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European Journal of Advances in Engineering and Technology, 2015, 2(11): 49-55

Research Article ISSN: 2394 - 658X

Histogram Equalization and Histogram Matching for the Biomedical Image Enhancement and Visualization

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ABSTRACT

The main purpose of Image enhancement is to process an image to ensure that results are more desirable than the original image for a particular application. Digital image enhancement techniques offer a plethora of alternatives for improving the visual quality of the images. Suitable choice of such techniques is significantly influenced by the imaging modality, task and the viewing conditions. This paper gives an overview of fundamental concepts, as well as algorithms common for image enhancement. In this paper, instead of using normal images, the image enhancement methods are being used for medical images as the basic approach for reading, analyzing and applying some enhancements to medical images is much more complex as compared to normal images.

Key words: Fuzzy, LMS, HE, CDF

INTRODUCTION

Image Enhancement is a digital processing method that basically modifies the pixel intensity of original image to improve the interpretability or perception of information for providing a better view for human viewers and input for other automated image processing systems. Image Enhancement improves the quality of an image by manipulating intensity and contrast, by reducing noise level, filtering and making the edges more sharp. The key objective of image enhancement is to modify attributes of an image to make it more desirable for a given task and a specific observer. With this process, several attributes of the image are changed. The selection of attributes and the way they are modified are explicit to a given task. Moreover, observer-specific factors, like the human visuals and the observer's experience, introduce a lot of subjectivity into the choice of image enhancement methods. There exist a lot of techniques that can improve digital image without spoiling it. These methods can be divided into the following two categories:

- Spatial Domain Techniques
- Frequency Domain Techniques

In spatial domain methods, we directly deal with the pixels of an image. The pixel values are manipulated to accomplish preferred enhancement. In the frequency domain methods, the image is first changed in to the frequency domain. Thus the Fourier Transform of the image is calculated first. All the enhancement operations are performed after doing the Fourier transform of the image and at last, the Inverse Fourier transform is conducted to have the final image. These enhancements are performed to be able to change the image distribution of the grey levels, contrast or the brightness. Therefore, the pixel value of the output image becomes modified as outlined by the transformation function which is applied on the input values [1].

In [1], Maini and Aggarwal focus on spatial domain techniques for image enhancement, with particular reference to point processing methods and histogram processing. Numerous contrast enhancement techniques were reviewed by Christian [2], out of which four representative techniques such as homomorphic filtering, fuzzy-logic enhancement and single-scale retinex techniques have been implemented. Sawant and Chavan [3] analyzed the performance of a traditional LMS algorithm for different. This algorithm can be applied to the beam forming with the software Matlab. The result obtains can achieve faster convergence and lower steady state error. Various Techniques have been studied by Gupta and Purkayastha [4] and tested on different images for their results and effects in the border extraction, edges detection, pixel value matrix computation and controlling and contrast of images. MATLAB based image processing tools have been utilized for the complete enhancement and analytical operations.

Mundhada and Shandilya [5] presented that image enhancement is to improve the image quality so that the resultant image is better than the original image for a specific application or set of objectives. Enhancement techniques such as alpha rooting operate on the transform domain. The transform domain enables operation on the frequency content of the image, and therefore high frequency content such as edges and other subtle information can easily be enhanced. However, these techniques bring about tonal changes in the images and can also generate unwanted artefacts in many cases, as it is not possible to enhance all parts of the image in balanced manner. Al-Samaraie[6], introduces a new image Enhancement approach suitable for digital cameras. High contrast images are common in the scenes with dark shadows and bright light sources. It is difficult to show the details in both dark and light areas simultaneous on most display devices. For solving this problem, there are many methods of image enhancement proposed to improve the quality of the images. However, most of them often get poor results if the Images are high contrast and have wide dynamic range. This method for enhancing the high-contrast digital camera images, which enhances the global brightness and contrast of images while preserving details. Kaur et al [7] presented a review of new forms of histogram for image contrast enhancement. The major difference among the methods in this family is the criteria used to divide the input histogram. Brightness preserving Bi-Histogram Equalization (BBHE) and Quantized Bi-Histogram Equalization (QBHE) use the average intensity value as their separating point. Fuzzy logic is employed to deal with the uncertainty of colour cast in the image. RGB channels are fuzzy individually using Gaussian membership function between two sets the LOW and the HIGH. Six fuzzy rules have been defined to find the cast in the colour image. Then according to the cast, the correction factor is found using the mean of RGB channels as done in the gray world based correction.

