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MAMMOGRAM ENHANCEMENT USING QUADRATIC ADAPTIVE VOLTERRA FILTER- A COMPARATIVE ANALYSIS IN SPATIAL AND FREQUENCY DOMAIN

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ABSTRACT

Early breast cancer in women can be detected efficiently, by processing Mammograms in an effective way. Mammographic images are affected by noise which has low contrast and poor radiographic resolution based on ill-performance of X-ray hardware systems. This leads to improper visualization of lesion detail. Generally Non-linear filters are preferred for image enhancement applications. Because they provide better filtering results not only by suppressing background noise but also preserving the edges. In this paper, an Adaptive Volterra filter is used for contrast enhancement of mammograms. A mammogram image which is affected by three types of noise individually like Gaussian, poison, white noise is considered. These noise elimination are done using adaptive Volterra filter and the performance of adaptive Volterra filter is compared with other spatial nonlinear filters like mean, median, min, max filters. The noisy mammogram is enhanced with five different filters in frequency domain which includes Volterra, Median, Min, Max, Mean filters. The comparison between spatial and frequency domain enhancement is done using five different filters with three types of noises. The performance measures like Peak Signal to Noise Ratio (PSNR) and Mean Square Error (MSE) are computed and presented in this paper.

Keywords: adaptive volterra filter, median filter, min filter, max filter, mean filter, peak signal to noise ratio (PSNR), mean square error (MSE).

1. INTRODUCTION

As per the report given by Indian Council of Medical Research (ICMR), in India one in 22 women is likely to suffer from breast cancer during her lifetime. In America one in eight women is affected by the deadly breast cancer. The surveys give an alarm about the importance of early identification of breast cancer that increases the survival rate. Mammogram is picture of breast captured by using X rays. Mammography is used as an effective imaging modality for breast cancer screening. Mammography is radiographic examination which is very much useful for detecting breast pathology. Before classifying the mammograms into masses and micro-calcification which are again classified into benign and malignant, the preprocessing of mammograms is very much essential.

Different types of filters are used to remove the noise in mammogram images. Medical images are affected by various types of noises like salt and pepper noise, Gaussian noise, Poisson noise etc. To remove these noises either linear or nonlinear filter are used. But nonlinear filters give better results than linear filters. The flow in this paper is as follows. Part II deals with related work. Part III gives proposed methodology in this paper. We have discussed results in Part IV and conclusion in Part V.

2. RELATED WORK

Breast cancer is the leading cause of death in women both in developed and developing countries of the world and it is found between the age group of 35 and 55. The National Cancer Institute estimates that in the United States one out of eight women will develop breast cancer at some point during her lifetime [2].Mammogram enhancement is very important preprocessing work to detect any abnormalities in female breast. Previous enhancement techniques to enhance mammogram images started with basic histogram equalization technique [3], Unsharp masking [4], Wavelet – based techniques [5]. In [14], the image was enhanced using different wavelet transforms like curvelet, contourlet and non-sub sampled wavelet transforms and the performance measure like PSNR and MSE were calculated. The other techniques which are useful for mammogram enhancement are contrast stretching, power law transformation, Morphological Processing, Median Filtering, Anisotropic Diffusion Filtering, Bilateral Enhancement, Homomorphic Filtering [6] and many others. The combination of Modified histogram with homomorphic filtering is followed for contrast enhancement of mammogram images in [7]. DCT with USM were followed for colour image enhancement [11]. The algorithm for improving the image colour levels and contrast effectively without causing block art effects was the dominant brightness level analysis [12]. Dominant brightness level analysis decomposed the image into several layers. DWT was applied for calculating brightness level by using average luminance in LL sub-band. The combination of USM, Bilateral filter, CLAHE and Adaptive gain control (AGC) gave better PSNR and MSE in mammogram enhancement [13].These techniques are useful to enhance the local contrast of mammograms.

