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Novel Invisible Watermarking for Various Images using HWT- GA-PSO based Hybrid Optimization

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Abstract— ***In this paper a novel invisible robust watermarking scheme for embedding and extracting a digital watermark in an image is presented. The novelty lies in determining perceptually important coefficients of transform in the host image using simple Haar Wavelet Transform (HWT) and Genetic Algorithm(GA)-Particle Swarm Optimization(PSO) based hybrid optimization. Invisible watermark is embedded such that it does not destroy or degrade the esthetic quality and value of the image. The proposed method is found more suitable for copyright protection as it is more imperceptible and robust than purely wavelet transform based or DCT-PSO based or only DWT-GA or DWT-PSO based watermarking techniques. The horizontal and vertical sub bands are selected for embedding watermark. In order to have a watermarked image with the best possible quality, GA-PSO is used to find the best DWT coefficients for embedding the watermark sequence. The method exhibits impressively high PSNR values as compared with previous techniques. It has been found that the method works well with the standard image processing database images as well as standard medical images the method shows high performance for black and white as well as colour images. HWT-GA-PSO based hybrid optimization method is shown to be robust against many signal processing operations.***

Keywords— ***HWT-Haar Wavelet Transform, HPSO-Hybrid PSO, HWT-GA-PSO : Haar Wavelet Transform- Genetic Algorithm-Particle Swarm Optimization, GPSO-Gentic Algorithm and PSO,DCT-PSO: Descrete Cosine Transform and Paricle Swarm Optimization, DWT-PSO: Discrete Wavelet transform and Particle Swarm Optimization***

I. INTRODUCTION

Recent progress in digital media and digital distribution systems, such as the Internet and cellular phones, has enabled us to easily access, copy, and modify digital content, such as electronic documents, images, audio, and video[1]. "Digital Watermarking" is the process of computer-aided information hiding in a carrier signal; the hidden information should, but does not need to contain a relation to the carrier signal. Watermark techniques can be divided into two groups: Visible and invisible. The visible watermark is used if embedded watermark is intended to be seen by human eyes while the invisible watermark is embedded into a host image by sophisticated algorithms and is invisible to the human eyes [2].

The main requirements of digital watermarking are invisibility, robustness and data hiding capacity [3]. Robustness is the resistance of an embedded watermark against intentional attacks, and normal audio/visual processes such as noise, filtering, scaling, rotation, cropping and lossy compression. Invisibility refers to the degree of distortion introduced by the watermark and its affect on the viewers or listeners. Capacity is the amount of data that can be represented by the embedded watermark [9].

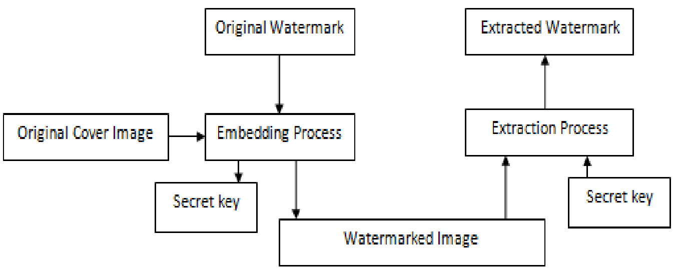


Figure 1: Process of invisible Watermarking

II. LITERATURE REVIEW

Human Visual System (HVS) has a very strong error correction. An image contains a lot of redundancies. Small changes are undetected [4]. Based on the method used for watermark embedding and extraction, invisible watermarking techniques are of three types– Spatial Domain, Frequency Domain and Mixed Domain. Invisible Watermarking is an optimization problem. There is a wide tradeoff between the two requirement- invisibility and robustness. Moreover various techniques show different level of robustness to different types of attacks. Therefore this research study aims for Performance optimization of invisible watermarking based on creation and robust extraction.