MATERIALS AND METHODS

Histogram Equalization

Histogram equalization (HE) is a frequently used contrast enhancement technique used for both colour and greyscale images. Histogram Equalization is accomplished by linearizing the cumulative density function of the image intensity levels.

The algorithm for the implementation of the classical histogram equalization is shown below [2]:

```
for each pixel p in image do
        deposit p in temporary bin bg(p).
end for
j ← 0
for each temporary bin bi do
      Increment count
      Copy pixels bi into histogram bin h(j/D).
j ← j + |bi| {|bi| = number of pixels in bi}
end for
for i= 0 to D − 1 do
     Set grey level of each pixel in bin hi to i.
end for
```

The performance of the HE in enhancing the contrast is associated with an image as a result of the dynamic range expansion; in addition, HE also flattens a histogram. Based on information theory, entropy of the message source can get the maximum value when the message has uniform distribution property. HE can introduce a significant alternation in brightness of the image, which hesitates the direct use of the HE scheme in consumer electronics [7].

Gray World Correction Techniques

It estimates the illuminant using the average color of the pixels. The gray world assumption is probably one of the best-known algorithms for color constancy. Gray world color correction algorithm is based on the assumption that if there is a sufficient amount of color variation within a given image, then the average of the R, G and B components of the image should be a standard gray value.

A simple method of Gray World Assumption technique is to find out average values of image's R, G and B components and to use this average to determine the overall gray value of the image.

Consider the image I(i,j), where (i,j) represents the corresponding pixel coordinates in RGB format,

$$I_{i,j} = (R_{i,j}, G_{i,j}, B_{i,j})$$
$$R_{i,j}, G_{i,j}, B_{i,j} \in [0,255]$$

$R_{i,j}$, $G_{i,j}$, $B_{i,j}$ represents the magnitude of R, G, B components of the image respectively. The value of i = 1… m and j = 1…n as m and n are the number of pixels in row and column respectively.

In the conventional gray world color correction approach the mean values of the RGB color channel is calculated for all the pixels of the image I denoted by, ,. R G B

Each color component is scaled according to the amount of deviation from this gray value. The corrected and enhanced image is obtained by multiplying the R-and B-channels with their associated scaling factors while the G-channel is left unchanged [9].

Homomorphic Filtering

Homomorphic filtering is a frequency domain method for contrast enhancement. Homomorphic filtering is based on a simple model of the imaging process, wherein images are formed from sensing light from the illumination source reflected from the surface of the objects being experiential. An image described by a two-dimensional intensity pattern f(x, y); can be broke into two diverse components:

$$f(x,y) = r(x,y) * i(x,y)$$

- The amount and spatial distribution of source illumination incident on the object i(x, y), and
- The two-dimensional reflectivity profile of the object

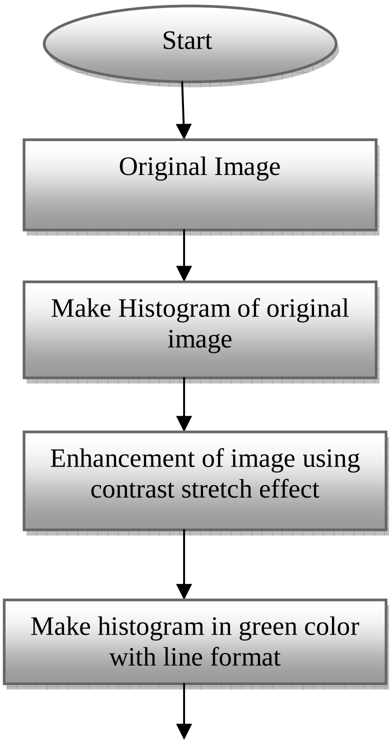
These are often referred to as the *illumination* and the *reflectance* components respectively. These spatial distribution components are then combined by simple scalar multiplication to form the image brightness pattern incident on the camera, as shown in $f(x,y) = r(x,y) * i(x,y)$ [2].

METHODOLOGY

The steps of our methodology are as follows:

1. Obtain all the inputs: Image, Number of regions in row and column directions, Number of bins for the histograms used in building image transform function (dynamic range), Clip limit for contrast limiting (normalized from 0 to 1).
2. Pre-process the inputs: Determine real clip limit from the normalized value if necessary, pad the image before splitting it into regions.
3. Process each contextual region (tile) thus producing gray level mappings: Extract a single image region, make a histogram for this region using the specified number of bins, clip the histogram using clip limit, create a mapping (transformation function) for this region.
4. Interpolate gray level mappings in order to assemble final CLAHE image: Extract cluster of four neighboring mapping functions, process image region partly overlapping each of the mapping tiles, extract a single pixel, apply four mappings to that pixel, and interpolate between the results to obtain the output pixel; repeat over the entire image.
5. Computational cost of the algorithm needs to be calculated.
6. The role of image enhancement, gray-level mapping, and image reconstruction from projections algorithms in CT and other radiological imaging modalities needs to be shown.
7. We need to compare the efficiency of this algorithm with other already implemented algorithms. For this, the user should be able to choose 2 other algorithms and compare the results.

