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Adaptive Switching De-noising Filter Cascaded with Cuckoo Search Algorithm to Minimize the Mean Error – Medical Image Application

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***Abstract*—** This paper presented the new work to minimize the mean absolute error of mammogram breast image which is highly corrupted by impulse noise density. The proposed methodology is implemented with the Adaptive Switching Weighted Median (ASWM) Filter cascaded with Cuckoo Search (CS) optimization algorithm. The efficient adaptive filter de-noises the medical image by detecting the corrupted pixel and replaces them with the median value. The CS algorithm minimizes the error rate between the ASWM filter image and corrupted image. It minimizes the Mean Absolute Error (MAE) percentage and also maximizes the Peak Signal to Noise Ratio (PSNR). This method removes the highly corrupted impulse noise of 90%. The experimental analysis is made and it is observed from the result that the proposed method is far superior to the other conventional techniques in terms of qualitative and quantitative factors. In terms of visual quality, it yields a well sharp edge region and better visual perception of the image quality.

***Keywords*—** Switching filter, image de-noising, impulse noise, optimization technique, Cuckoo search algorithm.

I. Introduction

Development of the Computer Aided System (CAD) in the recent era plays an important role in the image processing technique like segmentation, classification and pattern recognization etc., But before undergoing this processes, image should undergo pre-pre-processing techniques like enhancement, de-noising, restoration, registration and artefacts removal etc., Image pre-processing has a vital role in medical image diagnosis. Even today many researches are going on with the image de-noising and restoration. Medical image faces serious drawbacks in image quality. This quality issue arises due to the physical interference which causes the noise in the medical image and affects its visual perception. The medical diagnosis devices like mammogram and ultra-sound face this kind of visual quality issues. Mammography is the precise type of imaging source for breast cancer detection and calcification deposit in breast and these images are usually low contrast images [1].

Commonly affecting noises in medical images are impulse, speckle, Poisson and white Gaussian noises. Many efficient filters have been proposed to de-noise the medical image. There exist many median based filters; each one has separate individuality such as detection and filtration of noise pixel separately. The Median filter is the popular filter but the drawback is when the noise level increases it fails to preserve the edges and fine features. But when it combines with some other adaptive process it enhances its ability even when the noise level increases.

This paper mainly focuses on de-noising the mammography image from highly corrupted impulse noise. The ASWM filter with CS algorithm is used to detect and remove the corrupted pixel. This methodology of framework yields very low mean absolute error and also better visual perception. This paper is organized as follows: in section 2, the work related to our proposed method is described briefly. Section 3 explains the ASWM filter and section 4 detailed demonstrated the CS algorithm. In section 5 the development model of the proposed framework is elaborated. Section 6 explains the result and discussion of the performance of proposed method. The conclusion is drawn in section 7.

II. Related Work

The conventional method can suppress the noise but it fails to preserve the edge and fine details. The adaptive thresholding function with the nature-inspired algorithm is capable of removing the noise. This adaptive function chooses the appropriate threshold value to the only the noise pixel. Nature inspired optimization was used for the optimum performance [2]. The curvelet transformation with the ridgelet transform combination with CS algorithm de-noises the medical image without loss in structural and morphological information. This method is well suitable for removing the multiplicative and additive noises [3]. The atom transform concept with the modified cuckoo search is used for de-noising the fingerprint image. This system of process improvises the gray level distribution that maximizes the objective function [4].

The cuckoo search and particle swarm optimization (CS-PSO) was blended together for improving the low-contrast image. The global transformation of the image is handled well with this blending of the algorithm. The CS-PSO elevates the objective fitness criterion in order to enhance the contrast and detail in an image by adapting the parameters of a novel extension to a local enhancement technique [9]. The CS algorithm with morphological approach enhances the digital image with fine structuring element. The drawback such as over contrast discernibility of features inside the images is overcome. The fundamental characteristic of this CS algorithm is that the amplitudes of its components can objectively reflect the contribution of the gray levels to the representation of image information for the best contrast value of an image [10]. The logarithmic transformation with optimization is used to determine the optimal parameter for de-noising the medical image [11]. The structural optimization problem can be also solved by the CS algorithm with the combination of Le´vy flights. This also solves the nonlinear constrained optimization problem efficiently [17].