Surekha et al. [1] have proposed a new optimization method for digital images in the Discrete Wavelet Transform (DWT) domain. The tradeoff between the transparency and robustness is considered as an optimization problem and is solved by applying Genetic Algorithm. Particle swarm optimization (PSO) is a new promising evolutionary algorithm for the optimization and search problem. One problem of PSO is its tendency to trap into local optima due to its mechanism in information sharing. This paper proposes a novel hybrid PSO, namely (HPSO) technique by merging both a mutation operator and natural selection to solve the problem of premature convergence [2]HPSO is proposed to improve the performance of fragile watermarking based DCT which results in enhancing both the quality of the watermarked image and the extracted watermark [2].

Mona M. Suliman et al [3] have incorporated PSO with GA in hybrid technique called GPSO. This paper proposes the use of GPSO in designing an adaptive medical watermarking algorithm. S. M. Ramesh et al. [5] have presented an efficient image watermarking technique to defend the copyright protection of digital signatures. The major steps include the watermark embedding and watermark extraction. This work is implemented to watermark the original input medical image. The grayscale digital signature image as a watermark and it is embedded in the HL and LH sub-bands of the wavelet transformed image. Chaudhary et al. [6] have presented a new method for adaptive watermark strength optimization in Discrete Cosine Transform (DCT) domain. The DCT sub-band is selected using Genetic Algorithm (GA) and watermark strength is intelligently selected through Particle Swarm Optimization (PSO). In past years, singular value decomposition SVD-based watermarking technique and its variations has been proposed [7].

The proposed work is based on further improvement of the research work based on DCT, DWT, and optimization based on PSO, GA. significantly better results have been yielded with the single level DWT, and an optimization of Robustness and imperceptibility based on the hybrid technique of GA and PSO is achieved. The remainder of this paper is organized as follows. In section 2, the watermark embedding and extraction algorithm in the wavelet domain is described, In section 3, the PSO-GA based hybrid optimization technique is presented. Experimental results are given in Section 4. Finally, the paper ends with conclusions and future research directions.

III. IMPLEMENTATION WORK

In this section, we have prearranged for a brief overview about the proposed hybrid model optimization in which the embedding and extracting algorithms of watermarking in Descrete wavelet transform are combined with GA-PSO based hybrid optimization techniques for watermarking. The key parameters to be concentrated for this proposed model are orthogonality, symmetry and compact support which will enable the model to achieve a better watermarked media and robustness in watermarking. The watermarking technique proposed in this work may be very effective against different low-frequency attacks that demolishes the low frequency component of the image.

A. Embedding Process

In Embedding process, we have the inputs: original image $I_o(a,b)$ and one watermark image $I_w(a,b)$, and output is watermarked image $I_{wd}(a,b)$. By using Haar wavelet transform, the original image is decomposed into four sub-bands like HH, LL, HL and LH for embedding watermark image. Choose the HL $HL(a,b)$ and LH $LH(a,b)$ sub-bands for embedding the watermark image from the four sub-bands. Most techniques are utilizing these aforementioned two parts only for this purpose. So, here also we are using these parts because producing high PSNR and robustness for hiding information in different media and approximation coefficients are thought to be reasonably firm and less sensitive to slight changes of the image pixel, they are the perfect embedding area. Based on artificial intelligent method, the coefficients at widespread sub-bands HL and LH are chosen for watermark embedding, in order to attain a balance between robustness and fidelity. The watermarking pixels are, at the same time, embedded into the HL and LH sub-band based on the following step,

- ❖ In order to find embedding parts in the HL sub-band we have computed the mean value $\tilde{V}_{HL}(a,b)$ and the maximum value $V_{HL}(a,b)$. Similarly, the mean $\tilde{V}_{LH}(a,b)$ and maximum value $V_{LH}(a,b)$ of the LH sub-bands is computed. The formula for this operation is mentioned below,

$$\tilde{V}_{HL}(a,b) = \sum_{a=1}^{n} \frac{V_{HL}(a)}{n} \qquad -(1)$$

$$V_{HL}(a,b) = \max(HL) \qquad -(2)$$

We have to embed the first two pixels from the watermarking image $I_w(a,b)$ into the HL and LH sub-band respectively, after finding mean and maximum value of HL and LH sub-bands. With the position of one's place in the population vector P , we embed the first pixels into the HL sub-band. Similarly, with the next position of one's place, we embed the second pixel into the LH band. Since the watermarking image is a binary image with 0 and 1, the embedding process is accomplished in two steps. Below mentioned process is detecting the suitable location for embedding the watermark image

