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Comparative Performance Analysis of Frequency Domain Denoising Techniques Against Salt and Pepper Noise

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Abstract : This research work examines the various image de-noising methods in frequency domain and comparison among various filtering techniques is made in the presence of Salt and Pepper noise in order to achieve a high quality image. Performance of all the frequency domain filters are compared using parameters such as Mean Square Error (MSE) and Peak signal to noise ratio (PSNR). The comparative analysis of various de-noising techniques provides most suitable and reliable method for de-noising of salt and pepper noise corrupted image in frequency domain.

***IndexTerms* - Image Processing, Noise Removal, Filtering techniques,Butterworth filter,Gaussian filter,ideal filter, mean square error (MSE), Peak signal to noise ratio(PSNR).**

I. INTRODUCTION

Image smoothing and image sharpening can be achieved by frequency domain filtering. Smoothing is done by high frequency attenuation i.e. by low pass filtering. Sharpening is done by high pass filtering which attenuates the low frequency components without disturbing the high frequency components.Image enhancement in the frequency domain is processing the image in the Fourier domain. In spatial domain filtering, operation of the image is carried out by convolving the original image with a filter mask. Given the fundamentals of signal processing, filtering in the frequency domain would involve multiplying the image using the filter transfer function. The stepwise execution of filtering in the frequency domain can be given as follows:

- Multiply input image f(x, y) by (-1)(x + y).
- Obtain F(u, v) using the forward two-dimensional discrete Fourier transform (2D-DFT) of the result.
- Transform the image using the filter transfer function H(u, v).

$G(u,v) = U(u,v)F(u,v)$

- Take the two-dimensional inverse discrete Fourier transform (2D-IDFT) of G(u, v) and obtain part of the result.
- Multiply input image f(x, y) by (-1)(x + i).

II. Impulse noise (Salt and Pepper noise)

Another name for salt and pepper noise is the noise of impulses (impulse noise). The reason for this noise is a sharp and sudden disturbance in the image signal, because it is also called the impulse noise. This is due to sudden disruption such as dust faulty charge coupled devices during the arrest of the image. The noise effect is only at small no. of Pixels, leave the remaining picture, not touched. Images with salt and pepper noise have dark pixels in bright areas and bright pixels in dark areas, white and black pixels are distributed randomly over noisy image.

III. De-noising filter in frequency domain

A. Low pass filters

The low-pass frequency domain filter allows low-frequency components to pass and high-frequency components are attenuated. The result is that any sharp transition such as edges and boundaries will be replaced with a smooth transition (blurred).This filter is known as the smoothing filter.

1.Ideal low pass filter

The filter transfer function of an ideal LPF (ILPF) is given as follows:

$$H(u,v) = 1, \text{ for } D(u,v) \le D_0$$
$$H(u,v) = 0, \quad \text{otherwise}$$

where D(u, v) is the distance of the frequency component (u, v) from the origin of the frequency plane and D_0 is the cut-off frequency which specified non-negative distance. Mathematically, D(u, v) is given as follows:

$$D(u,v) = \left[\left(u - \frac{M}{2}\right)^2 + \left(v - \frac{N}{2}\right)^2\right]^{\frac{1}{2}}$$

This is called the ideal filter because it provides a sharp cut-off. All frequencies less than the cut-off are allowed to pass without attenuation, whereas all frequencies greater than the cut-off are completely attenuated.

2. Gaussian low pass filter

The transfer function of Gaussian LPF is defined as follows:

$$H(u,v) = e^{-D^2(u,v)/2\sigma^2}$$

The filter function is defined such that when D(u, v) = D0, H(u, v) has a maximum value of 0.607. The inverse FFT of Gaussian LPF is also Gaussian.

3. Butterworth low pass filter

The transfer function of the Butterworth LPF of order n and with a cut-off frequency locus at a distance D0 from the origin is defined as follows:

$$H(u,v) = \frac{1}{1 + \left[\frac{D(u,v)}{D_0}\right]^{2n}}$$

Unlike ILPF, the Butterworth LPF transfer function does not have a sharp discontinuity and clear cut-off between the passed frequency and filtered frequency.

B. High pass filters

The high-pass frequency domain filter allows high-frequency components to pass and low-frequency components are attenuated. The result is that any smooth transition (blurred) in an image will be replaced with a sharp transition (edges). This filter is known as the sharpening filter.