III. ADAPTIVE SWITCHING WEIGHTED MEDIAN FILTER

The non-linear filters are superior in detecting and removing the noise without degrading the information from the source image. The median filter is the base of all non-linear filters which is very useful for removing the impulse noise from an image. In this work, we have taken the two-step de-noising filter called Adaptive Switching Weighted Median Filter (ASWMF). The initial step of this filter is to detect the noise pixel alone from the corrupted image. In the detection process itself, the filter will cluster the noise and non-noisy pixel separately by calculating the local mean value Faragallah and Ibrahem (2016).

$$W_{(i,j)} = m_{(i,j)} * \alpha_{(i,j)} + (1-\alpha_{(i,j)})*f_{(i,j)} \quad (1)$$

Where the weighted median operation is given by $m_{(i,j)}$ and $f_{(i,j)}$ is the corrupted input image.

$$\alpha_{(i,j)} = \begin{cases} 0,\ if\ f_{(i,j)} & Noise\ free\ pixel \\ 1,\ if\ f_{(i,j)} & Noise\ pixel \end{cases} \quad (2)$$

In the detection process, the noise pixel is detected by the adaptive method. Here the detection process is tried out with the varying window size of 3×3 to 17×17 and also with the varying noise density. After the detection process of noise removal is done by the weighted median value. Initially, the 3×3 window is subjected to process, if the entire pixel in the selected window is found to be noisy, then window size is increased to 5×5 and so on. Also, the iteration process is also carried out to find out the missing corrupted pixel or else it will cause the distortions in an image [5].

IV. CUCKOO SEARCH ALGORITHM

The Cuckoo Search (CS) optimization algorithm is based on the obligate brood parasitic behaviour of some cuckoo bird species in combination with the L´evy flight behaviour of some birds [7]. It is based on the methodology of the meta-heuristic and nature-inspired algorithm [8].

The primary concept of CS algorithm is the bird cuckoo lays its eggs on the other species nest. When the other species bird discovers that the eggs present in their nest is not belong to their own species, the other species bird either thrown out of the nest or the whole nest is abandoned. Thereby the cuckoo bird needs to search for another nest to lay the eggs. This algorithm has three basic rules:

(i) Cuckoo bird randomly chooses a nest and lays one egg in it.
(ii) The best egg in the nest will be carried out to the next process.
(iii) The host nest remains constant and the chance of discovering the cuckoo's egg with the probability of [0 1]. In this case, other species bird can either destroy the cuckoo's egg or abandon the nest and build a new one somewhere else.

Generally, CS is used extensively to solve the global optimisation problem because it is able to maintain a balance between local and global random walks using switching parameter [6]. The basics steps to implement the CS algorithm are described below:

Step 1: Initialize the number of the nest, probability of other species bird discover the nest, set the stopping criteria and initialize the parameters boundary.

Step 2: The solution of obtaining 'n' different nests for 'n' different solution

Step 3: Calculate the fitness value of each solution. Mean Square Error is considered as a fitness function. The formulation of MSE is given by.

$$MSE = \frac{1}{(i,j)} \sum_{i=1}^{i} \sum_{j=1}^{j} \left[\hat{f}(i,j) - f(i,j) \right]^2 \quad (3)$$

Here i and j are the rows and columns of image. $\hat{f}$ and $f(i,j)$ denotes the enhanced and source image.

Step 4: Discover the best nest related to the minimum fitness value.

Step 5: Begin the iteration

Step 6: Generate a new nest using the Levy flight. The formulation of the Levy flight is given by:

$$W_i\ (x+1) = W(x)_i + \alpha \oplus levy(\lambda) \quad (4)$$

Where steps size function is denoted as . The distribution of Levy flight is mathematically given by (Yang 2010).

$$levy \sim u = x^{-\lambda}, (1 < \lambda \le 3) \quad (5)$$

Step 7: Calculate the solution to obtain the new fitness function.

Step 8: Evaluate preceding fitness value.

Step 9: Replace the old fitness value, if new one is found.

Step 10: Update the bNest to the fitness function.

Step 11: Continue the process until it produces the best fitness and best location.