- FFor embedding, if the watermarking pixel is "1", then we analyze all values in the HL and LH sub-bands which are compared against the maximum value. If the values in the HL and LH sub-band are greater than 1, then take the absolute value and embed the same. Otherwise, if it is lesser than 1, then add the corresponding pixel with the maximum value and embed the modified value. Similarly, embed the subsequent pixels into the LH sub-band.

$$\begin{aligned}&\textit{if}\quad HL(a) > 1\ \textit{then}\\ &\qquad W[a] << Abs\ [HL(a)]\\ &\textit{else}\\ &\qquad W[a] << HL(a) + V_{HL}[a,b]\\ &\textit{end if}\end{aligned} \quad - (3)$$

- FFor embedding, if the watermarking pixel is "0", then we analyse the values in the HL and LH sub-bands which are lesser than 0, and take the absolute value and embed the same. And, if it is greater than 1, then subtract the corresponding pixel with the maximum value and embed the modified value. In the same way, embed the subsequent pixels into the LH sub-band.

$$\begin{aligned}&\textit{if}\quad HL(a) < 0\ \textit{then}\\ &\qquad W[a] << Abs\ [HL(a)]\\ &\textit{else}\\ &\qquad W[a] << HL(a) - V_{HL}[a,b]\\ &\textit{end if}\end{aligned} \quad (4)$$

After you apply inverse DWT to the modified sub-bands, we get the watermarked image $I_{wd}(a,b)$,

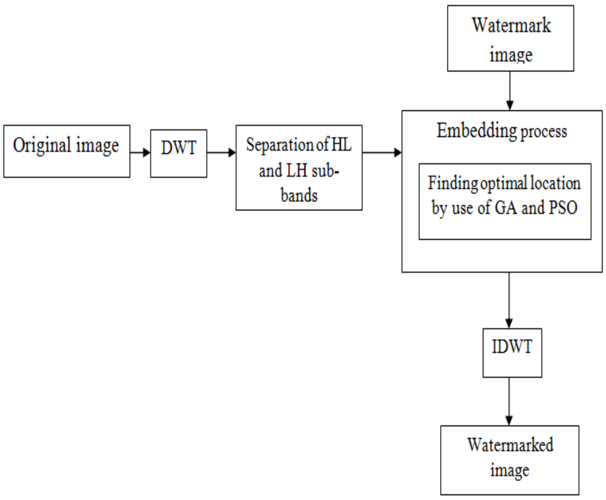


Figure 2. Watermark Embedding Algorithm

B. Extraction Process

Here the inputs are watermarked image $I_{wd}(a,b)$, size of the watermarking image $|I_w(a,b)|$ and an output is extracted watermarking image $E_w(a,b)$. Due to Biorthogonal wavelet transform the obtained watermarked image is decomposed into different sub bands such as HH, HL, LH and LL for extracting the watermark image. Select the HL $HL(a,b)$ and LH $LH(a,b)$ sub-bands for extracting the watermarking image. With the help of the following steps, take out the watermark pixels from the HL and LH sub-bands from the corresponding positions of the one's place. The extracted pixel value is one, if the embedded pixel value is greater than the mean pixel value. The extracted pixel is zero, if it is lesser.

$$E_S(a,b) = \begin{cases} 1, & HL[a,b] > \tilde{V}_{Hl}[a,b],\ 0 < a < n \\ 0, & \textit{otherwise} \end{cases} \quad (5)$$

Outline the matrix with the size of the watermarking image | $I_w(a,b)$ | and to take out the watermarking image $E_w(a,b)$, the extracted pixels are put in it.