1.Ideal high pass filter

The filter transfer function for the ideal HPF is given as follows:

$$H(u,v) = 1, D(u,v) \geq D_0$$
$$H(u,v) = 0, \quad \text{otherwise}$$

It allows all high-frequency components with a distance from the origin of greater than D0 without any filtering but completely attenuates all low frequency components.

2. Gaussian high pass filter

The transfer function of the Gaussian HPF is defined as follows:

$$H(u,v) = 1 - e^{-D^2(u,v)/2D_0^2}$$

3. Butterworth high pass filter

The transfer function of the Butterworth HPF of order n and with a cut-off frequency locus at a distance D0 from the origin is defined as follows:

$$H(u,v) = \frac{1}{1 + [D_0/D(u,v)]^{2n}}$$

Unlike ideal HPF, the Butterworth HPF transfer function does not have a sharp discontinuity and clear cut-off between the passed frequency and filtered frequency.

IV. IMAGE QUALITY PARAMETERS

1.M.S.E.

The lower the value of MSE represents lower the error.

$$MSE = \frac{1}{MN}\sum_{0}^{M-1}\sum_{0}^{N-1}[\,f(x,y) - g(x,y)]^2$$

2. P.S.N.R.

The PSNR is defined as the ratio of the maximum pixel intensity to the mean square Error. PSNR is commonly expressed in terms of the logarithmic decibel scale. Higher PSNR value offers a good image quality.

$$PSNR = 10\log_{10}\left[\frac{M * N}{MSE}\right]$$

V. Methedology

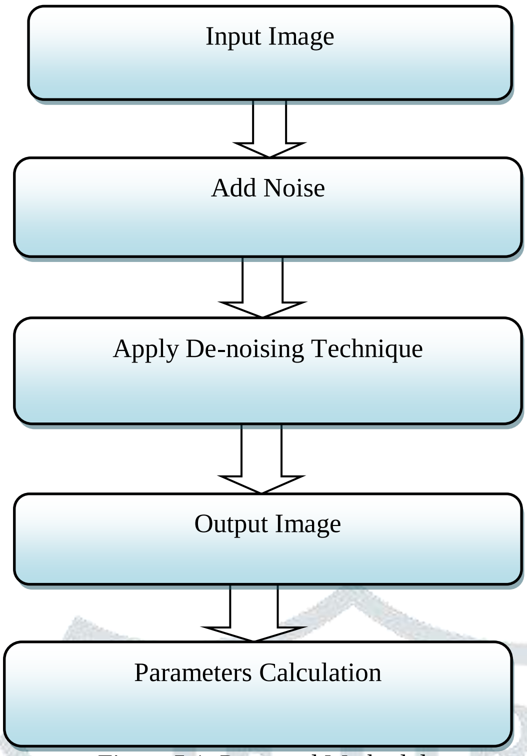

Figure 5.1: Proposed Methodology

VI. RESULTS AND DISCUSSION

The experiment was carried out in the standard Gray scale image of the "cameraman" size of 256 x 256.Simulation was carried out using the R2016A MATLAB software. input image is taken with salt and Pepper noise (noise density = 0.05). For denoising processes, various filters like ideal low pass filter , ideal high pass filter, Butterworth low pass filter, Butterworth high pass filter, Gaussian low pass filter, Gaussian high pass filter are used. Quantitative performance of filters are evaluated through figure below.

Fig 6.1 :(a) Noisy image (Salt and Pepper noise) (b) Ideal low pass filtered image

