laplacian Contrast Enhancement

Contrast enhancement [6-7] improves the perceptibility of objects in the scene of enhancing the brightness difference between the objects and their backgrounds. Here we are using laplacian method for improving contrast of an image.

1) *Generate the histogram:* The histogram [1-5]with luminance levels in the range K [0, L-1] is a discrete function as

$$h(l_k) = n_k \qquad (1)$$

Where l_k is the k^{th} luminance level in K and n_k represents the number of pixels having luminance level l_k.

So we generate the histogram of all our 3 separated images as shown below.

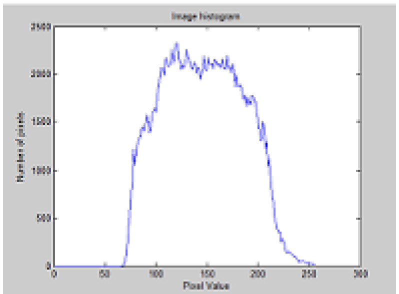


Fig 3(a): Generating histogram for R image

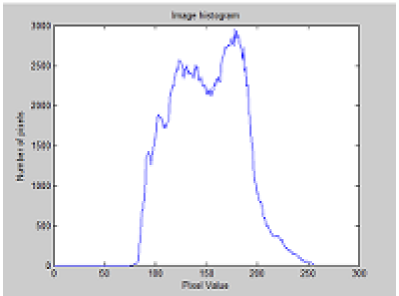


Fig 3(b): Generating histogram for G image

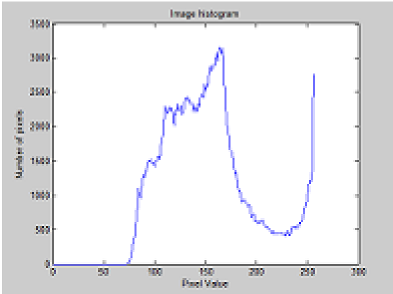


Fig 3(c): Generating histogram for B image

2) *Smoothing the histogram:* In the histogram, a ridge shape with some consecutive luminance levels can be regarded as the feature area of an image. To globally distinguish between ridges and valleys and remove their ripples, we smooth the histogram [11-13] like as follows:

$$h_g(l_k) = h(l_k) * g(l_k) \qquad (2)$$

Where

$$g(x) = e^{-x^2}$$

where g(x) is a Gaussian function, x is the corresponding location to a bin of the histogram, and coefficients of the Gaussian filter are normalized.

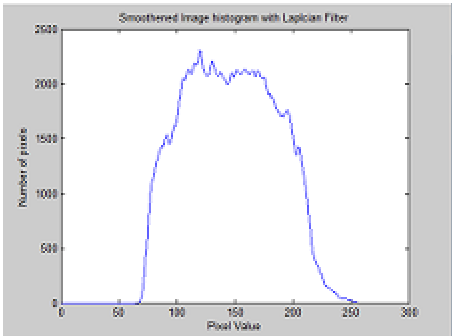


Fig 4(a) Smoothened histogram for R image

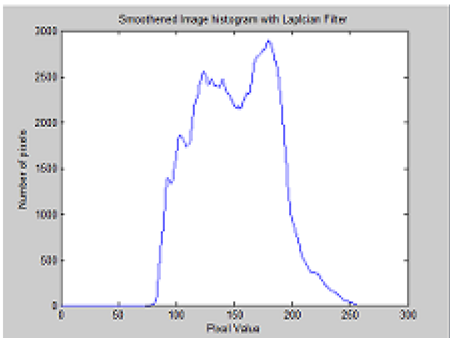


Fig 4(b) Smoothened histogram for G image

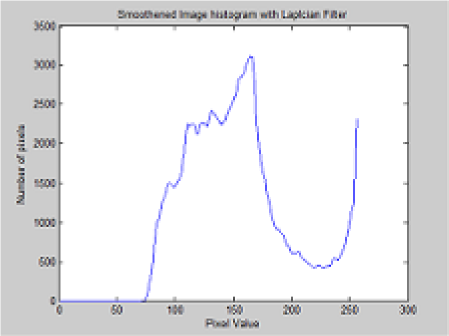


Fig 4(c) Smoothened histogram for B image

3) *Boosting minor areas:* This is a key strategy of proposed contrast enhancement to suppress quantum jump. First, the peak value in the smoothed histogram h_g (l_k) is found as

$$p\,(K) = \max_{k \epsilon K}\{h_g(l_k)\} \qquad (4)$$

Second, the ridges between valleys are searched and boosted. Ridge boundary is defined as the bins between the first point of the positive slope and the last point of the negative slope.

We find the constant factor of enhancement and then find the local minor areas of histogram. We check for local maxima, if it is found it means a peak value is found and we need to enhance it and store value to new histogram.