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Start
Objective function f(X), X=(x_1,….,x_d)^T
Generate the Initial population of n host nests
                                    X_i (i=1,2,…..,n)
While (t<Max Generation) or (Stop Criteria)
Get a cuckoo (say i) randomly by Levy Distribution;
Calculate its fitness value F_i;
Select a nest among n (say j) randomly;
Calculate its fitness value F_j;
If (F_i>F_j)
Replace j by the new solution
End
Fractions of (Pa) of worst nest are abandoned and new ones
are built at      new locations via Levy flights;
Keep the best solution (or nests with quality solutions);
Rank the solution and find the current best;
End While
Post-Processing result
End
```

Figure 1- Pseudo code for Cuckoo Search Optimization Algorithm

V. DEVELOPMENT MODEL

The development model of this approach initially deals with the corrupting the mammogram and standard benchmark image with the impulse noise density. Initially, the image is corrupted with 10% and tested with the proposed method and the percentage of the noise density increases to find the efficiency of the method. After the noise addition process, the ASWM filter is applied to the corrupted image. This process is considered as a second step in the development model of the proposed method. In the third stage of the process, both the corrupted image and enhance output image from ASWM filter is led into the CS algorithm as a search variable. This process is to done to minimize the error in the enhanced filtered image and corrupted image.

In CS algorithm, we have found the suitable parameters for this method after the several experiments made. Initially, a total number of the nest is 25 which are made default. The total number of iterations taken here is 110. The probability of finding that it is another species egg is 0.30. The parameter considered in this work yields a good convergence and very flexible to implement.

V. RESULT AND DISCUSSION

In this section, the performance analysis is made for the proposed work ASWM filter with CS algorithm. In this work, we have used medical images such as mammogram breast image and standard benchmark image i.e., Lena image. The mammogram image is taken from the MIAS dataset which is a publically available dataset. The Lena image is taken of size 512×512 and the mammogram image is of size 315×280. To find the efficiency of the proposed work, the source images are corrupted with the impulse noise percentage from 10% to 90%. The performance factors such as Peak-Signal to Noise Ratio (PSNR) and Mean Absolute Error (MAE) is used for evaluating the proposed method. Table 1 and Table 2 shows the performance of the proposed work in terms of PSNR and MAE and total minimized error is also calculated from the MAE.

