A Secure Transmission of Medical Images over Wireless Networks using Intelligent Watermarking

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Abstract: In wireless and general communication networks, Illegal data access has become ubiquitous. Requirement for protected transmission of medical images as telemedicine and e-health is progressively more being used. Wireless networks have been regularly more used together inside hospitals and at patient homes to broadcast medical information. Patient information is very important to secure. In general, wireless networks endure from decreased security. However, digital watermarking can be used to secure medical information. In this paper, we have proposed an adaptive and optimal watermark method for brain magnetic resonance images. First we have used segmentation to extract region of interests (ROI). Patient information and hospital logo has been used as a watermark and embedded in the non region of interest part so that ROI remain same after embedding watermark. Watermark has been embedded in the Discrete Wavelet Transform (DWT) domain. Particle swarm optimization (PSO) has been used to optimize the strength of watermark intelligently. PSNR and SSIM have been used for quantitative measures of imperceptibility and presented in experimental results. Results show better robustness and imperceptibility than the existing methods.
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1. Introduction

It is extremely enviable to access and share data among medical workforce thorough wireless networks for health care of a patient. However, illegal data access poses a great threat on the privacy of patient's information, when digital images are transmitted over a public network. In such a scenario, to protect the privacy of information, encryption of the medical images is very important. Sensitivity to early environment and have power over parameters has led to the progress of chaos-based encryption and decryption algorithms [1, 2].

A similar force, usually including watermarks entire image in the regional distribution of the original image, and include the watermark is not being diligent. However, this kind of watermark embedding, the number of objects in the image appear undesirable solids can support for even more insight noise in the image, and therefore more often, because it is these variables in this field. To reduce these differences should be reduced strength of the watermark in the general area. However, the sustainability of the loss or potential presence of pretentious is the critical factor. So the watermarking strength selection is the tradeoff between imperceptibility and robustness [5,6,7].

In figure 1, we can see that information has to transfer from different places to other places. Like if a patient lies at home and some scan has been performed at his home, then those scans needs to transfer to some healthcare centers or medical experts. Similarly patient information can also be transferred to some physician or diagnosis systems to check the disease.

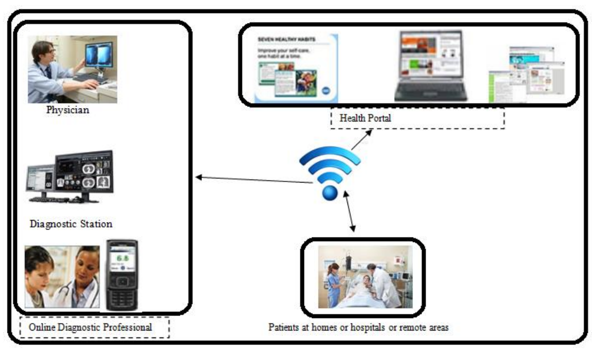


Figure 1: Architecture of e-health System

There are some online diagnosis professionals available so also there is also need to transfer information from one place to other. So now a days these transferring could be possible through wireless communication. But wireless communication is not secure place to transfer these types of information. Thus there is a need of some method that hide these information secretly. It also save the requirement of streams to transfer information. If transfer images, patient information then there are needs of two different streams like one for patient information and other for images or may be videos. So there is also need a method that can combine all these different types of information into single source and thus required less streams to transfer data. In this paper, we have proposed an adaptive and optimal watermark method for brain magnetic resonance images. First we have used segmentation to extract region of interests (ROI). Patient information and hospital logo has been used as a watermark and embeded in the non region of interest part so that ROI remain same after embedding watermark. Watermark has been embedded in the Discrete Wavelet Transform (DWT) domain. Particle swarm optimization (PSO) has been used to optimise the strength of watermark intelligently. It is less perceivable to the human visual system.

Organization of the paper is given as follows. Particla Swarm optimizations presented in section 2. Proposed methods has been discussed in section 3. Section 4 and 5 contains the implementation details and results discussion. At the end conclusion has been presented in the section 6.

