A SURVEY OF MRI ENHANCEMENT TECHNIQUES

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Abstract : ***Enhancement of medical Images is a requisite for increasing the accurancy of computer aided diagnosis in radiology. The Research issue in medical image enhancement is to enhance the visual appearance without compromising with the intrinsic image features as they are crucial for diagnosis.This paper presents a short overview of different image enhancement techniques.The impact of different techniques for T1 C+ MRI brain ring enhancing lesions are evaluated based on Peak Signal to Noise Ratio.***

IndexTerms - Medical image enhancement, Histogram Equalization, Bilateral filter, Wiener filter, Homomorphic filtering

I.INTRODUCTION

The quality of medical images are deteriorated during image acquisition and illumination conditions. Image enhancement apply mathematical transformation on images to improve the viaual appearance for assisting radiologists for diagnosis and surgical planning. Different techniques are proposed to solve this issue based on spatial methods,wavelet methods,histogram methods and contrast improvement to enhance the appearance of images for better visual interpretation, understanding and image analysis[1].

Medical image enhancement technologies have gained attention since advanced medical equipments were put into use in the medical field [2]. As intensity levels, edge details, enhancement pattern plays a crucial role for medical image analysis, the enhancement methods should be choosed without affecting this details in images. Also ,in case of real time image processing,enhancement techniques should be less time consuming even in case of bulk volume MRI. MRI poses certain challenges like intensity non-uniformity, high visual similarity between normal and abnormal tissues.

Several techniques for enhancement based on histogram, contrast stretching, tone mapping are proposed[3] . The spatial domain methods operate directly on image pixels. It considers the pixel neighborhood information for image enhancement. Frequency based method transforms image into its fourier representation for applying the filtering techniques and then revert the image by its inverse fourier tranform.Histogram Equalization techniques can be used to improve the contranst of images. Contrast techniques can be local, global, partial in images.The following section discusses the seven differernt types of image enhancement techniques.

II. ENHANCEMENT TECHNIQUES

2.1. Histogram Equalization and Local Histogram Equalization

Histogram equlaization manipulates the image histogram to uniformly distribute the pixel intensity resulting in a uniform histogram. For each pixel in the image the 3X3 window is extracted and the histogram equalization is used to compute the enhanced pixel value. The process of Local Histogram equalization[4] is that:

1.Compute the probability distribution function, $p(X_k)$

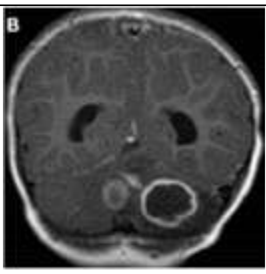
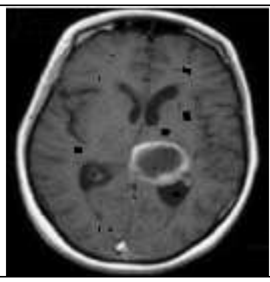
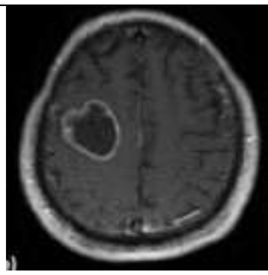
$$p(X_k)=\frac{nk}{n} \qquad (1)$$

2.Compute the cummulative distribution function c(X) for each pixel value

$$c(X)= \sum_{i=0}^{k} p(Xi) \quad (2)$$

3.The centre pixel is replaced with the c(X) value.

Table I Results of Histogram Equalization and Local Histogram Equalization using 3X3 window and K=0.1

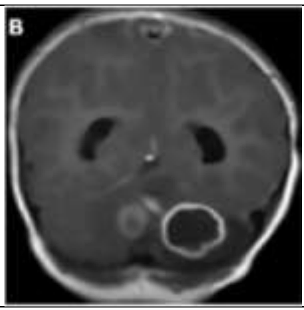
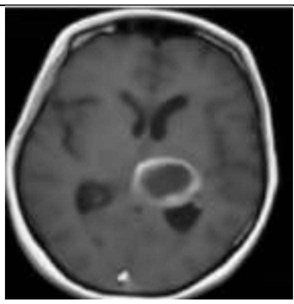
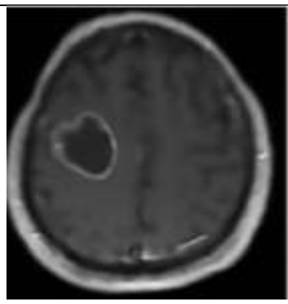
Image	Abcess	Gliblastomamultiforme	Metastasis
Histogram Equalization and Local Histogram Equalization			
PSNR	77.26	75.25	73.28