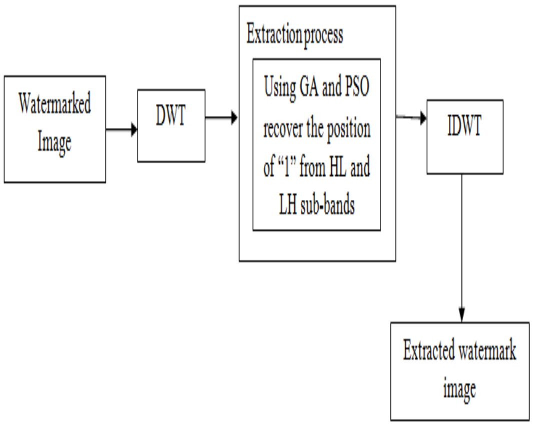


Figure 3.Watermark Extraction Algorithm

IV. OPTIMIZATION BASED ON HYBRID MODEL

In order to achieve both quality of watermarked media and robustness of the watermarked media, we use the Genetic algorithm (GA) and Particle swarm Optimization (PSO). In this, GA for generating the choromosome and PSO for selecting the optimal location for embedding the watermark media to original media. GA and PSO optimization techniques are applied in embedding and extraction process. So we can take the watermarked media parameters like intensity, etc., for computing PSNR and NCC of the watermarked media. These values are based on the original media size and intesnity. The optimization process of GA and PSO process is described as follows,

A. *Generation of Chromosome*

The function of the randomly generated set of chromosomes (set of genes) is the generation of chromosomes. Presently, population size plays an important role in presenting the solution to the problem at hand. The beginning population set up is done by producing a population set P that comprises of set of chromosome vectors having half size of the HL or LH sub-band. Subsequently, we have placed the one's value with the size of the watermarked (hiding) media in that vector in a random manner. And, the remaining cases are filled down by zero value. Then, the beginning set of chromosomes is brought forth at random with minimum number.

B. ***Fitness Computation***

Finding the optimized solution to the chromosomes is the better way. Till finding the locations defined in the chromosomes for each chromosome in the population set, the watermarking embedding process is iterated. Here embedding and extraction process is carried out using these procedures which were defined in the section 3. Then the fitness of GA is calculated by us, which is utilized for calculating PSNR along with the measure of NCC value. Below cited the formula is for discovering the fitness value of PSO. Fitness computation formula is depicted below,

Fitness=PSNR+NCC (6)

Below mentioned formula for computing the value for PSNR and Normalized correlation n coefficient (NCC) is,

$$PSNR = 10\log_{10}\frac{P_{\max}^2 \times W_a \times W_b}{\sum\left(W_{pq} - W_{pq}^*\right)} \quad (7)$$

$$NCC = \frac{\sum_{p=0}^{j}\sum_{q=0}^{i} O_w(p,q)\times E_w(p,q)}{\sum_{p=0}^{j}\sum_{q=0}^{i} O_w(p,q)^2} \quad (8)$$

Where,

W_a and W_b - width and height of the watermark media

W_{pq} - Original media pixel value at coordinate (p, q)

W_{pq}^* - watermark media pixel value at coordinate (p, q) $P_{\max}^2$ - Largest energy of the image pixels (i.e., $P_{\max}$ = 255 for 256 gray-level images)

$O_w(p,q)$ - Original watermarking media

$E_w(p,q)$ - Extracted watermark media

C. *Selection of optimized chromosomes*

Selection of optimized chromosomes is described as each chromosome has the value for fitness. In fitness value itself we are finding the optimal chromosomes for our project. As per the requirement we have to select the minimum or maximum value on the fitness computation. These selected fitness value corresponding chromosome is mentioned as the parent chromosome.