2. Particle Swarm Optimization (PSO)

Kennedy and Elberhart [8] proposed Particle swarm optimization (PSO) that is an evolutionary computation facsimile. It is stimulated by the actions of fish schooling or bird flocking. PSO is an optimization course of action like other optimization technique such as Genetic Algorithm (GA). A swarm is defined as a set of mobile agents that cooperatively carry out a disseminated problem solving. In a swarm each particle keeps pathway of its own attributes. Initially a population of particles is generated randomly and then the search for optima is performed iteratively. Each particle has a velocity and a position vector is associated with it. The velocity and position vector of the ith particle in the m-dimensional search space can be represented as Vi = (vi1, vi2, …, vim) and Xi = (xi1, xi2, …, xim) respectively. The best position value encountered by each particle represented as Pit = (pi1, pi2, …, pim) and is known as personal best position. The global best particle is the best particle in the swarm at time t. It is represented as Pgt = (pg1, pg2, … , pgm). The new position of the particle in the search space can be computed using following equation. [9].

$$x^i_{t+1} = x^i_t + w_t v^i_t + c_1 r_1 (p^i_t - x^i_t) + c_2 r_2 (p^g_t - x^i_t)$$

Where w is the inertia weight, c1 is the cognitive parameter and c2 is the social parameter, r1, r2 are random numbers uniformly distributed in the interval [0, 1]. The particle's new position is calculated according to Eq. 1. The new position of the particle depends on its previous position, the distance between its current position and its own best position found, and the collaborative effect of the particles. Each particle has cooperation with all particles so that they can share information.

3. Methodology

For segmenting the MR image accurately, the Digital watermarking is the procedure of embedding any information within the digital media like text, image, audio, video etc with some miniature modifications. Since we are only focusing on image watermarking, therefore our watermarked image should endure some frequent image processing as well as forgery attacks. In the proposed method patient information and hospital logo are worn as a watermark. Watermark is embedded in the selected coefficients of the dwt image. In my proposed method, PSO has been used to select the strength of the watermark. In PSO, every particle can be represented one complete solution. In my proposed method, the particle is the strength of watermark for each selected co-efficient.

The following subsections describes the detail of the major components one by one.

3.1 Segmentation of Region of Interest

First, we have proposed a method for the segmentation of region of interests. We have used fuzzy entropy based thresholding method for segmentation of region of interests (ROI) and background. Background has been used to embed watermark information. Watermark consists of patient information and hospital logo. M. Stella and Blair [10] presented a method which performs automatic segmentation of the Brain from MR images. This method has been used for skull removal from whole brain MR images. It plays an important role for the segmentation of tumor from MR images. It is also used for the brain portion extraction from MR images. It is very helpful for this purpose. So after the extraction of this brain portion,, tumor have to be extracted from the remaining portion. For this purpose, fuzzy logic has been used that will calculate segments in the remaining part and based upon those segments, tumor can be extracted. It also help to calculate automatic threshold which is also optimal. This method is very important for tumor extraction and threshold calculation. In fuzzy logic, there are many different versions available. But I have used a special method that is known as fuzzy c-mean algorithms. It also find out accurately segments in the images. It helps to calculate optimal segments and also the threshold to separate those segments. Thus, by using this FCM, segmentation of tumor has been done in proposed method. For Thresholding, fuzzy entropy has been used. This fuzzy entropy based upon the fuzziness of FCM and use membership matrix of FCM. It calculate the best threshold by choosing the best point at which Thresholding can be selected for tumor extraction. I have converted first image into signle vector, and then give input to the FCM. It gives the membership matrix that can be used further to calculate threshold. By using this membership matrix, entropy of these different segments can be calculated by iterating it many times and then select the best number of segments at which that entropy is maximum [12]. Figure shows the results of all experimentations. We first perform separation of ROI and background and then perform watermarking in background area of the original image.