2.2. Non Local Means Filter

The pixel value is estimated based on the pixel similarity and the weighted average of all the pixels in the image.For the intensity image v={v(i) |i € I}, the estimated value NL[v](i)[5], for a pixel i, is computed as a weighted average of all the pixels in the image and is given by ,

$$NL[v](i),=\sum_{j \in I} w(i,j)v(j) \qquad (3)$$

Weights $w(i,j)$ depend on the intensity similarity between the pixels i and j, and in the range $0 \leq w(i,j) \leq 1$ and $\sum_j w(i,j) = 1$

Image	Abcess	Gliblastomamultiforme	Metastasis
Non Local Means Filter			
PSNR	72.09	72.09	69.31

2.3. Bilateral Filter

Tomasi and Manduchi [6]proposed bilateral filter as an alternative to anisotropic diffusion filter. Bilateral filter combines domain and range filtering.The similar neighborhood pixels are isolated and the weighted average is used for estimating the enhanced pixel value. For the intensity image v={v(i) |i € I}, the estimated value BL[v](i) is computed as

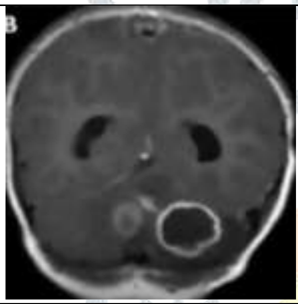
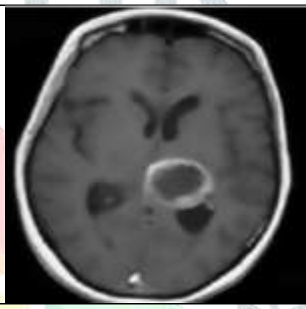
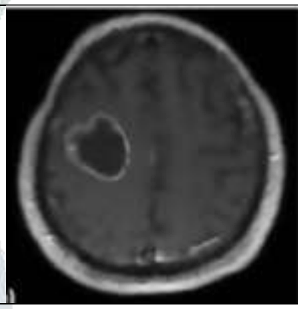
$$BL[v](i)=\frac{1}{W_p}\sum_{x_i\in\Omega} v(x_i)\, f_r\left(||v(x_i)-v(x)||\right) g_s\left(||x_i-x||\right) \quad (4)$$

W_p is the normalization term and is given by,

$$W_p=\sum_{x_i\in\Omega} f_r\left(||v(x_i)-v(x)||\right) g_s\left(||x_i-x||\right) \quad (5)$$

Where, Ω is the neighborhood window, f_r is the range kernel for smoothing intensity differences, g_s is the domain kernel for smoothing spatial coordinate differences.

Table III Results of Bilateral Filter with normalization w=5

Image	Abcess	Gliblastomamultiforme	Metastasis
Bilateral filter			
PSNR	75.05	73.41	70.98

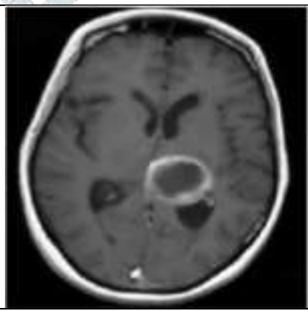
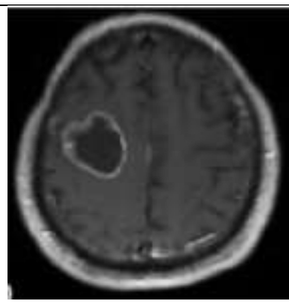
2.4. Anisotropic diffusion

Anisotropic diffusion is a multi-scale technique to detect edges [7]. The diffusion process performs smoothing in continuous regions and prevents smoothing in edges. The filter is based on constrained differential diffusion equation for the intensity image I with diffusion time t,

$$I_t=div|(c(x,y,t),\nabla I) = c(x,y,t)\Delta I) = c(x,y,t)\,\Delta I + \nabla c.\nabla I \quad (6)$$

Where, div is the divergence, ∇ is the gradient , Δ is the Laplacian operator and c(x, y, t) is the diffusion strength. The diffusion strength is close to zero at edges having large gradients and maximum in homogeneous regions having small gradients.