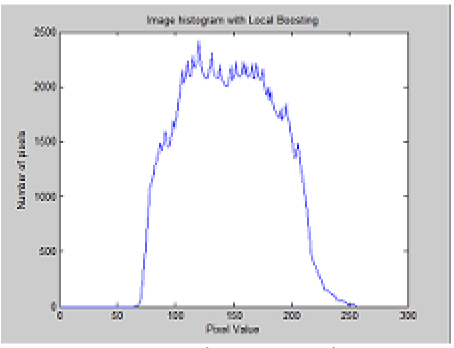


Fig 5(a) Local boosting for histogram of R image

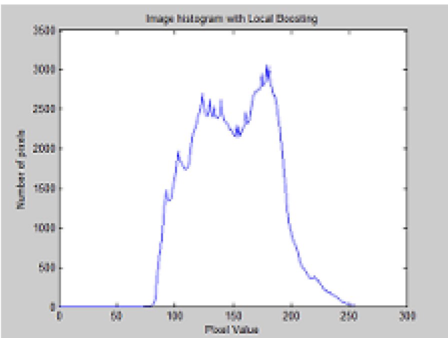


Fig 5 (b) Local boosting for histogram of G image

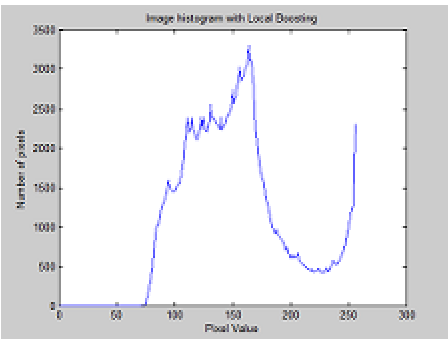


Fig 5(c) Local boosting for histogram of B image

4) *Slantwise clipping:* The clipping technique is used as it effectively suppresses the quantum jump. We find the mean of newly generated histogram and then find the mid value and then we gather the residual from local and global clipping.

5) *Generating new image:* Find the normalised cumulative histogram

h= (cdf- cdf(min)/MN- cdf(min)) * 255

and replace the values with new equalised values.

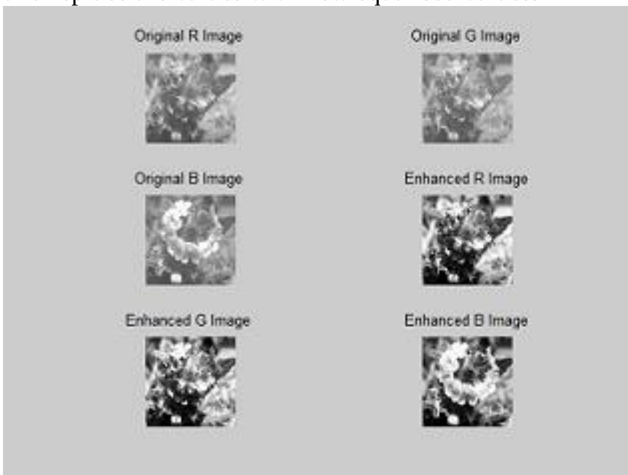
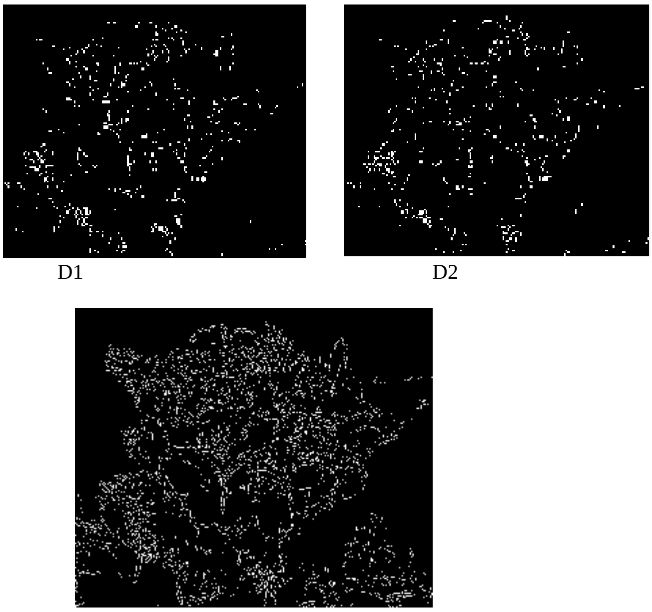


Fig 6: Original and enhanced R, G, B images

C. *Detail Enhancement*

HE-based methods have inherent limitations on improving the local information of an image. To solve this problem, we employ detail enhancement through the proposed framework which initially separates an image into band-pass images. With this framework, we can deal with the original details of high-pass images.

The proposed detail enhancement has the effect of distinctively emphasizing reliable details. An example of the detail enhancement scheme is shown below:



D1 D2

D'

Fig 7 : Detail enhancement

D. Color restoration

Using (1), the enhanced luminance image is obtained as

$$I' = I_N' + D' \quad (5)$$

Where the right hand components are obtained by combining the enhanced images.

The concept here used is that we combine all the contrast enhanced and decomposed images together along with luminance and get the enhanced luminance image.

Fig 8 : Final Enhanced image

III. EXPERIMENTAL RESULTS

The most important part of our technique is about the number of layers of image to be decomposed. In the proposed framework, a new HE algorithm was proposed to enhance contrast information. Practically, the proposed HE algorithm alone can improve image quality. Robustness is an important factor for practical use. The allowable degree of over-enhancement and the well performed degree of quality heavily depend on the viewers' subject. Fewer enhancements is preferable in some difficult conditions like a flat background.

Another difficult task occurs when a narrow band of the histogram dominates an image. Especially, when we observe the results processed under dominant dark regions.

IV. CONCLUSION

The image enhancement technique used by joint effort of histogram equalization and Laplacian pyramid aims to overcome the quantum jump that conventional HE-based algorithms are likely to suffer from and for supplementing the improved local details that those methods cannot provide due to their inherent limitations. The proposed combination framework aims to provide an output image with well natural look without over-enhancement or severe failure.

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