3.2 Watermark Embedding Process

In this phase, patient information and hospital logo as the watermark V is inserted into the background image I of size M x N. Watermark embedding algorithm is as follows:

The main steps to embed the watermark are:

Step 1: Wavelet Transform: For a selected image M of same height and width, discrete wavelet packet transform will be app\lied up to l levels. This will produce 4l sub bands of wavelet packet coefficients. Each resulting sub band consists of coefficients with the resolution of size m = M/4 l/2

Mathematically, DWT and IDWT can be stated as follows. Let

$$H(\omega) = \sum_k l_k \,.\, e^{-jk\omega} \quad (1)$$

$$G(\omega) = \sum_k h_k \,.\, e^{-jk\omega} \quad (2)$$

be a low pass and high pass filter respectively. A signal can be decomposed as

$$f_{j-1}^{low}(k) = \sum_n h_{n-2k}\, f_j(n) \quad (3)$$

$$f_{j-1}^{high}(k) = \sum_n g_{n-2k}\, f_j(n) \quad (4)$$

for where is the index of highest resolution level and is the index of the low resolution level. The coefficients

$$f_{J_0}^{low}(k), f_{J_0}^{high}(k), f_{J_0+1}^{high}(k), \ldots, f_J^{high}(k)$$

are called the DWT coefficients of the given signal , where is the approximation sub-band of the given signal and are the details of at various bands of frequencies. The given signal can be reconstructed from its DWT coefficients as

$$f_j^{low}(n) = \sum_k h_{n-2k} \,.\, f_{j-1}^{low}(k) + \sum_k g_{n-2k} \,.\, f_{j-1}^{high}(k) \quad (5)$$

To ensure the relationship between DWT and IDWT given in equation (5), the following orthogonality condition on the filters and given in equations (3) and (4) is needed.

$$|H(\omega)|^2 + |G(\omega)|^2 = 1 \quad (6)$$

Step 2: Energy Calculation: By using the equation mentioned below, energy for each resulting sub band will be calculated:

$$H = \frac{1}{m\ x\ m} \sum_{\mathrm{i}=1}^{\mathrm{m}} \sum_{\mathrm{j}=1}^{\mathrm{m}} J^2\,(\mathrm{i},\mathrm{j}) \quad (7)$$

Where energy is indicated by H, the size of the matrix of sub band is indicated by m x m. J is the value of the coefficient of discrete wavelet packet transformed.

Step 3: Watermark Generation: we have two things hospital logo and patient information history to embed as a watermark:

First we read the hospital logo and using optimal threshold method, convert this logo image into binary image. Then, we have applied BCH encoding to encode it and call it vector V1.

We read the patient information and convert into its corresponding ASCII code and then into its corresponding binary code. Apply the BCH encoding on it and call it vector V2.

Now concatenate all the watermarks VI and V2 and call it V, which is the resultant watermark to be embedded into the host image.

Step 4: Watermark Embed: In each block, only one bit is inserted. On the value of the bit, either 1 or 0, the fastidious block of reference image is added to block of selected sub band by using the following equation:

$$b'_{i,w} = \begin{cases} b_{i,w} + \alpha R_w & if\ s = 0 \\ b_{i,w} - \alpha R_w & if\ s = 1 \end{cases} \quad (8)$$

Here denotes the strength given to the block during watermark embedding and s is the watermark bit. Strength has been calculated using PSO. Detail is given below.

Step 5: Termination Criteria: When the watermark is completely embedded in the selected sub bands, the iterations for watermark embedding stop.

Step 6: To convert the watermarked image in pixel domain, the inverse discrete wavelet packet transform is applied.

3.2 Watermarking Strength Level (α)

Step 1: The coefficients for embedding are selected by performing Just Noticeable Difference ( ) threshold and Watson perceptual Model [13] for each coefficient in HL, LH and HH bands after converting into wavelet domain.