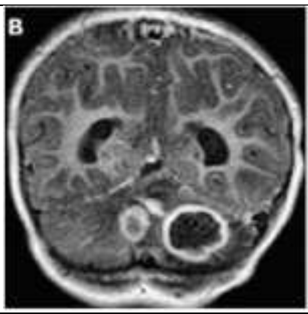
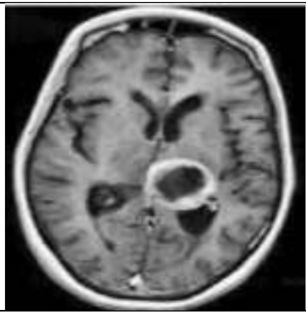
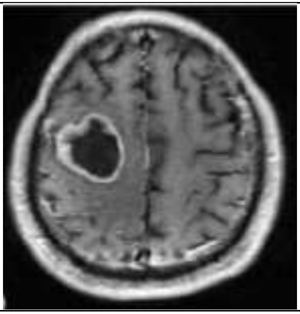
Table IV Results of Anisotropic diffusion with iterations=2, delta= 1/7 kappa = 30

Image	Abcess	Gliblastomamultiforme	Metastasis
Anisotropic diffusion			
PSNR	42.90	42.39	42.41

2.5. Contrast-limited adaptive histogram equalization (CLAHE)

CLAHE addresses the problem of noise amplification. It operates on small regions called tiles in image .For each tile, contrast is enhanced based on a distribution parameter. Artificial boundaries are prevented by combining the neighborhood tiles using bilinear interpolation [8].

Table V Results of Contrast-limited adaptive histogram equalization

Image	Abcess	Gliblastomamultiforme	Metastasis
Contrast-limited adaptive histogram equalization			
PSNR	42.29	42.34	50.60

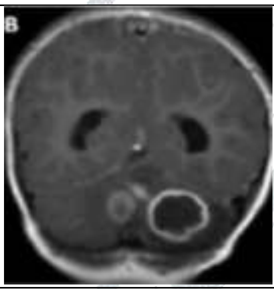
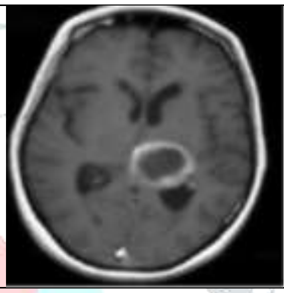
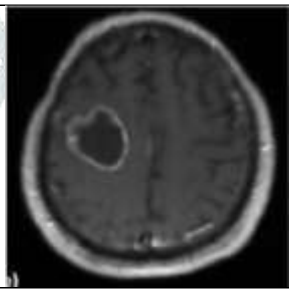
2.6. Wiener Filter

For each pixel, local statistics are measured from its 3X3 neighborhood η in the image I and the filtering is based on the following equation,

$$w(n_1,n_2)=\mu+\frac{\sigma^2-v^2}{\sigma^2}(I(n_1,n_2)-\mu) \qquad (7)$$

Where v^2 is the noise variance, σ^2 is the variance, μ is the mean in η.

Table V Results of wiener filter

Image	Abcess	Gliblastomamultiforme	Metastasis
wiener filter			
PSNR	38.71	37.87	39.45

