Development Of A New Watermarking Algorithm For Telemedicine Applications

Remya Elizabeth Philip[1], Sumithra M.G.[2],
PG Student[1], Professor of ECE Department[2]
Bannari Amman Institute of Technology.

Abstract-

Watermarking algorithms are used for embedding watermark like patient's history and doctor's signature in binary image format into host's medical image for telemedicine applications. In this work the watermarking of medical image is done in DCT and DWT domains and the performance is evaluated based on PSNR and MSE. From the obtained results it is observed that the watermarking in wavelet domain using Haar wavelet yields better result than in DCT domain.

Keywords: *Watermark, DWT, DCT, PSNR, MSE*

I.INTRODUCTION

The Institution of Medicine defines telemedicine as the use of electronic information technologies to provide and support health care when distance separates the participants. The most common application today is in the transmission of high resolution X-rays, cardiology, orthopedics, dermatology and psychiatry. Telemedicine arose originally to serve rural populations or any people who are geographically isolated, where time and cost of travel make access to the best medical care difficult. Now it is increasingly being used in mainstream medicine, to allow doctors the world over to share expensive recourses and valuable experience. Hence, healthcare industry demands secure, robust and more information hiding techniques promising strict secured authentication and communication through internet or mobile phones.

Medical image watermarking requires extreme care when embedding additional data within the medical images because the additional information must not affect the image quality as this may cause a misdiagnosis [7]. This kind of a system requires a high level of security, which can be ensured by using digital watermarking techniques. This imposes three mandatory characteristics: robustness, capacity and imperceptibility. There are different methods that has been using for medical image watermarking. The watermark can directly be embedded in the LSB as described by Mohamed Ali et al [14], [7]. In some applications it is often not allowed to alter the image contents even one bit of information. The requirement of imperceptibility can be satisfied by two methods (1) by selecting region of non interest (RONI) watermarking which embeds the watermark information in RONI and keeping the region of interest (ROI) distortion free, and (2) by selecting reversible watermarking method which recover the original cover image by undoing the watermark embedding process at the receiving end after the image verification process is completed [3], [12].

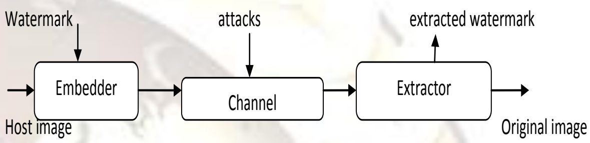


Fig. 1 A generic watermarking system model

In this generic watermarking model shown in Fig.1, there is a watermark embedder which embeds the information that is to be hidden (the watermark) in the original image (cover image) and the watermarked image is sent through the channel where there is a large probability of attacks such as removal attack, geometric attacks, cryptographic attacks, protocol attacks. At the receiver side there is an extractor which extracts the watermark from the stego image.

Digital image watermark techniques can also be classified based on the type of information needed in the extraction process. Using this classification criterion, it can be classified into two categories; non-blind and blind watermarking. A non-blind watermarking system requires the host image and the watermarked image in order to detect and extract the watermark data, but on the other hand, a blind watermarking system requires nothing other than the watermarked image itself to complete the process. In dealing with watermarking of medical images, some important constraints need to be satisfied. When watermark is embedded in the host image, it generates distortion. This distortion is highly undesirable in medical applications, whereby, even a small distortion in the images such as MRI and X-ray images might affect the decision of a physician. For this reason, it is necessary not only to extract the watermark but also to restore the original image completely. Reversible watermarking fulfills this requirement. It can restore the exact state of the original image. Whereas non reversible watermarking algorithms do not provide the exact reconstruction of the image

II. PROPERTIES OF MEDICAL IMAGE WATERMARKING

Security of medical information, derived from strict ethics and governmental rules, gives rights to the patient and duties to the health professionals. This imposes three compulsory characteristics: robustness, imperceptibility, capacity. Robustness is defined as the ability of watermark to resist against both lawful and illicit attacks. One of the stringent requirements of the image watermarking is the imperceptibility. Imperceptibility means that watermark embedded in the image must be invisible to the human eye. In watermarking of medical images, all the information necessary for physician such as identification of patient, diagnosis report, origin identification (who created the image) are embedded. This information is further increased when the image is sent to other physician for second opinion. Therefore, capacity for embedding the payload must be high.

Based on the domain in which the watermark can be embedded, the watermarking techniques are classified into 2 categories: spatial domain techniques and transform domain techniques. The most clear cut way to hide the watermark within the cover content is to directly embed it in the spatial domain. There is number of advantages for using spatial domain watermarking. One advantage is temporal or spatial localization of the embedded data can automatically be achieved if the watermarked content undergoes some attacks and distortions are introduced in the watermarked content. Another advantage of spatial domain watermarking is that, an exact control on the maximum difference between the original and watermarked content is possible which allows the design of near-lossless watermarking systems, as required by certain applications such as protection of sensing or medical images. The oldest and the most common used method in this category is the insertion of watermark in the least significant bit of the pixel data [1], [14]. Since the modification of the pixel data takes place in the LSB it is not visually perceptible. To obtain better imperceptibility as well as robustness, watermarking is done in frequency domain. The frequency domain watermarking techniques are also called multiplicative watermarking techniques. Discrete Fourier Transform (DFT), Discrete Cosine Transform (DCT) [14], Discrete Wavelet Transform (DWT) [5] is the most popular transforms operating in the frequency domain etc then the transform domain coefficients are modified by the watermark, [1], [10]. The inverse transform is finally applied in order to obtain the watermarked image. Due to complicated calculations of forward and inverse transform the spatial domain techniques are less prone to attacks.