Step 2: Then PSO is initialized. Following steps are performed for each particle of PSO.

A single particle consists of the watermarking strength for the selected frequency coefficients in wavelet domain. Fitness of each particle has been calculated. After then, the particle which has the highest fitness values has been selected and known as glocal best particle. Then position of local best and other particles has been updated. Initially, for a swarm size of 50 particles and 5000 iterations

Step a: Watermark is embededded in the middle frequency bands. For this purpose, the first L coefficients selected in step 1 are left and the watermark is embedded into the next L+M coefficients. Suppose the first L+M coefficients are:

$$C = \{c_1, c_2, \ldots, c_L, c_{L+1}, \ldots, c_{L+M}\}$$

And the pseudo-random watermark is

$$W = \{w_1, w_2, \ldots, w_M\}$$

The updated coefficients obtained after embedding are

$$\tilde{c}_{L+i} = c_{L+i} + \alpha_i |c_{L+i}| w_i$$

where α is the watermarking strength and i has values from 1 to M-L, i.e. the no. of coefficients selected after first L coefficients. The strength is taken from the particle of the PSO algorithm.

Step b: Then inverse DWT on these modified coefficients has been performed.

Step c: Calculate the fitness of each particle again so that the local best particle and global best particles can be obtained.

Step 3: Repeat steps a-c until the termination criteria is achieved.

3.3 Digital watermark detection process

The detection process is as follows.

1) I have to convert given image till k level by using discrete wavelet packet transform. For this purpose just transform the input image into wavelet domain. As a results, there will be total 4*k sub bands after converting into transform domain.

2) After converting into sub bands, these sub bands can be used for selection.

3) After that, select an image that can be used as a reference. This image will be divided into further sub blocks of 4 x 4.

4) Then for retrieving the watermark information, correlation of the reference image sub block and the corresponding sub block of sub band will be calculated by using the following equation:

c=(1/4x4)R_j.b_(i,k) (9)

After that the recovered watermarked bit is selected as follows:

$$b'_{i,j} = \begin{cases} 0 & if\ c \geq 0 \\ 1 & if\ c < 0 \end{cases}$$

5) To attain the information of patient the steps that were used in the watermark production are applied in turn around
manner. The host watermarked image is converted into its equivalent discrete wavelet packet transform domain. To get the best value for strengthening the watermark embedding, here PSO is used. Then watermark is injected in the host image according to the equation explained above. To check the quality of the watermarked image, Peaks Signal to Noise Ration and Mean Squared Error are used. Normalization coefficient is used to measure the robustness of the image.

The block diagram of watermark detection is shown in Figure 3.

4. Implementation Details

PSO has been used for watermark strength selection. It shows better performance in this case. IT provides good optimal strength. The global best particle after 1000 iterations is then copied and it is used for watermark embedding purpose. Mean Squared Error (MSE) and Peak Signal to Noise Ratio (PSNR) as provided below are used to find and check the perceptual imperceptibility of the watermarked image. PSNR is used as the fitness function to evaluate each particle.

$$MSE = \frac{1}{MN}\sum_{m=0}^{M-1}\sum_{n=0}^{N-1}[I(m,n) - I^{'}(m,n)]^2 \tag{10}$$

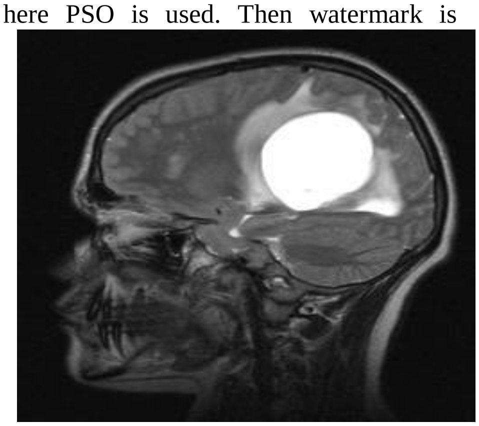
$$PSNR = 10\log_{10}\left(\frac{(I_{MAX})^2}{MSE}\right) \tag{11}$$

Where I is the original image, I' is the watermarked image IMAX is the maximum possible value of the image I. For every particle, lowest strength of the watermark MSS is calculated. MSS can be calculated using eq. 10.