Nonlinear filters are very much useful for not only image enhancement but also for edge preservation. The usual nonlinear spatial filters are otherwise called as

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order-statistics or rank filter. The examples for rank filters are mean, median, min, max filters. Even though these are nonlinear filters, these filters are suitable to remove certain type of noise and these cannot preserve edgesstrongly. But the proposed quadratic volterra filter is suitable for any kind of noise removal from the images and also efficient in edge preserving.

3. PROPOSED METHODOLOGY

a) Adaptive volterra filter for mammogram enhancement

Most of the real life and practical systems are nonlinear. These nonlinearities can be modeled by Volterra power series. With input vector x[n] and output vector y[n] ,aN^{th} order Volterrafilteris realized by

$$y[n] = h0 + \sum_{r=1}^{\infty} \sum_{n1=1}^{N} \sum_{n2=1}^{N} \dots \dots \sum_{nr=1}^{N} hr[n1, n2 \dots .nr]$$

x[n-n1]x[n-n2]……x[n-nr] (1)

Where r indicates the order of nonlinearity. When r = 1, the system is linear and when r = 2 the system is quadratic and so on. hr [n1, n2, . . . nr] is the r^{th} order Volterra kernel. The identification of Volterra kernel is one of the main issues in polynomial signal processing. When no input is present, $h0$ is the constant offset at the output. By assuming homogeneity, the complexity of the kernel can be reduced considerably. With respect to the Volterra filter weights, the output y[n] is linear. Much of the nonlinearity is comprised of the quadratic components in practical systems. So it is proposed that a two dimensional quadratic filter can model and process inherent nonlinearities in medical images.

b) Two dimensional discrete quadratic volterra system

The two dimensional quadratic system with input x[n1, n2] and output y[n1, n2] is given by the equation

$$y[n1, n2] = \sum_{m11=0}^{N1-1} \sum_{m12=0}^{N2-1} \sum_{m21=0}^{N1-1} \sum_{m22=0}^{N2-1} h1[m11, m12, m21, m22]$$

X [n1-m11,n2-m12]x[n1-m21,n2-m22] (2)

Equation (2) can be represented in the matrix form as

$$Y [n1, n2] = X^T [n1, n2]\ H_2\ X [n1, n2] \quad (3)$$

The quadratic kernel H2 has N1N2×N1N2 elements and each element consists of N_2^2 submatrices H (i, j) with N1 × N2 elements given as

$$\begin{matrix} H(0,0) & H(0,1) \dots.. & H(0,N2-1) \\ H(1,0) & H(1,1) & H(1,N2-1) \\ \vdots & \vdots & \vdots \\ H(N2\text{-}1,0) & H(N2\text{-}1,1) & H(N2\text{-}1,N2\text{-}1) \end{matrix}$$

where each submatrix H(i, j) is given by

$$H(i,j) = \begin{bmatrix} h(0,i,0,j) & \dots\dots & h(0,i,N1\text{-}1,j) \\ h(1,i,0,j) & \dots\dots & h(1,i,N1\text{-}1,j \\ . & . & . \\ . & . & . \\ H(N1\text{-}1,i,0,j) & \dots\dots & h(N1\text{-}1,i,N1\text{-}1,j) \end{bmatrix} \quad (4)$$

The key issues in Volterra systems are the identification of the kernel H2 and its computationally efficient implementation. There are no general design methods for finding H2. Design of two dimensional kernels for specific applications can be done using methods like optimization, bi-lateral transformation method etc.