From the table 1 and table 2, it is observed that when ASWM filter works along with the CS algorithm it yields a far better result when it works standalone. The proposed method also calculated the minimized error from the MAE and it is found that the proposed method lowers the MAE factor. The performance analysis of the proposed method is given in figure 2 to figure 8 which shows the superiority of the proposed work.

Table 1: Performance result of ASWM filter and ASWM filter with CS algorithm in terms of PSNR and MAE for mammogram image.

Noise Density (%)	Peak Signal to Noise Ratio		Mean Absolute Error		Total Error Minimized
	ASWMF	ASWMF with CS	ASWMF	ASWMF with CS	
10	34.1264	39.7281	0.0336	0.0043	0.0293
30	32.6220	35.8740	0.1250	0.0089	0.1161
50	29.3491	33.6911	0.3917	0.0170	0.3747
70	25.1641	30.1247	0.4586	0.0237	0.4349
90	19.0622	28.6929	0.5014	0.0484	0.453

Table 2: Performance result of ASWM filter and ASWM filter with CS algorithm in terms of PSNR and MAE for Lena image.

Noise Density (%)	Peak Signal to Noise Ratio		Mean Absolute Error		Total Error Minimized
	ASWMF	ASWMF with CS	ASWMF	ASWMF with CS	
10	33.4705	39.0005	0.0412	0.0069	0.0343
30	30.0114	37.3992	0.1027	0.0092	0.0935
50	28.2652	35.2650	0.2542	0.0150	0.2392
70	23.1078	31.2174	0.4506	0.0299	0.4207
90	18.6070	27.5612	0.5001	0.0353	0.4648

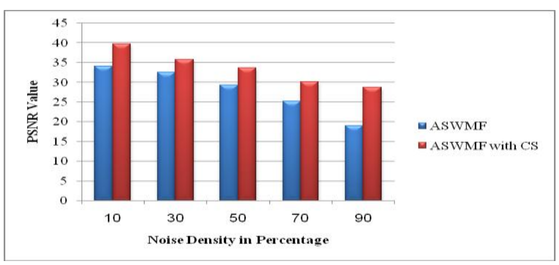


Figure 2 - Comparison analysis of PSNR for ASWM and ASWM with CS algorithm for Mammogram Image

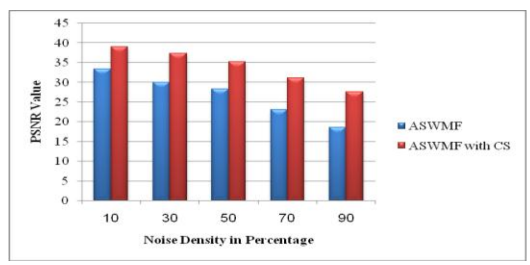


Figure 3- Comparison analysis of PSNR for ASWM and ASWM with CS algorithm for Lena Image

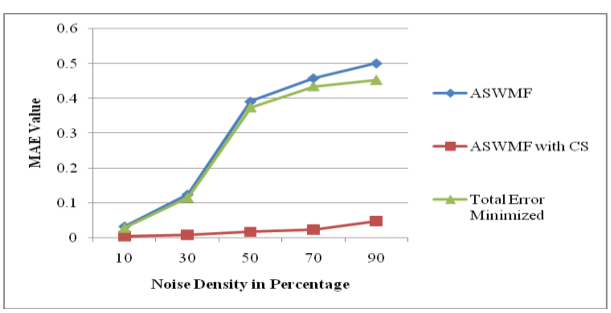


Figure 4 - Comparison analysis of MAE for ASWM, ASWM with CS algorithm and total error minimized for Mammogram image.

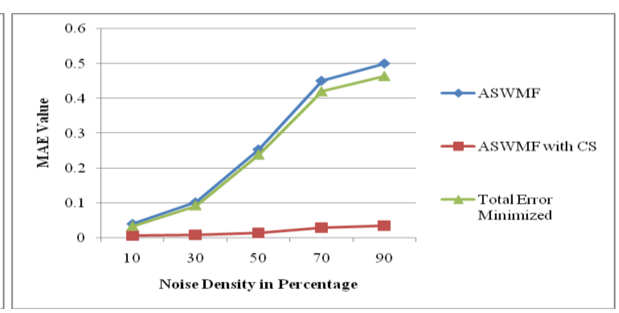


Figure 5 - Comparison analysis of MAE for ASWM, ASWM with CS algorithm and total error minimized for Lena image

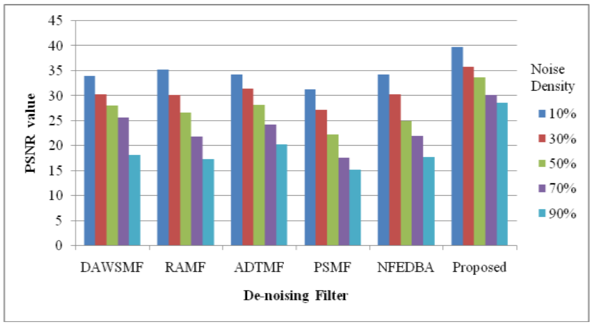


Figure 6 - Comparison analysis of PSNR for various de-noising filters for mammogram image

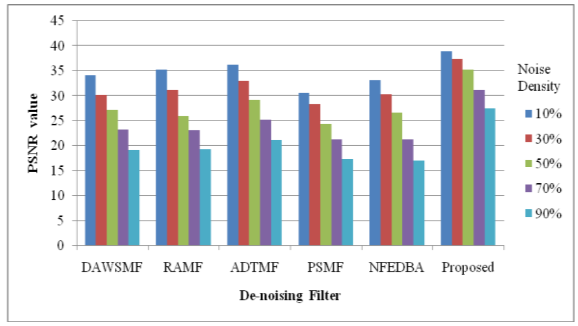


Figure 7- Comparison analysis of PSNR for various de-noising filters for Lena image

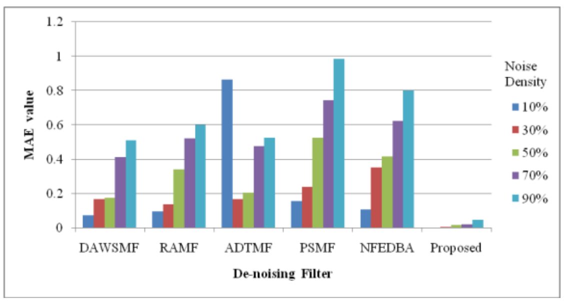


Figure 8 - Comparison analysis of MAE for various de-noising filters for mammogram image

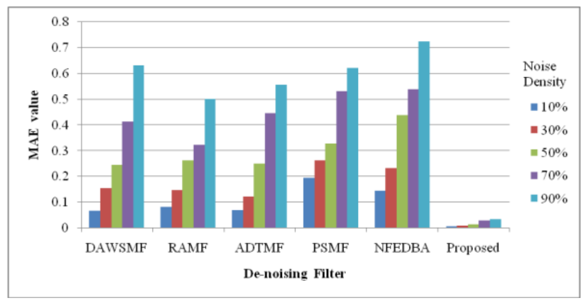
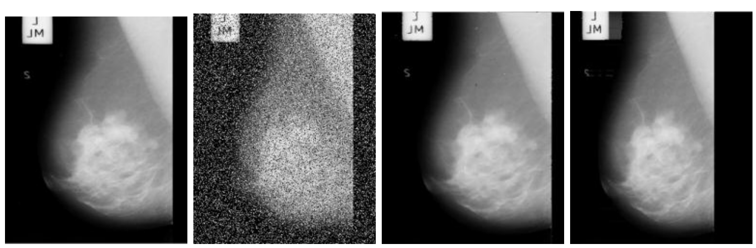


Figure 9 - Comparison analysis of MAE for various de-noising filters for Lena image



(a) (b) (c) (d)

Figure 10 – (a) original mammogram image (b) impulse noise corrupted (c) represent the ASWM filter (d) show the ASWM filter with CS algorithm

