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Abstract: In this paper we proposed an enhancement technique of medical images based upon a new application of contrast limited adaptive histograms on transform domain coefficients called logarithmic transform coefficient adaptive histogram equalization (*LTAHE*). The method is based on the properties of logarithmic transform domain histogram and contrast limited adaptive histogram equalization. A measure of enhancement based on contrast measure with respect to transform will be used as a tool for evaluating the performance of the proposed enhancement technique. The algorithm's performance will be compared quantitatively to classical histogram equalization using the aforementioned measure of enhancement. Experimental results will be presented to show the performance of the proposed algorithm alongside classical histogram equalization.

Keywords: Medical image enhancement, histogram equalization, LTAHE, EME.

1. Introduction

In medical imaging, such as the computer tomography and magnetic resonance, two- and three-dimensional images (or stack of two dimensional images) of different organs and tissues are processed. There are many sources of interference in the production of medical images, such as the movement of a patient, insufficient performance and noise of imaging devices. The quality of many images is poor in their contrast, and to improve the quality of the images, enhance edges, to see clearly enough critical details, and to reduce the noise for diagnosis purposes, methods of enhancement can be used. Digital image enhancement is necessary to improve the visual appearance of the image or to provide a better transform representation for future automated image processing such as image analysis, detection, segmentation, and recognition [1-3]. Processing techniques for image enhancement can be classified into spatial domain enhancement and transform domain enhancement.

Linear contrast stretching and global histogram equalization are two of the most widely used non transform based uniform enhancement technique. Histogram equalization attempts to alter the spatial histogram of an image to closely match a uniform distribution. Adaptive histogram equalization [4], contrast-limited adaptive histogram equalization [5] belongs to spatially non uniform enhancement technique. Spatial domain enhancement techniques deal with the image's direct intensity values. While the spatially uniform methods use a transformation applied to all pixels of the image, the later methods use an input output transformation that varies adaptively with the local characteristics of the image. Histogram equalization suffers from the problem of being poorly suited for retaining local detail due to its global treatment of the image. Histogram equalization tends to over-enhance the image contrast if there is a high peaks in the histogram resulting in a undesired loss of visual data, of quality and of intensity scale [6-7]. Also small scale details that are often associated with the small bins of the histogram are eliminated. AHE applies locally varying gray-scale transformation on each small region of the image. This method does not completely eliminate noise enhancement in smooth regions. A survey of the spatial domain enhancement techniques can be found in [8-9].

In case of transform domain enhancement techniques, the image intensity data are mapped into a given transform domain by using transform such as 2-D discrete cosine transform (DCT), Fourier transform and other fast unitary transforms. The basic idea in using this technique is to enhance the image by manipulating the transform coefficients. One of the well-known and proven enhancement techniques is alpha rooting, which was modified later on into log-alpha-rooting, modified unsharp masking and filtering [10-11] as well as methods based on wavelet transforms [12-13]. The main disadvantage in using the alpha rooting method relates to the difficulty of selection of the value of parameter alpha. This value should be chosen in an optimal way to enhance all parts of the image very well. Transform based image enhancement techniques suffers from some disadvantages such as they introduce certain objectionable artifacts, they cannot simultaneously enhance all parts of the image very well and it is difficult to automate the image enhancement procedure. The other drawbacks of all the above methods is that the brightness is changed and the enhanced images look far from natural and the extend of enhancement is not controllable. To solve these problems transform histogram can be used [14-15]. This paper explains a method of medical image enhancement which combines adaptive histogram equalization and logarithmic transform enhancement. This method gives better performance as it combines both spatial domain and transform domain enhancement technique. The rest of the paper is organized in the following way. Section 2 presents necessary background. This includes discrete orthogonal transform, logarithmic transform, adaptive histogram equalization, and performance measure of enhancement. Section 3 discusses about the proposed method. Section 4 discusses some experimental results. Section 5 concludes the experiments and algorithm. Last of all list of necessary references are given.

2. Background

In this section, description about necessary background is given so that the proposed method can be understood easily.