4. RESULTS

In this paper, mammogram enhancement is done in two domains (i) Spatial domain (ii) Frequency domain

a) Spatial domain enhancement

The digital input mammogram (either black and white or colour) is considered with different size. First step is to convert the input mammogram into grey scale image. With grey scale image, white noise is included and mammogram enhancement is done in spatial domain using adaptive volterra filter. Simultaneously noise removal is performed with other non-linear spatial filters like mean, min, max, median. The performance measures MSE and PSNR are calculated from each filter output and are compared. The same procedure is repeated for other types of noises like Gaussian and Poisson.

b) Frequency domain enhancement

The digital input mammogram (either black and white or colour) is considered with different size. First step is to convert the input mammogram into grey scale image. With grey scale image , white noise is included and The noisy image is divided into four sub-band like High-High(HH),High-Low(HL), Low-High(LH), Low-Low(LL) using 2D discrete wavelet Transform(DWT).Mammogram enhancement is done with HH sub-band using adaptive volterra filter, because micro-calcification in mammogram consists of high frequency content.. The High-High (HH) subband Image is considered as input for other non-linear filters like mean, median, min, max. Here, the analysis is carried out in the frequency domain. The performance measures like MSE and PSNR are calculated from each filter output and are compared .The same procedure is repeated with Gaussian noise and Poisson noise.

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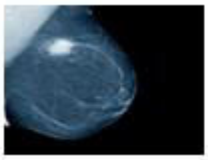
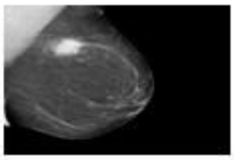
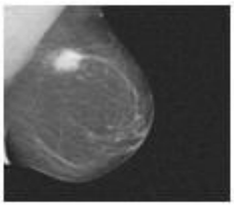


Input mammagram



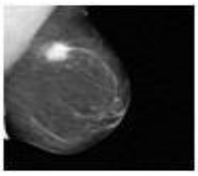
Grey scale image



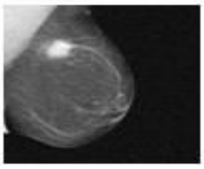
Mammogram With white noise

OUTPUTS IN SPATIAL DOMAIN

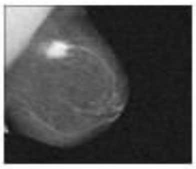
Enhanced outputs from various filters



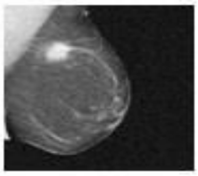
Volterra filter



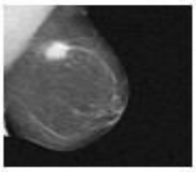
Mean filter



Min filter

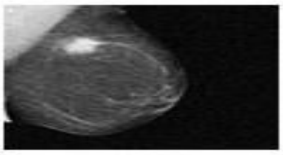


Max filter



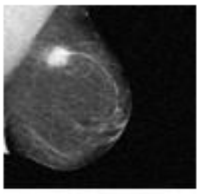
Median filter

Type-2:

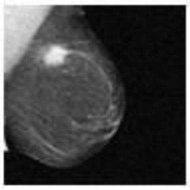


Mammogram with Gaussian noise

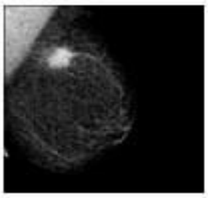
Enhanced outputs from various filters



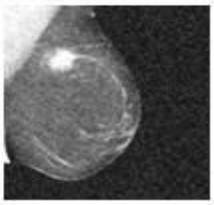
Volterra filter



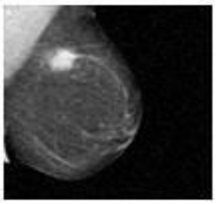
Mean filter



Min filter

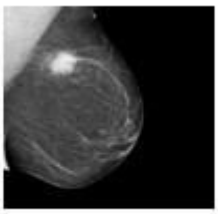


Max filter



Median filter

Type-3:



Mammogram with poissonnoise

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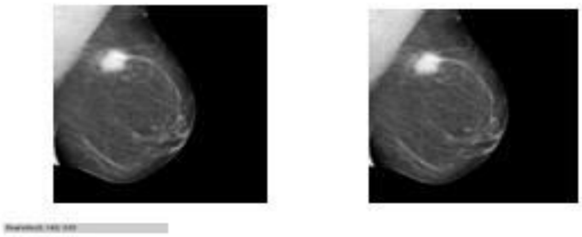
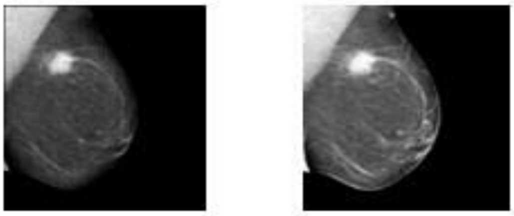
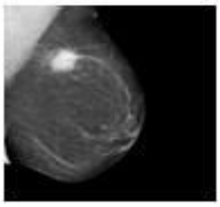
Enhanced Outputs from Various Filters



Volterra filter Mean filter

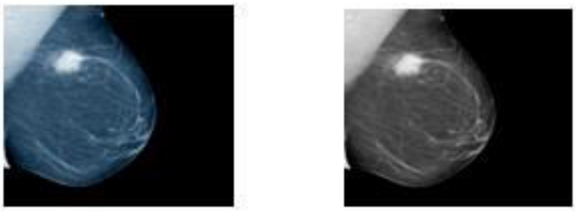


Min filter Max filter

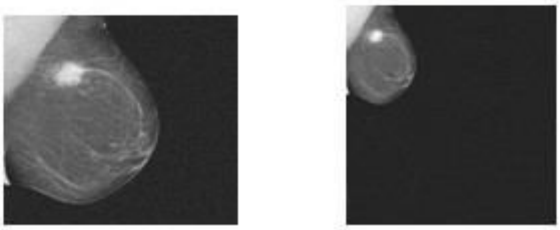


Median filter

Type-1:



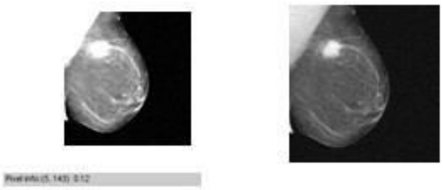
Input mammogram LL Grey scale image LH



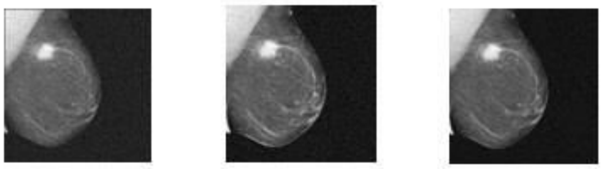
Mammogram with white noiseDWT Output HL HH

OUTPUTS IN FREQUENCY DOMAIN

Enhanced outputs from various filters



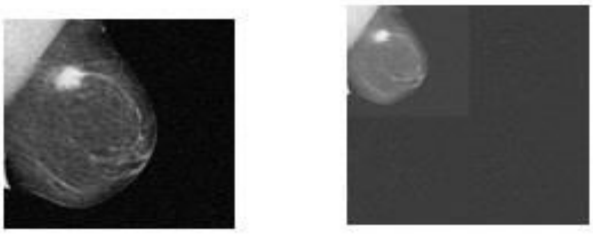
Volterra filter Mean filter



Min filter Max filter Median filter

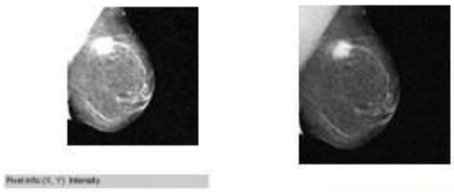
Type-2:

LL LH

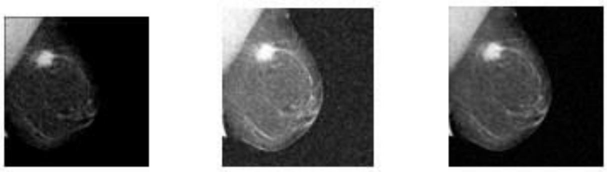


Mammogram with Gaussian NoiseDWT output HLHH

Enhanced outputs from various filter



Volterra filter Mean filter



Min filter Max filter Median filter

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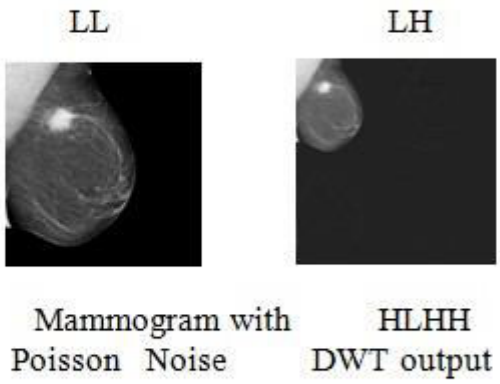
Type-3:



Enhanced Outputs from Various Filter

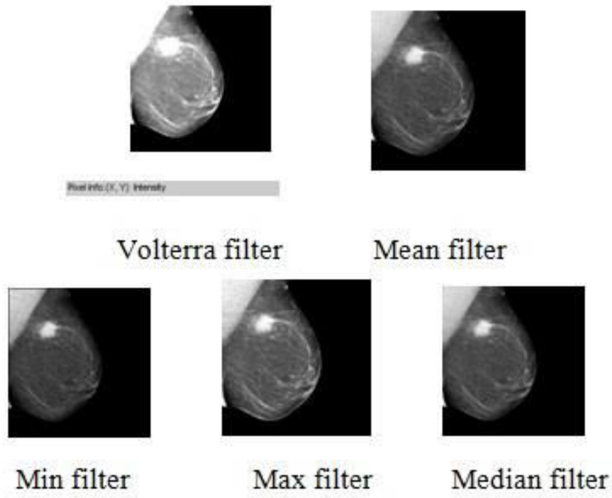


Table-1. MSE and PSNR calculation in frequency domain.

No.	Type of noise	MSE					PSNR(dB)				
		Volterra filter	Mean	Min	Max	Median	Volterra filter	Mean	Min	Max	Median
1.	White noise	0.0020	0.3527	0.3628	0.3597	0.3628	75.1171	52.7723	52.5337	52.5716	52.5337
2	Gaussian	0.0019	0.3529	0.3636	0.3451	0.3629	75.1176	52.7719	52.5332	52.5813	52.5334
3.	Poisson	0.0022	0.3527	0.3630	0.3606	0.3628	75.1167	52.7723	52.5337	52.6120	52.5337

Table-2. MSE and PSNR calculation in spatial domain.

No.	Type of noise	MSE					PSNR(dB)				
		Volterra filter	Mean	Min	Max	Median	Volterra filter	Mean	Min	Max	Median
1.	White noise	4.8828e+03	4.9167e+03	4.9296e +03	4.9137e+03	4.9213e + 03	25.8906	11.2142	11.2027	11.2168	11.2100
2.	Gaussian	4.8827e+03	4.9168e+03	4.9352e +03	4.9081e+03	4.9214e + 03	25.8907	11.2140	11.1977	11.2217	11.2099
3.	Poisson	4.8829e+03	4.9167e+03	4.9286e +03	4.9145e+03	4.9214e + 03	25.8903	11.2142	11.2035	11.2160	11.2099

5. CONCLUSIONS

This paper deals with mammogram enhancement using adaptive volterra filter and the performance measure to know the efficiency of the filter MSE and PSNR are calculated. The output from volterra filter is compared in spatial domain with other non- linear filter like mean, median, min and max. The Table-2 shows that volterra filter provides high PSNR than other filters in spatial domain. In order to improve contrast of filtered image further and to improve PSNR value, enhancement of mammogram is done in frequency domain using Volterra filter and other four filters. The output figures show that the frequency domain enhancement from Volterra filter is better than other filter's output in same domain. The MSE and PSNR using Volterra filter are higher than other four filters as in Table-1. The overall observation is the frequency domain enhancement using five different filters have given outputs with improved quality of images than spatial domain enhancement using the same five filters.

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