International Journal of Advances in Image Processing Techniques– IJIPT
Volume 1 : Issue 3 [ISSN 2372 – 3998]
Publication Date : 30 September, 2014

A Novel Approach using Image Enhancement based on Genetic Algorithm

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Abstract: **A robust wavelet domain method for noise filtering in medical images is one of the techniques used to reduce the noise. The method adapts various types of image noise as well as to the preference of the medical expert: a single parameter is being used to balance the preservation of (expert-dependent) relevant details against the degree of noise reduction. A versatile wavelet domain despeckling technique to visually enhance the medical ultrasound (US) images for improving the clinical diagnosis is used. The method uses the two-sided generalized Nakagami distribution (GND) for modeling the speckle wavelet coefficients and the signal wavelet coefficients are approximated using the generalized Gaussian distribution (GGD) [1]. Combining these statistical priors with the Bayesian maximum a posteriori (MAP) criterion, the thresholding/shrinkage estimators are derived for processing the wavelet coefficients of detail subbands. Consequently, two blind speckle suppressors named as GNDThresh and GNDShrink have been implemented and evaluated on both the artificial speckle simulated images and real US images.**

This paper introduces an analysis of a new approach of image enhancement technique based on Genetic Algorithms. The task of the Genetic Algorithm is to analyze the result of a novel image denoising method using various parameters and enhance the quality and details of the image according to an objective fitness criterion i.e SNR and quantitative analysis by subjective criteria. The visual comparison of despeckled US images and the higher values of quality metrics (coefficient of correlation, edge preservation index) indicate that the method suppresses the speckle noise well while preserving the texture and organ surfaces. The method clearly outperforms single-resolution spatially adaptive algorithms, in terms of quantitative performance measures as well as in terms of visual quality of the images[2].

Keywords: **Genetic Algorithm, Image Enhancement, Speckle Noise.**

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I. INTRODUCTION

Ultrasonography is considered to be one of the most powerful techniques for imaging organs and soft tissue structures in human body. It is preferred over other medical imaging methods because it is: non-invasive, portable, versatile, does not use ionising radiations and low cost. Ultrasound (US) images are contaminated with multiplicative noise called 'speckle' which is one of the major sources of image quality degradation This spatial correlation makes the speckle suppression a very difficult and delicate task, hence, a trade-off has to be made between the degree of speckle suppression and feature preservation [1].

Speckle significantly degrades the image quality and hence, makes it more difficult for the observer to discriminate fine detail of the images in diagnostic examinations [2]. Speckle is a form of multiplicative noise, which makes visual interpretation difficult [3]. Laser holography and ultrasound imaging are two techniques susceptive to speckle degradation. Speckle noise causing greater degradation within bright areas of an image than in dark areas.

Image denoising is used to remove the noise while retaining as much as possible the important signal features [4]. The purpose of image denoising is to estimate the original image form the noisy data. Image denoising is still remains the challenge for researchers because noise removal introduces artifacts and causes blurring of the images.

The method consists of applying the DWT to the original data, thresholding the detailed wavelet coefficients and inverse transforming the set of thresholded coefficients to obtain the denoised signal as discussed in Figure 1:

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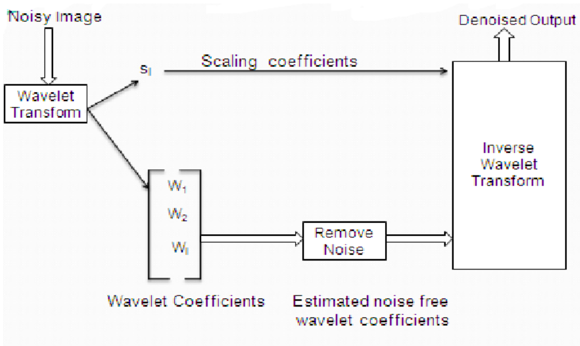

Figure 1: Wavelet based denoising

Due to major drawback of homomorphic filtering techniques i.e the log transform being a nonlinear operation leads to the biased estimation of reflectivity by changing the mean of the homogeneous areas and also computationally very expensive due to additional log and exponential operations non-homomorphic approaches are being preferred.