2.1. Discrete orthogonal transform

Orthogonal transforms are commonly used in image enhancement technique for their various properties. One of the most common properties is that orthogonal transform produces DC values in the top-left corner and high frequency content in the lower right corner. The common orthogonal transform functions those are used for image enhancement are Discrete Cosine Transform, Discrete Fourier Transform and Discrete Hartley Transform. The forward and inverse N-point 2-D Discrete cosine transform are defined as

$$y(u,v)=\frac{2}{N}C_uC_v\sum_{n=0}^{N-1}\sum_{m=0}^{N-1}x(n,m)\cos\left[\frac{(2n+1)u\pi}{2N}\right]\cos\left[\frac{(2m+1)v\pi}{2N}\right]\cdots\cdots\cdots(1)$$

$$x(m,n)=\frac{2}{N}\sum_{u=0}^{N-1}\sum_{v=0}^{N-1}C_uC_vy(u,v)\cos\left[\frac{(2n+1)u\pi}{2N}\right]\cos\left[\frac{(2m+1)v\pi}{2N}\right]\cdots\cdots\cdots(2)$$

Where $C_u = C_v = \frac{1}{\sqrt{2}}$ for u=v=0, $C_u = C_v = 1$ otherwise.

n,m=0,1,…….N-1; y(u,v) is the 2-D DCT and x(m,n) is the original 2-D function.

2.2. Logarithmic transform

Logarithmic transform helps us to show the frequency content of an image. This transformation maps a narrow range of low gray level values in the input image into a wider range of the output level. The opposite is true of higher values of input level. This type of transformation is used to expand the values of dark pixels in an image while compressing the higher level values. The log function has the important characteristic that it compresses the dynamic range of images with large variation of pixel values. However, the histogram of this data is usually compact and uninformative.

Log transformation is done in two steps. The first step requires the creation of a matrix to preserve the phase of the transform image. This will be used later to restore the phase of the transform coefficients. In the second step logarithm is taken on the modulus of the coefficients according to the following equation.

$$\hat{X}(i,j)=\ln\left(\left|X(i,j)\right|+\lambda\right)\cdots\cdots\cdots\cdots\cdots\cdots\cdots(3)$$

where λ is a shifting coefficient, usually set to 1.

2.3 Adaptive histogram equaliztion

Histograms are the basis for numerous image processing techniques. Histogram equalization maps the input image's intensity values so that the histogram of the resulting image will have an approximately uniform distribution. Let the variable r represents the gray level of an image to be enhanced, T is the transformation function and s is the transformed value. Then s can be represented as

$$s=T(r)=\int_0^r p_r(w)dw\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots(4)$$

If p_r and p_s represents the probability density function of r and s respectively then then p_s can be obtained by applying a simple formula

$$p_s(s)=p_r(r)\left|\frac{dr}{ds}\right|\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots(5)$$

Given a transformation function T(r) we can get $p_s(s)$ so that $p_s(s)$ follows almost uniform distribution which results histogram equalized image.

Histogram equalization expands dynamic range of intensity values while flatten the histogram. On many images, histogram equalization provides satisfactory results, but due to its global treatment of the image, sometimes it over enhance the image.

Adaptive histogram equalization enhances the contrast of images by transforming the values in the intensity image. Unlike histogram equalization, it operates on small data regions, rather than the entire image. The contrast transform function is calculated for each of these regions individually. The optimal size of regions depends on the type of the input image, and it is best determined through experimentation. Contrast factor prevents over-saturation of the image specifically in homogeneous areas. These areas are characterized by a high peak in the histogram of the particular image tile due to many pixels falling inside the same gray level range. The contrast of each region is enhanced, so that the histogram of the output region approximately matches the specified histogram. The neighboring tiles are then combined using bilinear interpolation in order to eliminate artificially induced boundaries. The contrast, especially in homogeneous areas, can be limited in order to avoid amplifying the noise which might be present in the image.

