Performance Analysis of Various Filtering Techniques for Smoothing and Sharpening the Brain Tumour Images

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Abstract

Image filtering is considered as one of the procedure to remove the noise in order to improve the digital images for various applications. The main intention of filtering the image is to obtain the processed image so that the resultant image will be quite applicable for a precise application when compared with the original image. This paper addresses the various Image processing applications and filtering techniques that suits for the health care domain to check for some major disease in human being. In order to obtain the objective, smoothing and sharpening of the image must be done. In this paper, the Ideal, Gaussian and Butterworth high pass and low pass filtering are applied on images. In this work different recent image filtering methods are compared based on certain factors.

Keywords: Fourier Transform, Ideal filter, Gaussian Filter, Butterworth Filter.

1. Introduction

Digital Image Processing is really a wide field which provides the different fundamentals for the digital image. A digital image is really a depiction of two dimensional images as a finite group of digital values. It concentrates on two important tasks. Primary is a pictorial data for human elucidation. Next, the storage and transmission of image is considered and finalized according to the illustration for autonomous machine observation [9].Digital Image is also defined as the two dimensional image which have a finite quantity of elements in which all the elements are with a specified position and value. The other names for these elements are picture element, pels or pixels. The least administrable element of an image viewed on the screen is known as pixel [13].

Altering the attributes of the captured image to make it more acceptable for further processing is the main aim of the Image enhancement process. During this process, attributes of the image are modified according to the method applied on that. The way the attributes are chosen and their variance are particular according to a specific application [16].

Filter out unwanted frequencies from the image is called filtering. Processing an Image and finding the applicable resultant image for the expected applications is the main aim of the Image filtering. Removal of noise in order to improvise the resultant image for various applications is referred as Image filtering [2]. The digital filter can be categorized as a low pass or high pass filter depending on which part of the frequency spectrum it affect [7].

Enhancement of image in the frequency domain is simple and easy. The image to be enhanced is computed using the Fourier Transform and the result is multiplied by a filter then it is inversed in order to receive the resultant image. The high frequency components can be reduced to blur an image or the magnitude can be increased to sharpen the image to make it easy to understand [3].

Image Analysis, filtering, reconstruction and compression are the wide applications of Fourier transform in image processing. It is indicated that signal energy is distributed over a range of frequencies in frequency domain analysis [6]. Computing a 2-D discrete Fourier transform of the image and manipulating the transform coefficients by an operator performing the inverse discrete Fourier transform is the essential theory of the frequency domain image filtering [12].

2. Fourier Transform

The Fourier transform (FT) of the function *F(u, v)* is:

$$A(i, j) = \iint a(i, j)\, e^{-j\,2\pi\,(ux + uy)}\, didj \quad \text{-- (1)}$$

and the inverse Fourier transform is

$$b(i, j) = \iint B(i, j)\, e^{j\,2\pi\,(ux + uy)}\, didj \quad \text{----- (2)}$$

The Fourier transform uses complex exponentials of various frequencies as its basis functions. If f is thought of as the insist on answer of a filter then we call F the filter's frequency response [1].A fast Fourier transform (FFT) computes the discrete Fourier transform (DFT) of a sequence, or its inverse (IFFT). Converting a signal from its original domain to a representation in the frequency domain and vice versa is done by Fourier analysis [4]. An FFT quickly computes such transformations by factorizing the DFT matrix into a product of sparse factors. As a result, it manages to trim down the difficulty of computing the DFT from which $\boldsymbol{O(n^2)}$, arises if one simply applies the definition of DFT, to $\boldsymbol{O(n \log n)}$ where $\boldsymbol{n}$ is the data size.