Select the optimized chromosome = $N_p / 2$ (9) Where, N_p--- Number of population

D. *Crossover*

On the basis of selction of chromosomes, we have the value of optimal solution. This solution is fed to the crossover operation. These set of fitness value corresponding chromosomes are provided the new off spring by the use of crossover operation. Every two individuals are chosen from the better set of chromosome to produce two new offspring by single crossover point.

E. *Mutation operation*

In mutation operation, we have to use the input of crossover operation output. The process of this function is to modify one gene value that is randomly selected and then that chromosome is fed to the fitness computation operation. So mutation operation is replaced with a velocity computation.

F. *Velocity computation*

Velocity computation operation is one part of the Particle swarm optimization. It is to find the weight value. But here is used for finding the optimal location of embedding location in original media. From the chosen optimized solution, in velocity computation, the chromosomes are named the different name. When the different name is utilized for velocity calculation only easily identified for the matrix of the chosen optimized solution. The matrix formulae is

$$v_{m+1} = v_m + c_1 r_1 (p_{best,m} - CP_m) + c_2 r_2 (g_{best,m} CP_m) \quad - (10)$$

$$CP_{m+1} = CP_m + v_{m+1} \quad - (11)$$

Where

v_{m+1} : Velocity of particle at m+1 th iteration

v_m : Velocity of particle at nth iteration

c_1 : acceleration factor related to gbest

c_2 : acceleration factor related to lbest

r1 ( ): random number between 0 and 1

r2 ( ): random number between 0 and 1

g_{best}: g_{best} position of swarm

p_{best} *t*: p_{best} position of particle

CP_{m+1} : Postition of particle at n+1th iteration

CP_m : position of particle at nth iteration

G. *Termination*

Later, in velocity computaion operation, we have newly obtained set of chromosomes which can be evaluated with the use of fitness function. If the optimal solution for embedding the watermark media to original media, this condition will be terminated, otherwise that solution will move to fitness computation operation. Again, the selection and velocity computation operators are performed iteratively. The PSO process will be iteratively performed until the desired termination is satisfied.

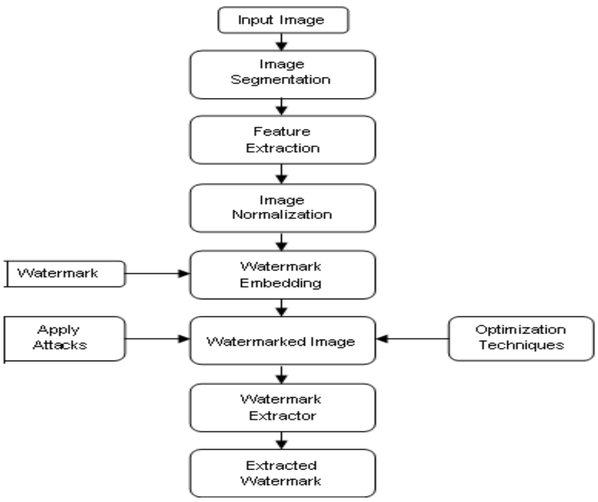


Figure4: DWT and GA-PSO Based Design

V. RESULTS

Experiments aimed at assessing the performance system both from the point of view of watermark imperceptibility and from the point of view of robustness. The novelty lies in determining perceptually important coefficients of transform in the host image using simple and efficient HWT-GA-PSO based hybrid optimization. Invisible watermark is embedded such that it does not destroy or degrade the esthetic quality and value of the image. The HWT-GA-PSO based hybrid optimization is found more suitable for copyright protection as it is more imperceptible and robust than purely wavelet transform based or DCT-PSO based or only DWT-GA or DWT-PSO based watermarking techniques. The method exhibits impressively high PSNR values as compared with previous techniques. It has been found that the method works well with the standard image processing database images as well as standard medical images the method shows high performance for black and white as well as colour images. HWT-GA-PSO based hybrid optimization method is shown to be robust against many signal processing operations.

