A Study on Histogram Equalization for MRI Brain Image Enhancement

N Senthilkumaran and J Thimmia
Department of Computer Science and Applications
Gandhigram Rural Institute - Deemed University,
Gandhigram, Dindigul, India
[nasenthikumaran, thimmia]@gmail.com

Abstract— Magnetic resonance imaging (MRI) of the brain is a precious tool to facilitate physician’s diagnoses and care for a mixture of brain diseases including stroke, cancer, and epilepsy. It presents exact information to discover the diseases. Histogram equalization is one of the important steps in image enhancement technique for MRI. This paper compares different methods like Brightness Preserving Bi-Histogram Equalization (BPBHE), Recursive Mean Separated Histogram Equalization (RMSHE), Brightness Preserving Dynamic Histogram Equalization (BPDHE), Dualistic Sub-Image Histogram Equalization (DSIHE), Minimum Mean Brightness Error Bi-HE Method (MMBEBHE), using different objective quality metrics for MRI brain image Enhancement.

Index Terms— Medical image processing, MRI brain image, Contrast enhancement, Histogram equalization

I. INTRODUCTION

Image processing is a vast and demanding area and its applications used in various fields like medical images, satellite images and also in industrial applications [1]. Vision is the most advanced of our senses; images play the single most important role in human perception [2]. In Medicine Digital Image Processing techniques are used to enhance the contrast for easier interpretation of X-rays and other Bio-medical images. Magnetic resonance imaging (MRI) of the brain is a secure and effortless test that uses a magnetic field and radio waves to generate in depth images of the brain and the brain stem. MRI imaging is moreover used when treating brain tumors, bleeding and swelling etc. These high-resolution images, used to obtain complete anatomical information to observe human brain maturity and discover abnormalities [10].

Image Enhancement techniques are used to develop the image feature for human perception. It is defined as a method of an image processing such that the result is much more appropriate than the original image. Histogram equalization is a fundamental tool in image Enhancement. It is likely to aid in perceptive of how they function on digital images [2].

The intensity level equalization method is an image with increased dynamic range, which will tend to have high contrast. The increased in contrast is due to the significant spread of the histogram over the entire intensity scale. In overall the increase intensity is due to the fact that the average intensity level in the histogram of the equalized image is better than the original. Its function is increase the dynamic range of intensity levels in an image [3].
This paper is organized as follows. Section II introduces about the brain image enhancement. Section III discusses about the Histogram Equalization Techniques. In this Techniques and the equations are explained. Section IV deals with Measurement of HE. Sections V discuss the Analysis of experiments and results for HE. The diagrams displays the Histogram Equalization for all the methods. Finally, Section VI presents the conclusion.

II. BRAIN IMAGE ENHANCEMENT

Enhancement is the alteration of an image to correct impact on the observer. The conditioning of the image can be passed out by preprocessing techniques is image enhancement. Image Enhancement techniques are used to develop the image excellence or appearance for human perception. The processed image is more fitting than the original image for a specific application. A very well-liked technique for contrast enhancement of images is Histogram Equalization (HE). The most part of method is used, due to its simplicity and moderately better performance on images.

Magnetic resonance imaging (MRI) of the brain is a secure and easy test that uses a magnetic field and radio waves to generate detailed images of the brain and the brain stem. MRI machines have better openings and supportive for patients with claustrophobia. MRI of the brain can be helpful in estimate problems such as persistent headaches, dizziness, weakness, and blurry vision or seizures, and it can help to notice certain chronic diseases of the nervous system, such as multiple sclerosis [10][13].

III. HISTOGRAM EQUALIZATION TECHNIQUES

Histogram Equalization (HE) and their complex methods are measured for contrast enhancement of the images. In this we discuss about some methods in HE.

A. Brightness Preserving Bi-Histogram Equalization (BPBHE)

BPBHE method divides the image histogram into two parts. The separation intensity is presented by the input mean brightness value, which is the average intensity of all pixels that construct the input image. After this separation process, these two histograms are independently equalized. By doing this, the mean brightness of the resultant image will lie between the input mean and the middle gray level. The histogram with range from 0 to L-1 is divided into two parts, with separating intensity. This separation produces two histograms. The first histogram has the range of 0 to $m$, and the second histogram has the range of $m+1$ to L-1 [4].