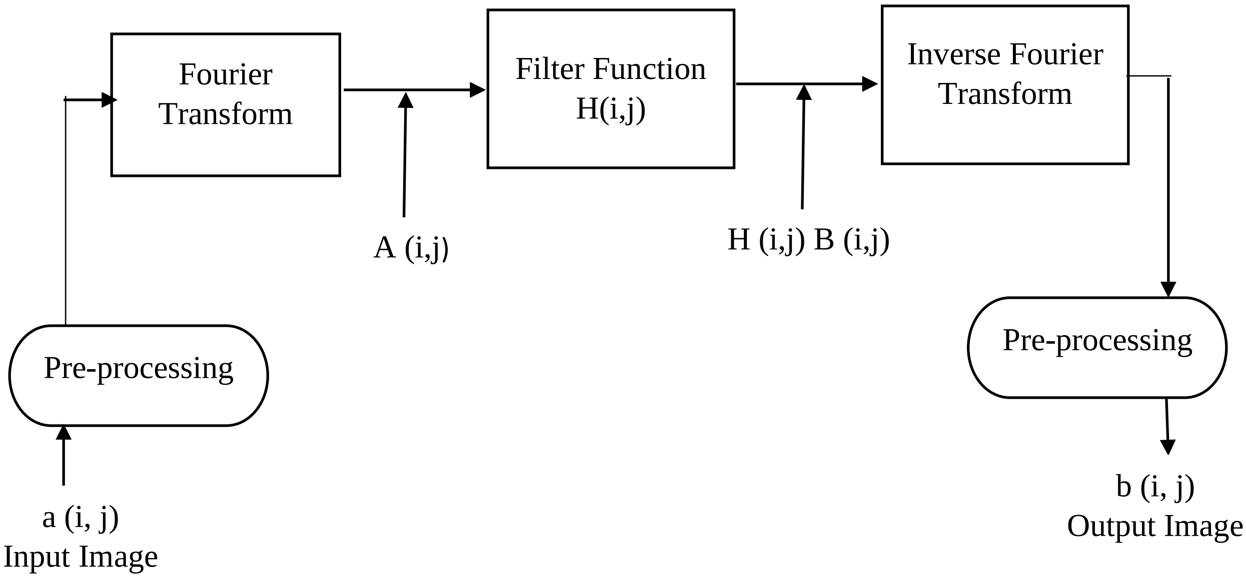


Fig.1 Basic steps for filtering in the Frequency Domain

3. Filters

Suppressing the high frequencies in the image like smoothing the image, the low frequencies, enhancing and detecting the edges of the input image is done by filters [12]. Spatial domain and Frequency domain techniques are the two types of enhancement techniques called for smoothing and sharpening the images [3].

3.1 Smoothing Domain Filters

The sharp transitions like edges and noises in the gray level contribute significantly to the high frequency. Low pass filter is used to smoothen or blur an image. For that the input image should be transformed by reducing the high frequency range. This type of filter reduces the high frequency range and maintains the low frequency untouched [5]. This results a smoothing filter in the spatial domain since high frequencies are blocked. Three types of low pass filters in the present report are Ideal, Gaussian and Butterworth [10].

3.2 Frequency Domain

Inorder to work with Frequency domain image enhancement technique, the Fourier coefficients are manipulated. This shows the working of mathematical functions and how it operates on Frequency transform i.e. Fourier coefficients discrete wavelet transform (DWT), and discrete cosine transform (DCT) [15].

3.3 Low pass filter

Low pass filter is the one which leaves the low frequencies as such and reduces the high frequencies [8]. It is mainly used to smoothen or blur an image. There are three different types of filters-Ideal, Butterworth, and Gaussian.

3.3.1 Ideal Low Pass Filter

The most simple low pass filter is the ideal low pass filter. It restrains all the higher frequencies when compared with the cut-off frequency $r0$ and passes smaller frequencies without any change:

$$H(i,j) = \begin{cases} 1 \; if \; D(i,j) \leq D0 \\ 0 \; if \; D(i,j) > D0 \end{cases} \quad \text{-(3)}$$

Where $r0$ is called the cutoff frequency (nonnegative quantity), and $D(u, v)$ is the distance from point (u, v) to the frequency rectangle [1, 2]. If the image is of size M x N, then

$$D(i,j) \left[= \left(i - \frac{M}{2}\right)^2 + \left(j - \frac{n}{2}\right)^2 \right]^{\frac{1}{2}} \quad \text{---(4)}$$

3.3.2 Butterworth Lowpass Filters: Design frequency-domain filter to remove high-frequency noise with minimal loss of signal components in the specified pass-band with order *n*

$$H(i,j) = \frac{1}{1+\left[\frac{D(i,j)}{D0}\right]^{2n}} \quad \text{----(5)}$$

3.3.4 Gaussian Low pass Filters: The transfer function of a Gaussian low pass filter is defined

$$H(i,j) = e^{-D^2(i,j)/2\,D_0^2} \quad \text{-----(6)}$$

3.4 High pass filters

High pass filter leaves high frequencies and reduces the effect of pass frequencies. Sharpening the image is done by High pass filter [14]. There are three different types of filters-Ideal, Butterworth, and Gaussian.