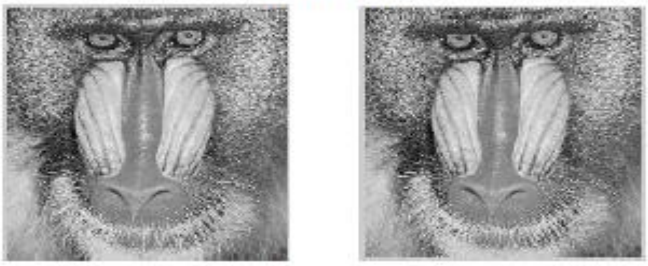
And the three different 75X75 bitmap images are used as watermark.

Figure 5: Watermark images

To investigate the robustness of watermark schemes, each watermarked image is attacked using JPEG compression, Gaussian noise, Salt and Pepper noises, Gaussian filter, and geometrical attacks like image cropping and scaling. It has been found that the proposed method provides a very high degree of invisibility with a high robustness values. The method works very well with the different types of noise attacks. Extensive experiments were conducted in [1], [2] for standard test images and in [3] and [7] for medical test images. So the results are compared against their results.

Figure 6. gives the comparision of original and watermarked images for Peppers, Mandrill, Lena, Barbara. And in Figure 7 a same type of comparision of proposed method is performed on three medical images i.e. kidney, skull and chest-1. The test images used are of 512x512 dimensions.

Mandrill.png



Lena.png

Barb.png

Boat.png

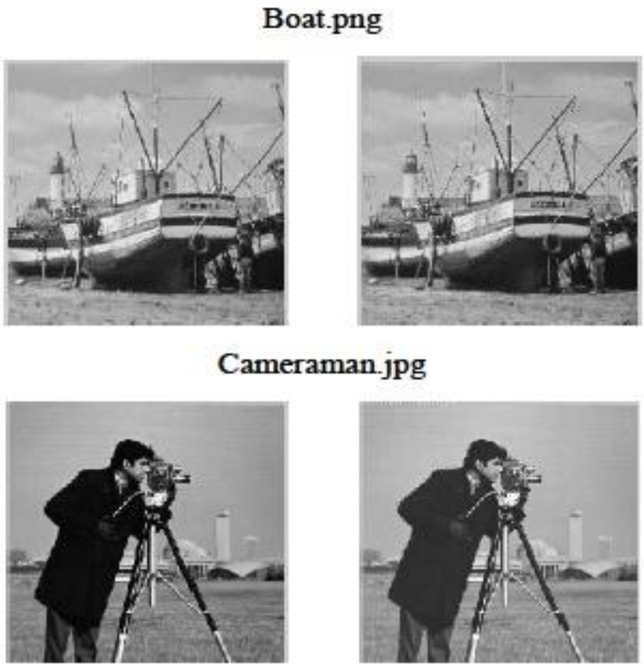


Figure 6:Original image (Left) and Watermarked (Right)

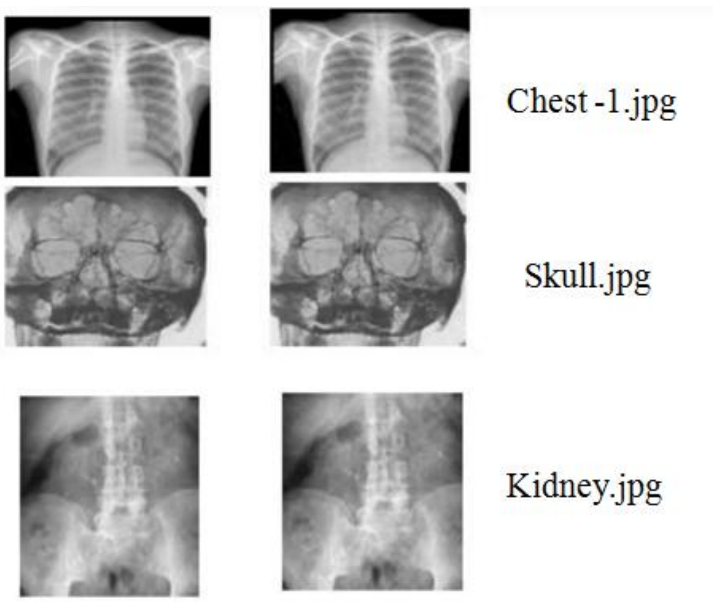


Figure 7:Original image (Left) and Watermarked (Right)