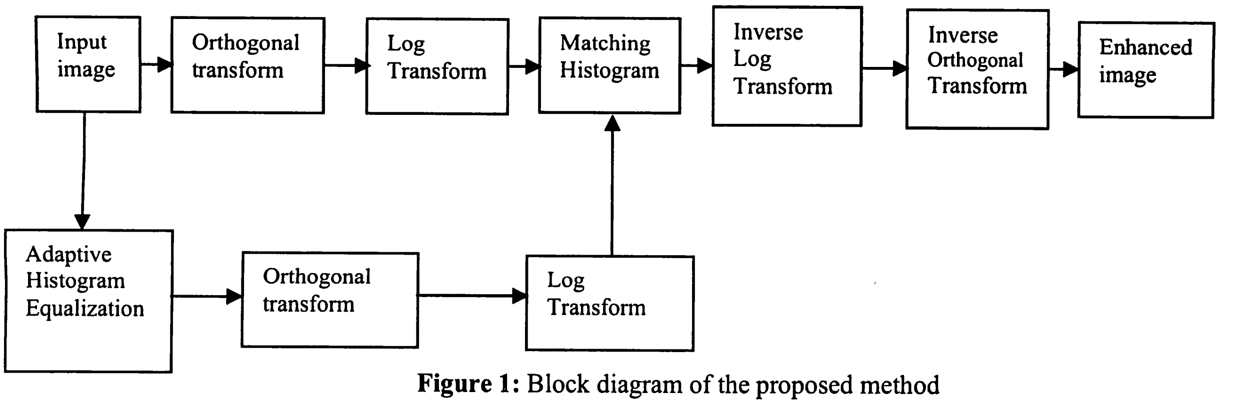


Figure 1: Block diagram of the proposed method

Histogram equalization automatically determines a transformation function that seeks to produce an output image that has a uniform distribution. Histogram mapping is a more generalized version of histogram equalization which allows us to specify the shape of the histogram that we wish the processed image to have. The method used to generate a processed image that has a specified histogram is called histogram matching or histogram specification.

2.4 Performance measure of enhancement

A processed image can be said to have been enhanced over the original image if it allows the observer to better perceive the desirable information in the image. The improvement in images after enhancement is difficult to measure, and therefore difficult to specify the objective and subjective validity of enhancement method [10]. There is no universal measure which can specify both the objective and subjective validity of the enhancement method. In practice many definition of contrast measure are used [14]. To measure the quality (or contrast) of images and select the optimal processing parameters, we use the following quantitative measure of image enhancement proposed in [16].

$$EME_{\alpha,k_1,k_2}(\Phi)=\frac{1}{k_1k_2}\sum_{l=1}^{k_1}\sum_{k=1}^{k_2}20\ln\frac{I^{w}_{\max;k,l}(\Phi,par)}{I^{w}_{\min;k,l}(\Phi,par)+c} \quad ....(6)$$

Where an image x(n,m) be split into k_1k_2 blocks, Φ is a given classical orthogonal transform, α is an enhancement parameter, $I^w\max;k,l$ and $I^w\min;k,l$ are the maximum and minimum intensity value in a given block and c is a small constant equal to 0.0001 to avoid dividing by 0. $EME_{\alpha,k_1k_2}(\Phi)$ is called measure of enhancement or contrast measure with respect to transform Φ.

3. The Proposed method

Transform coefficient adaptive histogram matching is a simple and effective procedure of image enhancement. Here we use adaptive histogram equalization as a baseline to enhance the given image. Figure (1) shows the block diagram of our proposed method. This method uses the following steps.

The first step of this method is to take an image and apply orthogonal transform like DCT, Fourier or cosine transform which involve mapping the intensity data into the given transform.

In the second step logarithmic transformation is applied on the magnitude of orthogonal transformed values which compresses the dynamic range and makes the histogram informative. In this step the phase of the transformed image is preserved by creating a matrix which will be used later to restore the phase of the transform coefficients.

In parallel with this, we use adaptive histogram equalization of the original image. This is operated on small data regions and the contrast transform function is calculated for each of these regions individually as described in section 2.3.