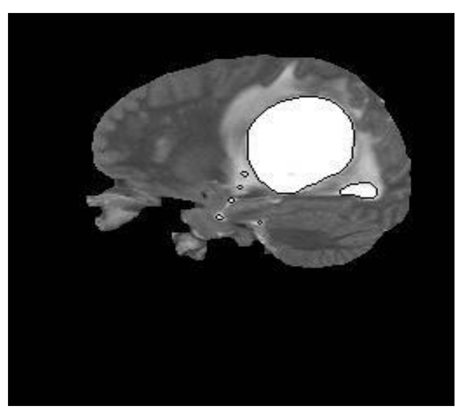
5 Experimental Results And Discussion

A. Segmentation of Region of Interests

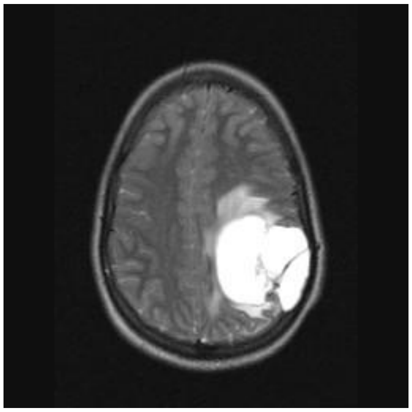
Segmentation of ROI from background results has been shown below. It shows that ROI is fully separated from background.