All highpass filter *(Hhp)* is habitually represented by its association to the lowpass filter *(Hlp):*

$$Hhp = 1 - Hlp \quad \text{----- (7)}$$

3.4.1 Ideal High Pass Filter:

We can obtain the Ideal high pass filter by using:

$$H_{hp}(i,j) = 1 - H_{lp}(i,j) \quad \text{-----(8)}$$

3.4.2 Butterworth High Pass Filter:

The Butterworth high pass filter of order n with cutoff frequency locus at distance D_0 from the origin is given by,

$$H(i,j) = \frac{1}{1+\left[\frac{D0}{D(i,j)}\right]^{2n}} \quad \text{-----(9)}$$

3.4.3 Gaussian High Pass Filter:

The Gaussian high pass filter with cutoff frequency locus at a distance $D_0$from the origin is given by,

$$H(i,j) = 1 - e^{-D^2(i,j)/2\,D_0^2} \quad \text{-----(10)}$$

4. Error Analysis Techniques

Various Error analysis techniques can be used for comparisons [11]:

4.1 Root Mean Square Error Method (RMSE): The root mean square error is one of the evaluation methods. It provides weight to large errors. The RMSE between the original image A (i,j) and the filtered image B (i,j) is

$$RMSE = \sqrt{\frac{\sum_{i=1}^{I}\sum_{j=1}^{J}[A(i,j)-B(i,j)]^2}{I\ X\ J}} \quad \text{-----}(11)$$

where A(i, j) and B(i, j) are the pixel values at the (i, j) coordinates of the original image and the filtered image. The image size is $I \times J$.

4.2 Peak Signal to Noise Ratio (PSNR): This basically represents the ratio of the highest possible value of the digital image data to the error obtained in the digital image data, where MSE is Mean Square Error.

$$PSNR = 10\ X\ log_{10}\left(\frac{peak^2}{MSE}\right) \quad \text{-----}(12)$$

4.3 Normalized Absolute Error (NAE): NAE is the average of the absolute difference between the originally and the enhanced image divided by the original

image. The large the value of NAE the poor is the image.

$$NAE = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n}(|A_{ij}-B_{ij}|)}{\sum_{i=1}^{m}\sum_{j=1}^{n}(A_{ij})} \quad \text{-----}(13)$$

4.4 Maximum Difference (MD): It represents the maximum difference between two images.

$$MD = max(|A_{ij} - B_{ij}|),$$

$$i=1,2, \ldots m, j=1,2,\ldots n \quad \text{-----}(14)$$

4.5 Average Difference (AD): This measure shows the average difference between the pixel values.

$$AD = \frac{1}{mn}\sum_{i=1}^{m}\sum_{j=1}^{n}(|\ A_{ij} - B_{ij}\ |) \quad \text{-----}(15)$$

4.6 Structural Content (SC): It is correlation based measure for the original and enhanced image.

$$SC = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n}(A_{ij})^2}{\sum_{i=1}^{m}\sum_{j=1}^{n}(B_{ij})^2} \quad \text{-----}(16)$$

5. Implementation and Results

The Brain Tumour image is taken for Image Analysis. The different filters are applied to the image and the resultant

images are tabulated in the Table.1 and Table.2. After getting the various resultant images it is applied in the error analysis techniques and the results are found and tabulated in Table. 3

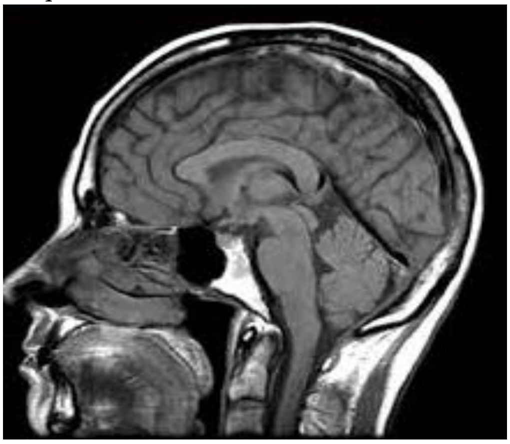


Fig.2 Original Brain Tumour Image

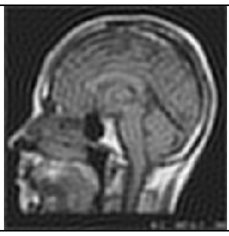
Name of the low pass filter	Resultant Image
Ideal	
Butterworth	
Gaussian	

Table.1 Resultant Images of low pass filters

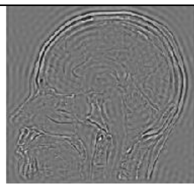
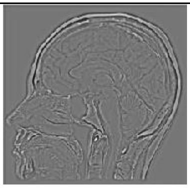
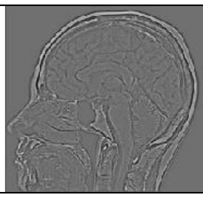
Name of the high pass filter	Resultant Image
Ideal	
Butterworth	
Gaussian	

Table.2 Resultant Images of high pass filters

The above tables show the resultant images of the various low pass and high pass filters. After that the various error analysis techniques specified above are applied and values are tabulated in the table.3.