2.7. Homomorphic Filtering

Homomorphic filtering [9] normalizes image brightness to increase contrast for enhancement. For uniform brightness the high frequency are amplified to contribute reflectance and low frequency components are attenuated to reduce illumination.
The illuminated image can be represented as,

$$I_{out}(x,y)=i(x,y).r(x,y) \qquad (8)$$

Where i(x,y) is the illumination and r is the reflectance at the position (x,y).
Taking log,

$$Ln(I_{out}(x,y))=ln(i(x,y))+ln(r(x,y)) \qquad (9)$$

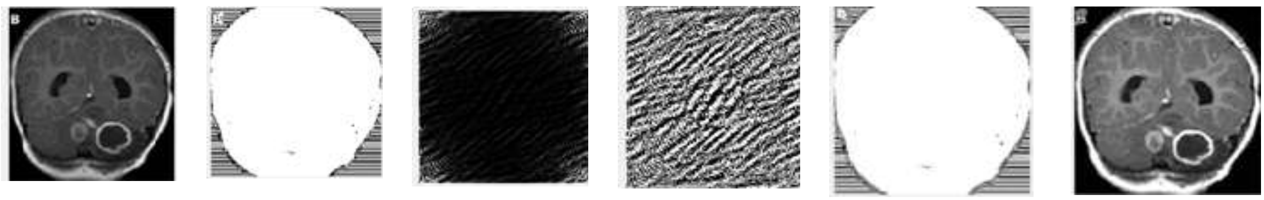
Applying Fourier transformation,

$$F(Ln(I_{out}(x,y)))=F(ln(i(x,y)))+F(ln(r(x,y))) \qquad (10)$$

$$\text{Or, } M(u,v)=I(u,v)+R(u,v) \qquad (11)$$

u,v refer to the frequency domain transformation.Applying High pass filter H we get the filtered image N,

$$N(u,v)=H(u,v)\ .\ M(u,v) \qquad (12)$$

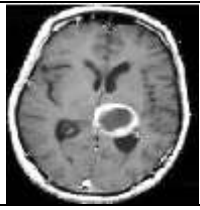
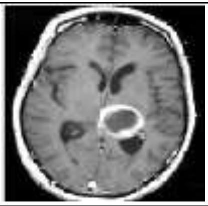


(a) (b) (c) (d) (e) (f)

Fig.2. Homomorphic filtering process in frequency domain

Fig.2.a Abscess image 2.b Natural logarithm of abcess 2.c Fourier Transform 2.d Homomorphic filtering 2.e Inverse Fourier Transform 2.f Enhanced Image

Table V Results of Homomorphic filtering

Image	Abcess	Gliblastomamultiforme	Metastasis
Homomorphic filtering			
PSNR	42.59	42.59	51.91

III.PERFORMANCE EVALUATION

The performance of the methods are analyzed visually and quantitatively using Peak Signal to Noise Ratio (PSNR). PSNR block computes the peak signal-to-noise ratio, in decibels, between two images. This ratio is often used as a quality measurement between the original and enhanced image. The higher the PSNR, better the quality of the estimated image. PSNR in decibels (dB) is computed by using the equation (13)

$$PSNR = 10\log 10\left(\frac{255^2}{MSE}\right) \qquad (13)$$

Where MSE is given by equation ()
Mean Square Error (MSE) is computed using the equation (14).

$$MSE = \frac{1}{MN}\sum_{y=1}^{M}\sum_{x=1}^{N}[I(x,y) - I'(x,y)]^2 \qquad (14)$$

Where I(x,y) is the original image, I'(x,y) is the enhanced image and M,N are the dimensions of the images. A lower value for MSE means lesser error.

Local Histogram Equalization techniques enhance by increasing the brightness but the contrast among the soft tissues is decreased. In case of Non Local Means Filter the pixels are estimated by global intensity computation which introduces a blurring effect in the enhanced image. Bilateral filter isolates the similar neighborhood pixels and assigns weights to each pixel for finding the estimated value. This performs well on de-noised image. Laplacian operator is used in Anisotropic filter for detecting the edges and homogeneous regions. This can increase the contrast of edges and prevents blurring of image. CLAHE introduces high contrast in image but the PSNR is decreased. The bright regions are even brighter and the dark regions are even darker but the in between intensities are not well enhanced. Even though wiener filter uses local statistics like variance and mean, image sharpness is reduced having less PSNR value.

Homomorphic filtering operates by amplifying high frequency components and attenuating the low frequency components based on the fourier transform. The skull portion of the enhanced image is homogeneous and be used for brain skull extraction. The enhancement techniques focus on contrast or brightness or edges. Global techniques might introduce a blurring effect. In general, for assisting radiologist, two or more enhanced images can be computed for a single image. The radiologist can choose the best enhanced image.

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