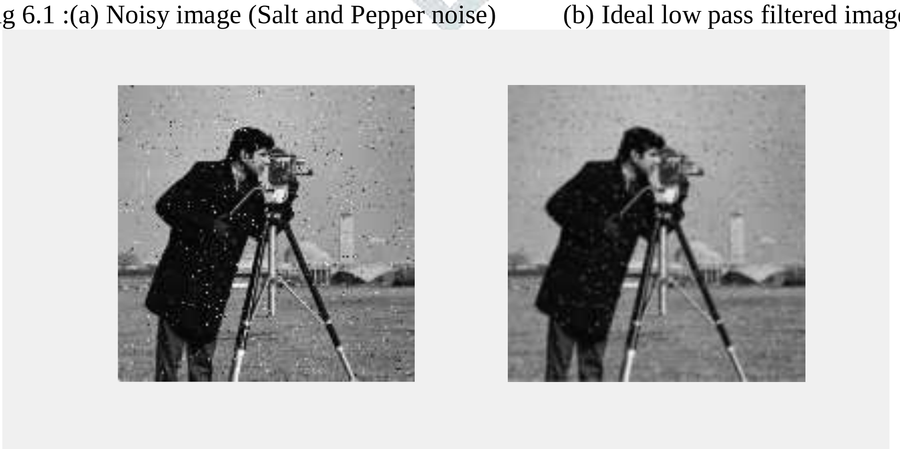

Fig 6.2:(a) Noisy image (Salt and Pepper noise) (b) Gaussian low pass filtered image

Fig 6.3:(a) Noisy image (Salt and Pepper noise) (b) Butterworth low pass filtered image

Fig 6.4:(a) Noisy image (Salt and Pepper noise) (b) Ideal high pass filtered image

Fig 6.5:(a) Noisy image (Salt and Pepper noise) (b) Gaussian high pass filtered image

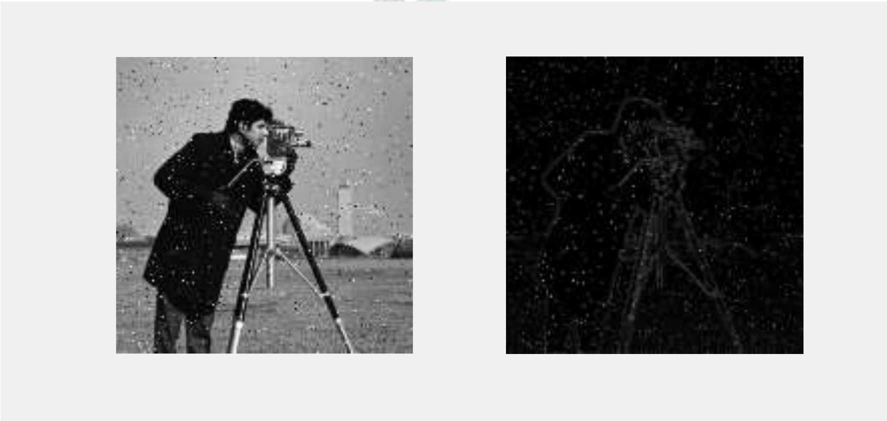

Fig 6.6:(a) Noisy image (Salt and Pepper noise) (b) Butterworth high pass filtered image

Denoising Technique	Noise	M.S.E. of noisy image	M.S.E. of Denoised image	P.S.N.R . of noisy image	P.S.N.R. of Denoised image
Ideal High Pass Filter	**Salt and pepper noise**	390.3607	15787.175	22.2161	6.1478
Ideal Low Pass Filter	**Salt and pepper noise**	390.3607	249.2046	22.2161	24.1652
Butterworth High Pass Filter	**Salt and pepper noise**	390.3607	16367.956	22.2161	5.9909
Butterworth Low Pass Filter	**Salt and pepper noise**	390.3607	180.632	22.2161	25.5629
Gaussian High Pass Filter	**Salt and pepper noise**	390.3607	16393.466	22.2161	5.9841
Gaussian Low Pass Filter	**Salt and pepper noise**	390.3607	174.853	22.2161	25.7041

Table 6.1: Performance of frequency domain filter against salt and pepper noise

VII. CONCLUSION AND FUTURE SCOPE

In this research paper, we focus on existing frequency domain based image enhancement techniques that includes filters that are useful in many application areas as medical diagnosis, army and industrial areas. Program is developed to compute and display the image after applying various low pass and high pass filters on it.

In this research paper frequency domain filters are implemented in MATLAB. It is found that low-pass filters smoothen the input image by removing noise and results in blurring of the image and high-pass filters sharpens the inside details of an image. Ideal filters results in the ringing effect in the enhanced image. Using the Butterworth filters the ringing effect gets reduced since there are no sharp frequency transitions, whereas the use of Gaussian filters completely gives the filtered image without any ringing effect. The future scope can be the development of adaptive algorithms for effective image enhancement using Fuzzy Logic and Neural Network. Many more filters can be added into functionality. The same work can be extended for further digital image processing applications such as image restoration, image data compression etc.

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