(a) (b) (c) (d)

Figure 11 – (a) original standard image (Lena) (b) impulse noise corrupted (c) represent the ASWM filter (d) show the ASWM filter with CS algorithm

The performance analysis from the above figures from figure 2 to figure 9, it is depicted that the ASWMF with CS works well for the high-density impulse noise. In figure 4 and figure 5 it is shown that total error minimized is almost equivalent to the proposed work. In figure 6, it is shown that our method is compared with the existing de-nosing techniques like Direction Based Adaptive Weighted Switching Median Filter (DAWSMF) [15], Recursive and Adaptive Median Filter (RAMF) [14], Adaptive Dual Threshold Median Filter (ADTMF) [16], Progressive Switching Median Filter (PSMF) [12] and New Fast and Efficient Decision Based Algorithm (NFEDBA) [13] with the noise density varies from 10% to 90%. Therefore the figure 6 analysis shows that the proposed methodology is found better in terms of PSNR and MAE.

The visual evaluation of the qualitative performance of the proposed work is shown in figure 10 and figure 11. Figure 10(a) and figure 11(a) is the original source image. Figure 10(b) and figure 11(b) are the impulse noise corrupted image. The portion which is degraded by noise is recovered and brightness is gained in the proposed work. In figure 10 (c) and figure 11 (c), even though the filter cleans out the noise, it fails to distribute the intensity level to an overall image. The low-frequency portion is not well enhanced in figure 10(c) and figure 11(c). But this drawback is overcome in the proposed work shown in figure 10(d) and figure 11(d). The edge portion affected by noise is also enhanced by the ASWM filter with CS method which is illustrated in figure 10 (d) and figure 11 (d). In this proposed method we have found that ASWM filter with CS algorithm comparatively yields a better visual and quantitative result.

VI. CONCLUSION

In this paper, a new approach is handled to de-noise the mammogram image from high density corrupted impulse noise. The methodology of using the Adaptive Switching Weighted Median (ASWM) filter with Cuckoo Search (CS) algorithm is introduced to reduce the mean error. The experimental result gives the recognizable outcome with high impulse noise density up to 90%. The visual result shows the promising improvement in the interior portion of the edges and maintains the structural features sharpen. The ASWM filter with CS algorithm can be useful for the de-noise tool in the CAD system and this methodology proves better by yielding a low mean square error.

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