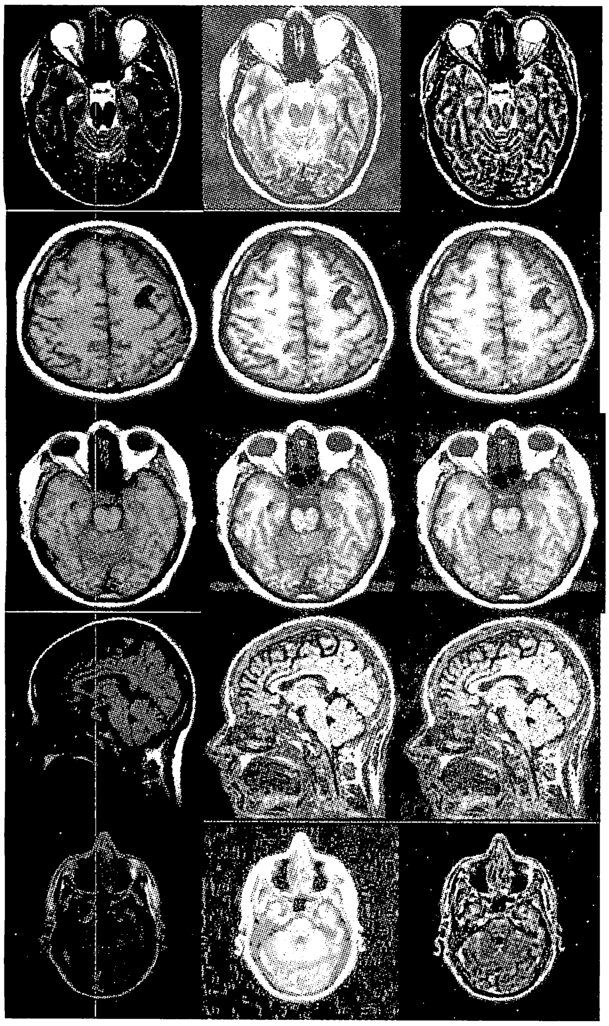
Orthogonal transform is applied to the adaptively histogram equalized image. Log transform is applied to the magnitude of orthogonal transformed values. Then we need to match the transformed data of the original image to the transformed data of adaptively histogram equalized image by using histogram mapping. After this the matched data are exponentiated and previously separated phase is restored. Inverse orthogonal transform is applied which gives the output enhanced image.

By mapping the image to the adaptively equalized histogram and returning the data to the spatial domain, the dynamic range of the image has been expanded, improving contrast and enhancing details throughout.

4. Experimental results

We have proposed a method of image enhancement where transform domain is combined with adaptive histogram equalization. This method provides a powerful and fast method for image enhancement. This method was investigated to show the performance of transform domain adaptive histogram enhancement compared to only histogram equalization technique. For this purpose five images are shown in figure (2).

Investigating figure (2) it can be seen that the proposed method gives better visual quality for different MRI images than general histogram equalization technique. Table (1) shows the numerical results of histogram equalization method and the proposed method with respect to EME using the test images of figure (2).



(a) (b) (c)

Figure 2: (a) Original, (b) histogram equalized and (c) logarithmic transform coefficient adaptive histogram equalized MRI images.

Table 1. Comparison EME of original image, histogram equalized image and LTAHE image

Image	Original	HE	LTAHE
Image 1	76.34	81.52	119.98
Image 2	59.79	62.91	89.44
Image 3	68.13	76.67	92.97
Image4	32.38	58.33	101.78
Image5	30.45	65.92	105.92

From images in figure (2) and table (1) it can be observed that the proposed method gives much impressive performance in the field of medical image enhancement.

5. Conclusion

This paper proposed a method of medical image enhancement based upon the logarithmic transform coefficient adaptive histogram equalization using EME as a measure of performance. The performance of this algorithm was compared to a classical histogram equalization enhancement technique.

LTAHE has been shown to be a powerful method for enhancing medical images. This method has advantage of being quick making it simple based on transform adaptive histogram. The results of this technique shows outperform from commonly used enhancement technique like histogram equalization.

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