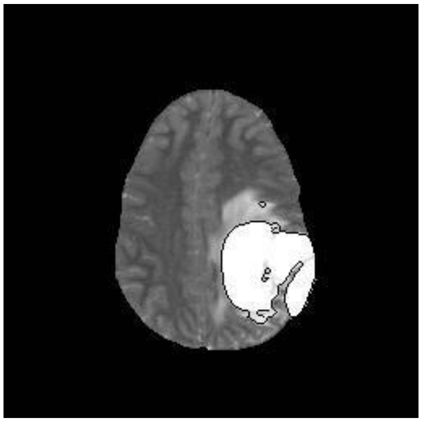
a. Original MR Image



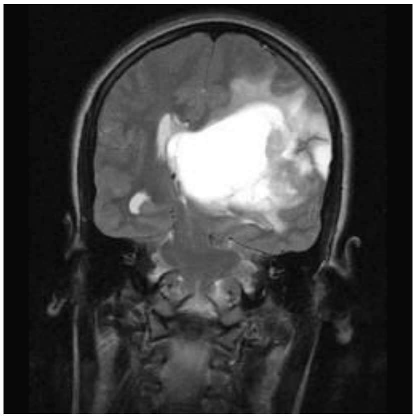
b. Tumor Extracted Region



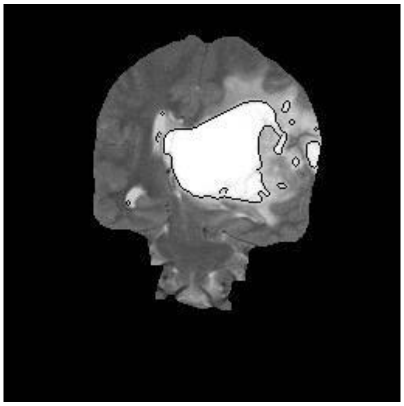
c. Original MR Image



d. Tumor Extracted Region

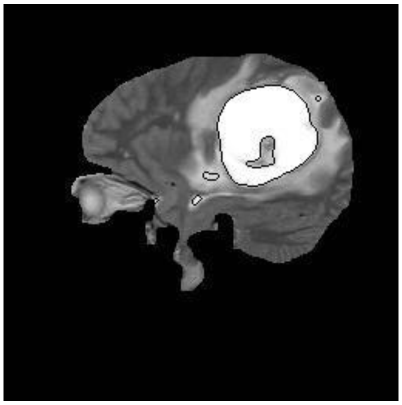


e. Original MR Image

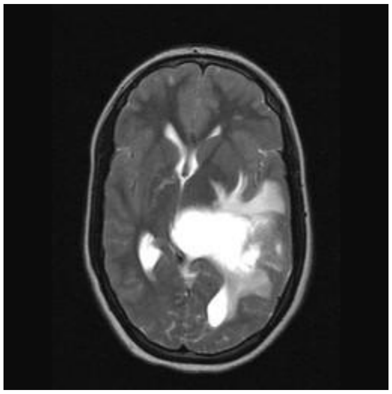


f. Tumor Extracted Region

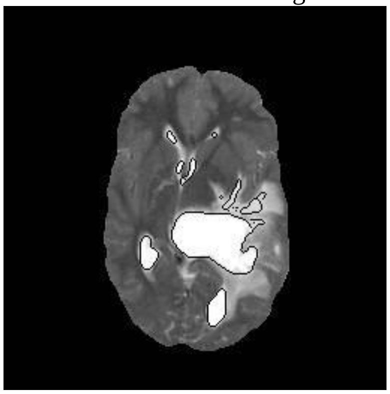
g. Original MR Image



h. Tumor Extracted Region



i. Original MR Image



j. Tumor Extracted Region

B. Watermark embedding:

We used the background area of brain MRI images as the cover image. Extracted ROI images are shown in Fig 2. Using PSO the watermarking strength for each DWT coefficients are optimized. The optimized strength is between the interval [0, 1]. We have compared our results with B. Sikander et al., [14]. The comparison table is shown below as table 1.

MSS is the Mean Squared Strength of the watermark here. This can be calculated by using this below formula.

$$MSS = \frac{1}{G}\sum_{i=1}^{G}\alpha_i^{\,2} \qquad (10)$$

Table 1: Comparison of the proposed methods with other techniques

Test Images		MRI1	MRI2	MRI3	MRI4
Proposed method	PSNR	47.2031	47.3521	**46.2512**	47.2510
	SSIM	0.9915	0.9951	**0.9943**	0.9912
B. Sikander et al. [14]	PSNR	46.351	45.732	44.315	44.1391
	SSIM	0.9901	0.9905	0.9912	0.9898