The flowchart of the methodology is as shown below:



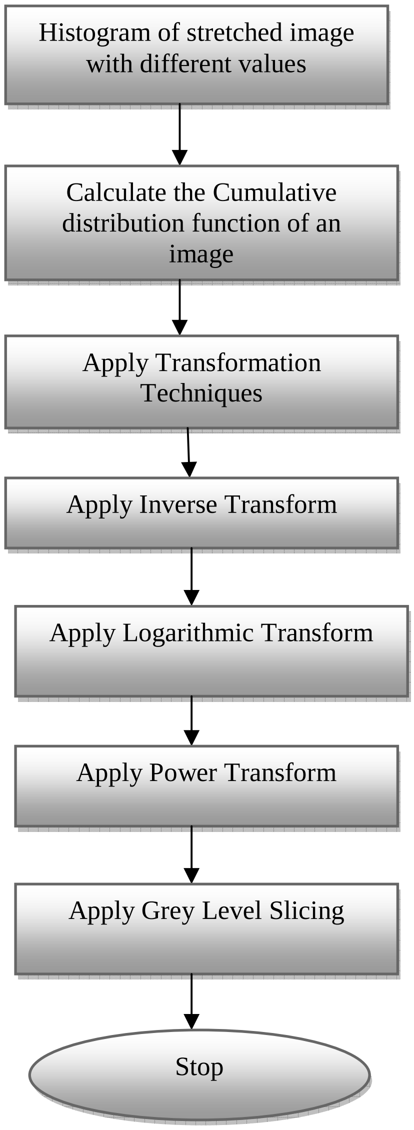


Fig. 1 Flowchart of proposed methodology

RESULT AND DISCUSSION

As we know that image enhancement makes it possible to modify the certain images in certain parts so that overall quality of the image is enhanced. These enhanced images can be used for some specific application or these can be general images which are enhanced on certain parts so that image is more clearly visible or brighter and illuminated than the original in some cases. Image enhancement is a simple process which can be implemented by using different algorithms. Histogram Equalization algorithm which enhances the images with minimum distortion and noise and takes minimum time is considered best. We can use the image enhancement if we have an image in which a bright object is in front and then we have a small object which is in the background and are not visible and bright. If we want the background object to be visible and bright then we can apply image enhancement algorithm to make this possible. We had applied image enhancement algorithm on the brain medical images.

In Fig. 2, the stretch function on to the brain image is used so that it can be enhanced for this feature. The stretch function is applied only for one dimension as shown in Fig. 2 but it can be extended for both the dimensions. In the contrast stretch image enhancement technique, we have tried to improve the contrast of the image by `stretching' or increasing the range of intensity values. We have found out the total span of the range of values for which enhancement is required. We can have full range of pixel values or partial multiple sets of pixel values that the image can support and allow to improve. Fig. 3 shows the various stages of image enhancement. We have Normalize the calculations to get the regions with similar values and then found CDF values so that we can apply convolution function to get the even pixel values. The whole technique is basically dependent on histogram gray scale spacing based processing.