Different non-homomorphic techniques are: Pizurica method**,** Baygau method (Bayes thresh for Gaussian Noise)**,** Baylap method (Bayes thresh for Laplacian Noise)**,** Fnm method (Nakagami estimator in multi domain of signal and f→using foucher) . The working of Pizurica and other thresholding methods is shown in Figure 2 and Figure 3.

Start

↓

Compute the non decimated wavelet transform with J levels

↓

Initialize $\hat{y}_j^D = w_j^D$, D {LH, HL, HH}

↓

For each orientation D and each scale 2^j, j=1…………………J-1

a) For all the spatial positions k=1…N.
(i) calculate the label estimate $\hat{x}_k$
(ii)Compute the loc al spatial activity indicator e_k.

b) Compute $\hat{r} = \sum_{l=1}^{N} \hat{x}_l / (N - \sum_{l=1}^{N} \hat{x}_l)$. (1)

c) Define $S_0=\{l: \hat{x}_l = 0\}$ and $S_1=\{l : \hat{x}_l = 1\}$ and estimate
$\hat{p}_{M|X}(m|0), \hat{p}_{M|X}(m|1), \hat{p}_{E|X}(e|0)$ and $\hat{p}_{E|X}(e|1)$ (2)
and e_l over $l \epsilon S_0$ and $l \epsilon S_1$.

d) Fit the log-ratios log (ξ_k) and $\log(\eta_k)$.

$\hat{y}_k = \hat{r}\xi_k\eta_k / (1 + \hat{r}\xi_k\eta_k) w_k$

↓

Apply the inverse wavelet transform.

↓

Stop

Figure 2: Steps to evaluate the Pizurica Non-Homomorphic Filtering Method [1]

Different Thresholding Methods:

Start

↓

Speckle image as input is applied using neighborhood operation to obtain the noisy image.

↓

Calculate the distribution parameters [m,s,Ω] using Generalized Nakagami and Gamma distribution.

↓

Choose the thresh name (‘baygau’, ‘baylap’ , ‘fnm’).

↓

Apply the Redundant discrete wavelet transform to decompose the image into four subbands (LL, LH, HL, HH) without using downsampling operation.

↓

Compute the result using ‘bayes thresh for Gaussian noise method ‘, ‘bayes thresh for laplacian noise’ and ‘nakagami estimator using -> foucher MAP method’ respectively.

↓

Invert the multiscale decomposition to reconstruct the denoised image

↓

Compute the best result using quality metrics (SNR, PSNR, CoC, EPI).

↓

Stop

Figure 3: Steps to evaluate different thresholding methods [2]

II. LITERATURE SURVEY

S. Gupta, L. Kaur , R.C. Chauhan , S.C. Saxena [1] have discussed a versatile wavelet domain despeckling technique which visually enhance the ultrasound images for diagnosis purpose. The different qualitative measures are visually being compared and shows the best result. **Aleksandra Pizurica, Wilfried Philips, Ignace Lemahieu, and Marc Acheroy, [2] ,**developed the method in which a parameter preserve the details on various noise images. The method outperforms single-resolution spatially adaptive algorithms, in terms of quantitative performance measures as well as in terms of visual quality of the images. **C. Munteanu and A. Rosa [3]**

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a new automatic image enhancement technique based on real-coded Genetic Algorithms (GAs) is developed in terms of subjective and objective evaluation which show the superiority of the method. **A. Buades, B. Coll and J. M. Morel [4]**, shows the most powerful evaluation method which removes noise from natural images. **N. K. Ragesh, A. R. Anil, Dr. R. Rajesh[5]** shows the survey on different techniques in ultrasound image denoising. **David E. Goldberg and Kalyanmoy Deb [6]** considers a number of selection schemes commonly used in modern genetic algorithms and analysed for more detailed analytical investigation of selection techniques. **S. Hashemi, S. Kiani [7]** demonstrated the genetic method which was stronger than counterpart methods in terms of contrast and detail enhancement and producing natural looking images. **MA Qi-ming , WANG Xuan-yin , DU Shuan-ping[8] shows t**he effectiveness of the methods which validates the results by analysing the simulated and real signals. **M. Paulinas and A. Usinskas [9],** that genetic algorithms are most powerful unbiased optimization techniques for sampling a large solution space. **K. Sri Rama Krishna, A. Guruva Reddy [10]**, developed the approach which is based on functional level evolution whose architecture includes nonlinear functions and uses genetic algorithm for finding the best filter configuration.