Let $X_m$ be the mean of the image $X$ and assume that $X_m, E \in \{X_0, X_1, ..., X_{L-1}\}$ the mean. The input image is decomposed into two subimages $X_L$ and $X_U$ [2].

$$X = X_L \cup X_U$$

$$X_L = X (i, j) | X (i, j) \leq X_m, \forall X (i, j) \in X$$

$$X_U = X (i, j) | X (i, j) \geq X_m, \forall X (i, j) \in X$$

The subimage $X_L$ is composed of $\{X_0, X_1, ..., X_m\}$ [1] and the other subimage $X_u$ is composed of $\{X_{m+1}, ..., X_{L-1}\}$. The respective cumulative density functions for $\{X\}_L$ and $\{X\}_U$ are then defined as

$$C_L(x) = \sum_{j=0}^{m} p_L(x_j)$$

And

$$C_U(x) = \sum_{j=m+1}^{L-1} p_U(x_j)$$

The following transform functions

$$f_L(x) = (X_0 + (X_m - X_0)C_L(x))$$

$$f_U(x) = X_{m+1} + (X_{L-1} - X_{m+1})C_U(x)$$

(2)
Equalize the two subimages over the two ranges $X_0, \ldots, X_m$ and $X_{m+1}, \ldots, X_L$ (2). Thus the entire range is covered, in order to qualitatively see the effects of equalization [8].

B. The Recursive Mean Separated Histogram Equalization (RMSHE)

The Recursive Mean Separated Histogram Equalization RMSHE is an extensive description of the Brightness Preserving Bi-Histogram Equalization BBHE method. BBHE specified that performing mean-separation earlier than the equalization process does preserve an images original brightness. It is described by decomposing the original image into two new sub-images based on the mean of the input image. This is consequent to divide the histogram into two based on the mean of the input images histogram [9]. After mean separation, the secondary new histograms are equalized independently. Instead of decomposing the image simply once, the RMSHE method proposes to execute image decomposition recursively, up to a scale $r$, generating $2^r$ sub-images [4].

Consider one of the segmented histogram $H_t(X)$ defined over gray level range $[X_l, X_u]$. The mean $X_M$ the sub-histogram $H_t(X)$ is computed by using

$$X'_M = \frac{\sum_{k} k \cdot p(k)}{\sum_{k} p(k)}$$  \hspace{1cm} (3)

Based on the computed mean $X'_M$, the histogram $H_t(X)$ is then divided into two sub-histograms $H^+_1 L(X)$ and $H^+_1 U(X)$ for the next recursion level $t+1$, where $H^+_1 L(X)$ and $H^+_1 U(X)$ are the two subsections of the segmented histogram. According to the specified recursion level $r$, the histogram produces sub histograms. Hence when $r=2$ we have some subsections of the histogram. Each subsection is normalized as the probability density function gives a sum greater than one. The regulated subsections are then equalized. The equalized four subsections are then combined together to give the equalized image [8].

C. The Brightness Preserving Dynamic Histogram Equalization (BPDHE)

The Brightness Preserving Dynamic Histogram Equalization BPDHE is an extension to HE that can produce the output image with the mean intensity almost same as that of the input image it completes the requirement of preserving the mean brightness of the image. The method partitions the histogram based on the local maximum of the smoothed histogram [5]. This method is really an expansion to both MPHEBP and DHE. Similar to MPHEBP, the method partitions the histogram based on the local maximums of the smoothed
histogram [4]. However, before the histogram equalization attractive the place, the method will map each partition to a new active range, similar to DHE. The change in the dynamic range will cause the change in mean brightness; the final step of this method involves the normalization of the output intensity. So, the average intensity of the resultant image will be same as the input. With this criterion, BPDHE will produce better enhancement compared with MPHEBP, and better in preserving the mean brightness compared with DHE [4] [5].

This is done by taking the derived and the identifying the point where four successive –ve signs are followed by eight successive +ve signs. The number of sections formed will depend on the number of peaks detected. Each of the subsection is mapped to a new dynamic range. Each section is equalized separately [8].
D. Dualistic Sub-Image Histogram Equalization (DSIHE)

Figure 4. DSIHE Image Image a) Original Image, b) histogram image for(a), c) HE image(a), d) histogram image for(c)

Dualistic sub-image HE follows the same basic idea of BBHE method. It decomposes the original image into two sub-images and then equalizes the histograms of the sub-images separately. Instead of decomposing the image based on its mean gray level, the method decomposed into two sub-images, being one dark and one bright, respecting the equal area property [4] [5]. It is shown that the brightness of the output image O formed by the DSIHE method is the normal of the equal area level of the image I and the middle gray level of the image, i.e., $L/2$. The authors of say that the brightness of the output image generated by the DSIHE method does not in attendance a major shift in relation to the brightness of the input image, particularly for the large area of the image with the same gray-levels (represented by small areas in histograms with great concentration of gray levels), e.g., images with small objects regarding to great darker or brighter backgrounds [5][6].