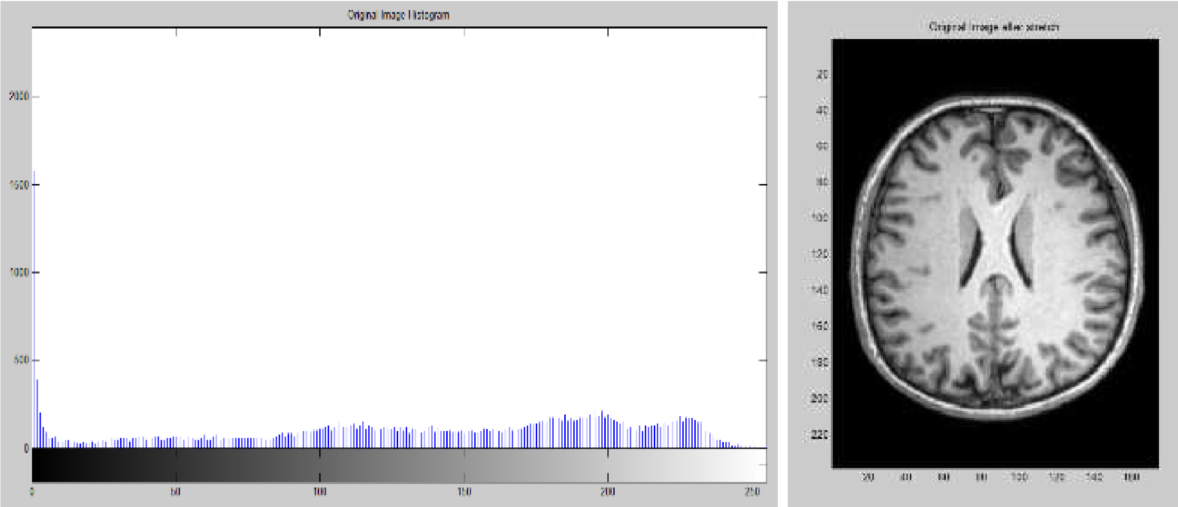


Fig. 2 Image enhancement using contrast stretch effect

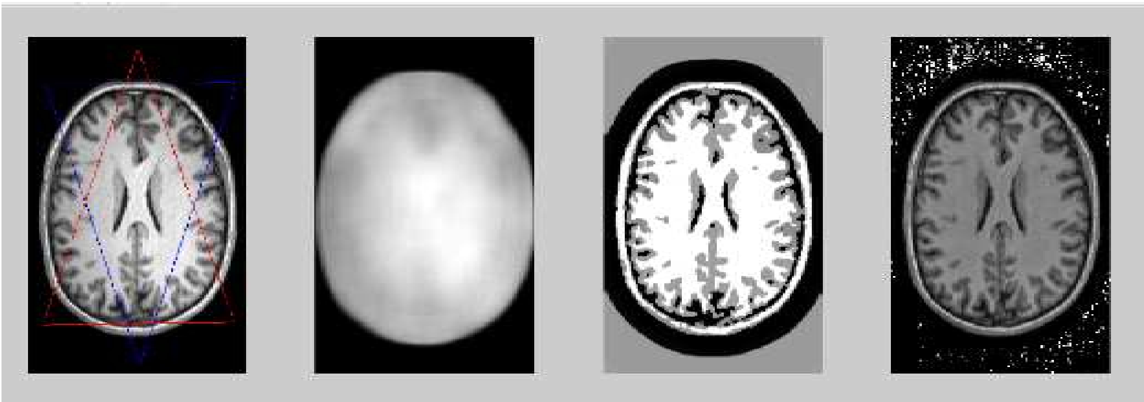


Fig. 3 Overall process of the Image enhancement

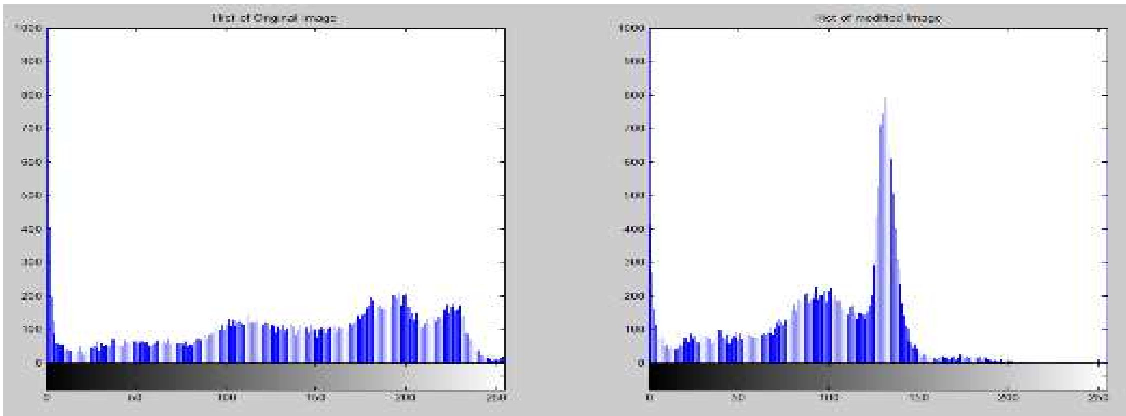


Fig. 4 Comparative figure for histogram of original and enhanced images

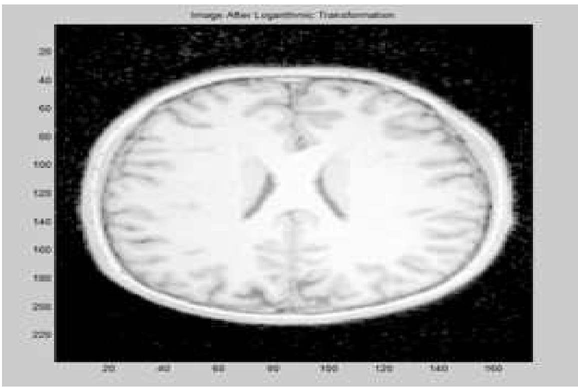


Fig. 5 Image after Logarithmic Transformation

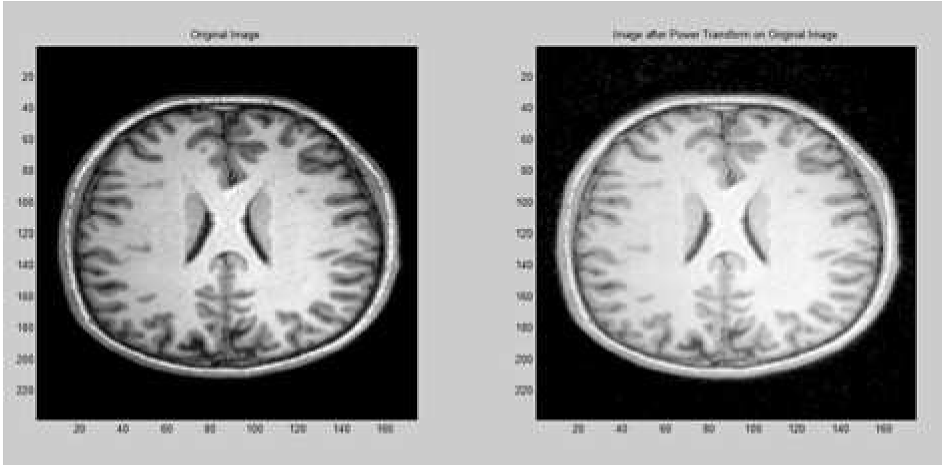


Fig. 6 Original Image and Image after Power Transform in Original Image

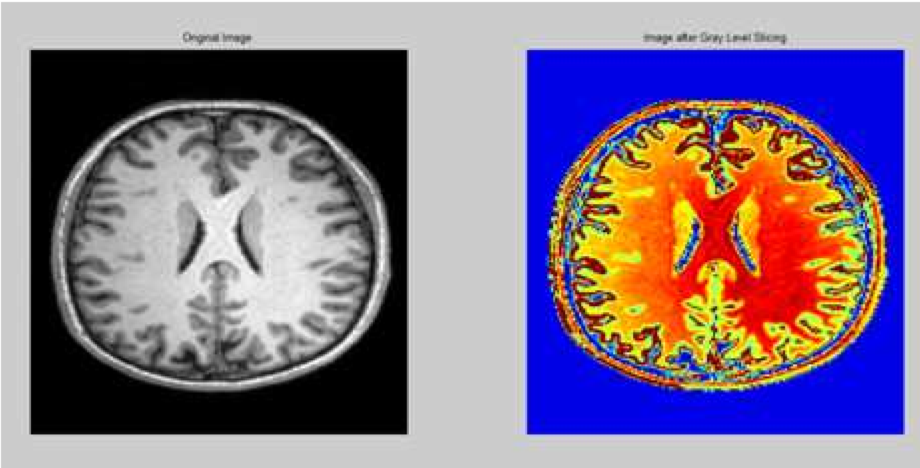


Fig. 7 Original Image and Image after Grey Level Slicing

Table 1: Transformation Techniques

Technique	Mean Value	Standard Deviation	Variance
Histogram Equalized	84.5536	86.2417	7.4376e+003
Inverse Transform	145.7631	53.1314	2.8229e+003
Logarithmic Transform	109.2369	53.1314	2.8229e+003
Power Transform	130.6497	110.5557	1.2223e+004
Gray Level Slicing	109.2133	98.5980	9.7216e+003

CONCLUSION

There are various techniques that can be used for reduction of noise from the image. A biomedical image enhancement technique helps us to get the parameters and implements various types' choices to improve and enhance a particular image. The histogram equalization helps us to enhance an input image by updating its histogram which will represents the intensity plot and the enhancement is done till the histogram shows a desired shape. The histogram equalization method is easy to use and implement. When the image is enhanced in such a way so that it reaches at threshold value then the desired shape of histogram is generated and this uniform method is called histogram equalization. We have concluded that it is possible to apply Image enhancement algorithms for biomedical images. We had run the algorithm multiple times to improve the modifying images and it is possible to get a visually acceptable image after enhancement. The method to implement enhancement is a function of the pixel values, image content, observer characteristics, and viewing conditions.

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