III. PROPOSED GENETIC ALGORITHM

Genetic algorithm (GA) achieves the solutions for optimization problems by following the process of natural evolution. It is based on the principle of “Survival of Fittest”. The method chooses a chromosome structure which is problem specific. An initial population is generated randomly. Further genetic operators such as crossover and mutation are applied to achieve desired optimized results[7].
Basically, simple GA consists of following steps:

1) Generate Initial Population randomly
2) Evaluate Fitness value of every chromosome based on some problem specific metrics
3) Select a pair of chromosomes on basis of some selection strategy
   a. Apply genetic operators i.e. crossover and mutation
   b. Selected chromosomes replaced by new chromosomes that are derived after application of genetic operators
4) Finally result obtained by choosing the chromosome with highest fitness value

In this paper a GA is proposed for noise enhancement problem. The proposed GA is based on chromosome structure as shown in figure 4. Chromosome is represented as an array consisting of 6 elements. The elements contain the following variables:
Element 1: Original Image
Element 2: Image format, which can be .jpg, .tif, .gif
Element 3: Noise variance, which can range from 0 to 1
Element 4: Method to be applied for noise enhancement, which can be Baylap, Pizurica, Baygau, Fnm
Element 5: Multiplicative Factor, whose value ranges between 1 and 10.
Element 6: Window Size, which can have value 3, 5 or 7.

Original Image	Format of file (.jpg/.tif/.gif)	Noise Variance (0 to 1)	Noise Enhancement Method (Speckled, Pizurica, Baygau, Baylap, Fnm)	Multiplicative Factor (1 to 10)	Window Size (3 or 5 or 7)

Figure 4: Chromosome Representation

A. Fitness function

In the proposed method, SNR metric is used as fitness value for each chromosome. This fitness function has been shown in equation below:

$$Fitness\ Function = SNR$$

where SNR is defined as follows: Signal-to-Noise Ratio(SNR) :

$$\text{SNR}= 10 \log 10 \left(\frac{\sigma_g^2}{\sigma_e^2}\right)$$

Where σ_g^2 is variance of noise-free reference image,
σ_e^2 is variance of error(between the original and denoised image).

Fitness function pseudo code:

```
Begin
Let I be the original image
And I’ is denoised image
F’= SNR(I,I’)
d=abs(f subtract f1)
mse=sum(sum(I multiply I))
variance=sum(sum(I multiply I))
If mse > 0
        x=10*log10(variance divide by mse);
End If
```

B. Genetic Operators

Genetic Operators are applied after selecting a pair of chromosomes based on Roulette Wheel Selection strategy. This strategy considers the chromosomes to be a part of roulette wheel where each chromosome

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occupies part based on their fitness values. Parent chromosomes are selected by spinning the wheel.

Original Image	.jpg	0.5	Baylap	8	3

Further crossover operator and mutation operators are applied to generate the best solution randomly [8].

Original Image	.jpg	0.5	Baylap	1	3

Offspring

C. Crossover

Original Image	.jpg	0.8	Baylap	8	3

Crossover operator is applied by applying crossover

Chromosome 1

Original Image	.tif	0.5	Pizurica	5	3

certain random element of selected pair of omosomes. Any random number is selected from

Chromosome 2

Original Image	.jpg	0.5	Baylap	8	3

the range 2 to 6. The selected element number is exchanged among the selected chromosomes as

Offspring 1

Original Image	.tif	0.8	Pizurica	5	3

own below in figure:

Offspring 2

Crossover Point

Crossover Point

D.Mutation

Mutation operator whe ected element of chromosome, changes n point is chosen randomly between the range 2 to 6. Mutation operator changes the values based on element chosen:

If element 2 is selected then its value can be changed by choosing randomly among the values {.jpg, .tif, .gif }.

If element 3 is selected then its value can be changed by choosing randomly within the range 0 to 1.

If element 4 is selected then its value can be changed by choosing randomly among the values {Speckled, Pizurica, Baygau, Baylap, Fnm}.

If element 5 is selected then its value can be changed by choosing randomly within the range 1 to 10.

If element 6 is selected then its value can be changed by choosing randomly among the values {3, 5, 7}.