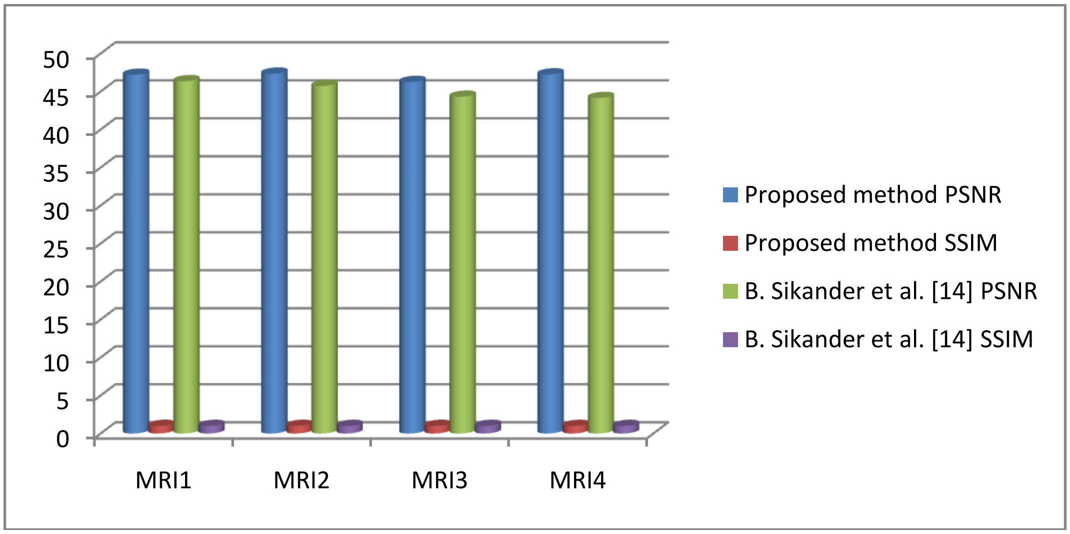


Figure 3: Comparison Results using PSNR and SSIM

Table 2: Minimum Mean squared strength (MSS) for images

Image	Minimum MSS
MRI1	0.0476
MRI2	0.0476
MRI3	0.0475
MRI4	0.0478
MRI5	0.0520

Even though embedding higher average strength watermark the PSNR and SSIM of my proposed method discussed above are better than [14]. The reason of better of my method is that I have chosen better watermark strength for every coefficient. The comparison results are given in Table 1. I have used the lowest threshold for the MSS for test images is given in

C. Watermark detection:

Correlation has been used for this purpose.

The uppermost correlation value is measured as the one that shows the original watermark which is used during the embedding process. For test image MRI1 the detected watermark is shown below:

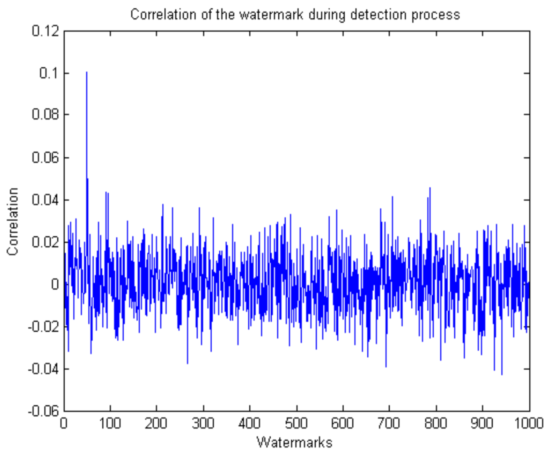


Figure 3: Watermark detected for MRI image

Table 3: Comparison of the system under different attacks for MRI1 image and results comparison with [14]

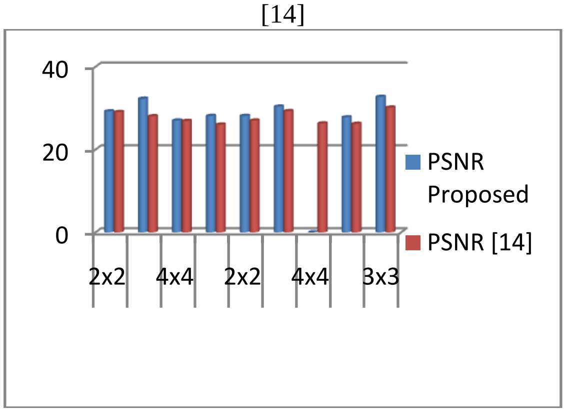


Figure 4: Comparison Results after filters attacks

6. Conclusion and Future Work

I have proposed an adaptive watermark method for brain magnetic resonance images that can be used to secure medical information. First we have used segmentation to extract region of interests (ROI). Patient information and hospital logo has been used as a watermark and embedded in the non region of interest part so that ROI remain same after embedding watermark. Watermark has been embedded in the Discrete Wavelet Transform (DWT) domain. Particle swarm optimization (PSO) has been used to optimize the strength of watermark intelligently. Detail experiments have been presented in section 4. For quantitative measures of imperceptibility PSNR and SSIM have been used. Results show better robustness and imperceptibility than the existing methods. In future we will test other methods for the strength optimization. Other optimization methods can be investigated that will be helpful for optimizing imperceptibility and robustness.

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