Table 1. gives the comparision of proposed method with [1]GA and[2]HPSO i.e. Peppers, Mandrill, Lena, Barbara and the PSNR, Robustness measure are evaluated. And in Table2. a same type of comparision of proposed method with [4]GPSO and [7] Adaptive is performed on three medical images i.e. kidney, skull and chest-1. The test images used are of 512x512 dimensions.

TABLE I

PERFORMANCE COMPARISION BETWEEN THE PROPOSED METHOD AND AND METHOD PROPOSED IN [1] & [2]

Images	Methods	PSNR	NC
Pepper	HWT-GA-PSO	**67.97938**	0.97938
	[1]GA	41.03	0.9984
	[2]HPSO	54	.91
Lena	HWT-GA-PSO	**66.6646**	0.99076
	[1]GA	43.34	0.9991
	[2]HPSO	53	.9

Barbara	HWT-GA-PSO	**61.6837**	0.99093
	[1]GA	42.47	0.9982
	[2]HPSO	NA	NA
Mandrill	HWT-GA-PSO	**65.6003**	0.9984
	[1]GA	41.04	0.999
	[2]HPSO	NA	NA

TABLE III
COMPARISION OF PSNR VALUES FOR VAIOUS MEDICAL IMAGES

Images	Methods	PSNR	NC
Chest-1	HWT-GA-PSO	**90.97611**	0.97938
	[3]GPSO	52.298	0.9984
	[7]Adaptive	51.69	NA
Kidney	HWT-GA-PSO	**76.6673**	0.99076
	[3]GPSO	51.677	0.9991
	[7]Adaptive	51.54	NA
Skull	HWT-GA-PSO	**71.6673**	0.99093
	[3]GPSO	51.752	0.9982
	[7]Adaptive	51.53	NA

TABLE IIIII
COMPARISION BETWEEN ROBUSTNESS FOR VARIOUS NOISE ATTACKS.

Kind of Attack		Method	Kidney	Chest-1	Skull
Salt and pepper	Den = 0.001	HWT-GA-PSO	**0.9904**	**0.98204**	**0.94773**
	Den =0.001	[3]GPSO	0.998	0.919	0.998
	Den =0.001	[7]Adaptive	0.99	.99	.99
	Den = 0.01	HWT-GA-PSO	**0.97084**	**0.97049**	**0.93849**
	Den = 0.01	[3]GPSO	0.968	0.842	0.967
	Den = 0.01	[7]Adaptive	.90	0.84	0..90
Gaussian Noise	Var =0.001	HWT-GA-PSO	**0.85849**	**0.8464**	**0.89476**
	Var =0.001	[3]GPSO	0.997	0.842	0.996
	Var =0.001	[7]Adaptive	0.99	.99	0.99
	Var =0.005	HWT-GA-PSO	**0.80551**	**0.88284**	**0.72693**
	Var =0.005	[3]GPSO	0.642	0.817	0.800
	Var = 0.001	[7]Adaptive	0.55	0.54	0.56

VI. CONCLUSIONS

In all of the watermarking algorithms imperceptibility of the watermark is very important. The HWT-GA-PSO based method shows promising results for high imperceptibility by high PSNR values with and without attack. Watermark is highly robust for noise attacks. Further, experimental results have shown better performance of the proposed method as compared with the current approaches in practice. The proposed method is highly imperceptible and robust against different attacks like gaussian filter, median filters, blurring, contrast, JPEG compression and SPHIT compression. It has been found that the proposed method works well with various types of standard image processing database images as well as standard medical images In future we propose to apply the proposed method for Video and audio Watermarking.

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