E. Minimum Mean Brightness Error Bi-HE Method (MMBEBHE)

It also follows the same basic principle of decomposing an image and then applying the HE method to equalize the resulting sub-images independently. The main difference between these technique is that earlier consider only the input image to execute the decomposition while the MMBEBHE searches for a threshold level that decomposes the image I into two sub-images $I[0, l_t]$ and $I[l_t+1, L-1]$, such that the minimum brightness difference between the input image and the output image is accomplished, that is called as absolute mean brightness error difference between the input image and the output image is achieved, whereas the former methods consider only the input image to perform the decomposition [5].

Once the input image is decomposed by the threshold level it, each of the two sub-images $I[0, l_t]$ and $I[l_t+1, L-1]$ has its histogram equalized by the classical HE process, produce the output image. Assumptions and manipulations for finding the threshold level $l_t$ in $O(L)$ time complexity was made in. Such approach allows us to obtain the brightness $l_{in}(O[O, I] \cup O[l_t+1, L-1])$ of the output image without generating the output image for each candidate threshold level $l_t$ and its aim is to produce a method suitable for real-time applications [4][7].

IV. MEASUREMENT OF HISTOGRAM EQUALIZATION

Every above method are compared by statistical point of view by using some standard quality measures.
A. Peak-signal-to-noise-ratio (PSNR):
PSNR is the evaluation standard of the reconstructed image quality, it is generally used in measuring the quality and it is important measurement feature. PSNR is measured in decibels (dB) and is given by [12]:
$$PSNR = 10 \log \left( \frac{255^2}{MSE} \right)$$
(4)
Where the value 255 is maximum possible value that can be attained by the image. Mean square error (MSE) is defined as, where \( M \times N \) (4) is the size of the original image. Higher the PSNR value is, better the reconstructed image [12]

B. Entropy
Discrete entropy \( E(X) \) measures the richness of details in an output image after enhancement (5) [11].
$$E(P) = -\sum_{k=0}^{L-1} P(k) \log_2 P(k)$$
(5)

C. Contrast:
Contrast can be specified as ratio, such at 3:1. An N:1 ratio means that dividing the brighter luminance by the darker luminance gives a number that is equal to N. This can also be specified as an equation:
$$Cr = \frac{Y_{\text{max}}}{Y_{\text{min}}}$$
(6)
For display systems, contrast ratios are white: black (6), and are often highly inflated by neglecting the impact of ambient illumination under typical viewing environments

D. Absolute mean brightness error (AMBE):
Absolute Mean Brightness Error is used to assess the degree of brightness preservation. It is calculated using the equation as [11]
$$\text{AMBE}(X, Y) = |X_M - Y_M|$$
(7)
Where \( X_M \) is the mean of the input image \( X = \{X(i,j)\} \) and \( Y_M \) is the mean of the output image \( Y = \{Y(i,j)\} \) (7).
A small value of AMBE indicates better brightness preservation in the output image [11].

V. ANALYSIS OF EXPERIMENTS AND RESULTS FOR HISTOGRAM BRAIN IMAGE

In this paper, we study and compare histogram based approach for contrast enhancement. The good contrast image is helpful for feature analysis and diagnosis. This contrast is measured with different objective quality metrics. All the above methods are applied on different brain MRI images. In below diagram Fig.6 and Fig.7 shows the different images for histogram equalization, Table.1 refers the Quality measurement for the values. Fig.8 refers the HE graph images. The proposed enhanced images create without any loss in the image information.

A. Results

![Figure 6. Histogram Equalization (a) BPBHE image, (b) Using RMSHE image, (c) Using DMISHE image, (d) Using DSIHEimage, (e) Using MMBEBHE image](image-url)
Figure 7. Histogram Images Corresponding to Figure 6. (a) Using BPBHE image, (b) Using RMSHE image, (c) Using DMISHE image, (d) Using DSIHE image, (e) Using MMBEBHE image

B. Quality measures

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<th>Metrics</th>
<th>BPBHE</th>
<th>RMSHE</th>
<th>DMISHE</th>
<th>DSIHE</th>
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C. Graphs
VI. CONCLUSION

The comparative analysis of different enhancement methods based on histogram processing. The enhanced images using histogram equalization by reconfiguring there pixel levels in histogram techniques. We achieve through the quality to evaluate the methods, we have used the PSNR, AMBE, entropy and contrast as parameters. These parameters show that how the results vary on applying different techniques of enhancement. DSIHE, MMBEBHE is the extension of BBHE method that provides maximal brightness preservation. It can perform good contrast enhancement methods for MRI Brain Image.

ACKNOWLEDGMENT

This research is supported by University grants Commission, India, through a Major Research Project, Grant (UGC.F.NO.42-131/2013 (SR)).

REFERENCES


325