Name of the Filter	RMSE	PSNR	AD	MD	NAE	SC
Ideal low pass	9.57	28.53	-0.90	255.00	0.02	0.94
Butterworth low pass	5.40	33.51	0.01	255.00	0.00	1.00
Gaussian low pass	6.72	31.60	0.00	255.00	0.01	0.99
Ideal high pass	19.01	22.58	-2.67	255.00	0.05	0.94
Butterworth high pass	18.73	22.71	-2.69	255.00	0.05	0.94
Gaussian high pass	17.69	23.21	-2.35	255.00	0.04	0.94

Table.3 Values of various Metrics

In experimental results, it is shown that RMSE of Gaussian low pass filter is 6.72, Butterworth is 5.40 and Ideal is 9.57 and the PSNR of Gaussian is 31.60, butter worth is 33.51 and ideal is 28.53. From these values, it is proved that lower RMSE and higher PSNR of Butterworth low pass filter is good for smoothening the image while image transformation. Also it is shown that RMSE of Gaussian high pass filter is 17.69, Butterworth is 18.73 and Ideal is 19.01 and the PSNR of Gaussian is 23.21, butter worth is 22.71 and ideal is 22.58. From these values, it is proved that lower RMSE and higher PSNR of Gaussian high pass filter is good to sharpen the image while transformation. The NAE value of Ideal high pass and Butterworth high pass is large and considered as the poor. The AD is normal in Gaussian Low pass filter. The MD is same in all the filters, since no noise is considered in the images. Because of the same reason, there is little difference in SC values.

References

[1] Amit Shukla, Dr R.K. Singh,"Performance Analysis of Frequency Domain Filters For Noise Reduction", e-Journal of Science & Technology (e-JST).

[2] AyushDogra and ParvinderBhalla, "Image Sharpening By Gaussian And Butterworth High Pass Filter", Biomedical & Pharmacology Journal, Vol. 7(2), 707-713 2014.

[3] Aziz Makandar& Bhagirathi Halalli, "Image Enhancement Techniques using High pass and Low pass Filters", International Journal of Computer Applications (0975 – 8887), Vol. 109 – No. 14, January 2015.

[4] B.D.Venkatramana Reddy, Dr.T.Jayachandra Prasad, "Frequency Domain Filtering of Colour Images using Quaternion Fourier Transforms", International Journal of Computer Science and Technology, Vol. 1, Issue 2, December 2010.

[5] B.Thamotharan, M.Menaka, SandhyaVaidyanathan, SowmyaRavikumar, "Survey On Image Processing In The Field Of De-Noising Techniques And Edge Detection Techniques On Radiographic Images", Vol. 41, Issue 1, 15 July 2012.

[6] Banupriya.S, Kannan.M and Sivakumar.R, "Performance Analysis of Various Filtering Algorithm for Biometrics Image", International Journal of Computer Science and Engineering (2347-2693), Vol.2- No.3, February 2014.

[7] Dr. Mohammed Nasir Uddin, Dr.Jebunnahar and Md. Abul Bashar, "A Comprehensive Study of Digital Image Processing for Finding Image Quality Dependencies", International Journal of Scientific and Research Publications, Vol. 2, Issue 3, March 2012.

[8] HardikPandit, Dr. D M Shah, "Application of Digital Image Processing and Analysis in Healthcare Based on Medical Palmistry", International Conference on Intelligent Systems and Data Processing, 2011.

[9] IoannisGiakoumis, Nikos Nikolaidis, Ioannis Pitas, "Digital Image Processing Techniques for the Detection and Removal of Cracks in Digitized Paintings".

[10] Jesna Varghese, "Literature Survey on Image Filtering Techniques", International Journal of Engineering Research & Technology (IJERT), Vol. 2, Issue 6, June 2013.

[11] K.Silpa, Dr.S.ArunaMastani, "Comparison of Image Quality Metrics", International Journal of Engineering Research & Technology (IJERT), Vol. 1, Issue 4, June – 2012.

[12] Md. Shahnawaz Shaikh, Ankita Choudhry, RakhiWadhwani, "Analysis of Digital Image Filters in Frequency Domain", International Journal of Computer Applications, Vol.140 – No.6, April 2016.

[13] Ramandeep Kaur, Kamaljit Kaur, "Study of Image Enhancement Techniques in Image Processing: A Review", I.J. Engineering and Manufacturing, 2016.

[14] Rasha Abdul Razak A, Harish Binu K, "A Survey on Various Image Filtering Techniques for Image Sharpening", International Journal of Science and Research, Vol. 6, Issue 4, April 2017.

[15] Swati Khidse&MeghanaNagori, "Implementation and Comparison of Image Enhancement Techniques",International Journal of Computer Applications (0975 – 8887), Vol. 96 – No.4, June 2014.