Thus, by applying mutation operator randomly on offspring 1 shown above, result is an image giving highest fitness value. The process is shown below by chosing element 5 randomly and changing its value from 8 to 1:

Chromosome

Proposed GA results randomly in following image which gives highest fitness function:

Original Image	.jpg	0.5	Baylap	1	3

IV. RESULTS AND DISCUSSIONS

A. Simulate Speckle Image

To investigate the quantitative performance of the method, the speckled images were simulated from the noise-free test images.First of all the original image is shown in the result, then the subimage in which the whole further processing is going on.Then the above speckle image is added as a input in every Non-homomorphic method and after applying the different techniques the results are obtained using sigma value as 0.5. Using different metrics the comparison between the four methods is done, and "Baylap" method shows the best result for speckle reduction in

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images.

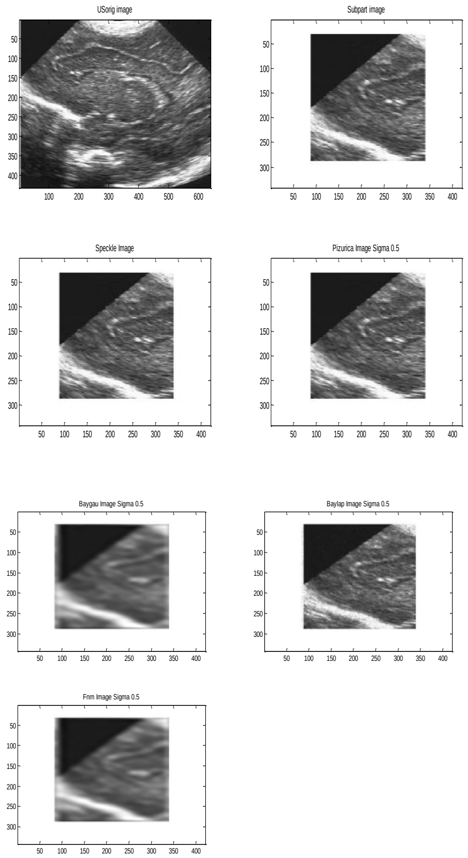

TABLE 1:
Comparison of different Non-Homomorphic Filtering Techniques using metrics:

Method	SNR(dB)
Speckled	19.29286
Pizurica	19.64034
Baygau	12.8662
Baylap	**19.90468**
Fnm	12.86186

SNR = Signal to noise ratio.

After comparing the different methods using metrics SNR value of “Baylap” method is the highest.The value of SNR should be greater than one. More the value best is the method for future use.

V. CONCLUSION

A new, robust and efficient wavelet domain denoising technique, which is applicable to various types of image noise, is used. The method is in particular for medical image denoising, since it accounts for the preference of the medical expert: a single parameter can be used to balance the preservation of (expert-dependent) relevant details against the degree of noise reduction. Such a user interaction is in the first place useful for speckle noise removal from the ultrasound images.

A versatile despeckling technique to visually enhance the medical US images for diagnosis is analyzed. The core of the method is the use of two-sided GND model for approximating the speckle statistics in the wavelet domain. To adapt the estimator to the local image statistics (homogeneous to highly heterogeneous areas), signal variance is estimated from the local neighborhood using scale-space adaptive window. A tuning parameter is used to make the method user-interactive so as to suppress the speckle according to the preference of medical expert. The performance superiority of the proposed algorithm over well-known spatial domain filters and state-of-the-art wavelet based denoising techniques in terms of different quantitative metrics (like SNR, PSNR, coefficient of correlation, structural similarity index, and edge preservation index) are maintained. The effectiveness of the proposed technique encourages the possibility of using this approach in real-time ultrasound image enhancement to improve clinical diagnosis.

A new and efficient technique for despeckling medical US images has been used. A spatially adaptive MAP processor, has been designed and tested which relies on the Nakagami distribution of speckle noise and Gaussian prior for modelling the wavelet coefficients in a logarithmically transformed US image. The process is based on the solid statistical theory, and does not depend on any adhoc parameter. The interesting result is that the estimator uses a simple statistical parameter such as ‘variance’ to adapt itself to the local spatial image context and tuning parameter to control the smoothness of the image. The results show that it reduces the speckle noise effectively while retaining the diagnostically important features, as was demonstrated on different US images. This indicates that the method is effective, tunable, feature-preserving despeckling technique.

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