III. METHODOLOGY

The various steps for embedding and extracting the watermark in DCT and DWT domain are given below

Steps for applying watermark

1. Read the CT image(cover image)
2. Read the signature (watermark)
3. Fix the alpha value to 1 (alpha=1)
4. Multiply the alpha value with the sign
5. Take the transform for the image(DCT/DWT)
6. Add the watermark into the cover image
7. Take the inverse transform to get the watermarked image
8. Calculate the MSE and PSNR between the original and watermarked image
9. Increment the alpha value and repeat the steps from 4 to 8

Steps for extraction process

1. Read the stego image (watermarked image)
2. Take the transform for the image(DCT/DWT)
3. Read the signature
4. Divide the signature by the alpha value
5. Subtract the signature from the watermarked image
6. Take the inverse transform
7. Reconstructed image is obtained
8. Calculate the PSNR and MSE of the original and recovered image and the original and retrieved watermark

IV. PERFORMANCE EVALUATION PARAMETERS

For evaluation of the watermarking algorithm, many criteria's are used. The most important among them are the quality of the image and the robustness of the watermarking scheme against various attacks.

- *Signal to noise ratio and peak signal to noise ratio*

Among the most important distorting measures in image processing is the Signal to Noise Ratio (SNR) and the Peak Signal to Noise Ratio (PSNR).The SNR and the PSNR are respectively defined by the following formulas:

$$SNR = 10\log_{10}\left\{\left[\sum_{i,j}\frac{I^2(i,j)}{\sum_{i,j}[I(i,j)-K(i,j)]^2}\right]\right\} \quad (1)$$

$$PSNR = 20log_{10}\left(\frac{MAX}{MSE}\right) \quad (2)$$

MAX is the maximum pixel value in the image where MSE is given by,

$$\mathrm{MSE} = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[I(i,j)-K(i,j)]^2 \quad (3)$$

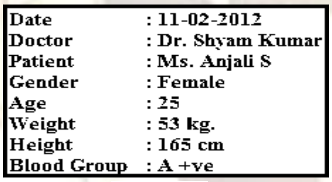
where I (i, j) and K (i, j) are original and watermarked image respectively.

V.EXPERIMENTAL RESULTS

A medical image (CT scan) 512×512 is taken as the test image; doctor's signature 60×100 and patient details 140×230 is taken as the watermark. Various experiments are conducted to develop an efficient watermarking algorithm. The first experiment is conducted to select the domain of watermarking. The watermark is first applied in the DCT and DWT domain and the performance is evaluated based on PSNR and MSE. It is found that DWT performs better than DCT, so the next step aims to find out which wavelet transform that can be used for the embedding purpose and also to find out the level of decomposition, for that three sets of mother wavelets are considered 'Haar', 'db2' and 'db4'. The result shows that Haar gives better performance compared to the others. Fig.2 represents the test image of size 512×512 and the watermarks. Watermark 1 of size 60×100 is the doctor's signature, and watermark 2 of size 140×230 is the patient detail. Watermark1 is used up to the selection of wavelet and for further analysis watermark 2 is used, these are embedded in the binary image format.

(a)

(b)



Date	: 11-02-2012
Doctor	: Dr. Shyam Kumar
Patient	: Ms. Anjali S
Gender	: Female
Age	: 25
Weight	: 53 kg.
Height	: 165 cm
Blood Group	: A +ve

(c)

Fig .2 (a) Test image (b) watermark 1(c) watermark 2

The results after applying the watermark in DCT for different pixel resolutions are found out. The PSNR values of DCT (8bit), DCT (16 bit) and DWT (first level decomposition) are given in table 1, table 2, and table 3.Table 1 shows the PSNR comparison of original and the watermarked image. From the table it is seen that the performance of DCT (16 bit) is better than DCT (8bit) and DWT outperforms both DCT (8bit) and DCT (16bit) for different alpha values, where alpha is the depth or weighing factor for the watermark.

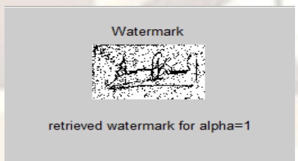
Table 1 PSNR comparison of original and watermarked image in different domains

Alpha	Domains		
	DCT (8bit)	DCT (16bit)	DWT
1	80.15	81.161	250
2	67.728	67.759	121.283
3	60.157	60.102	117.234
4	56.726	56.692	109.710
5	54.031	54.047	107.802

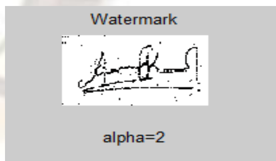
Table 2 PSNR comparison of original and retrieved signature in different domains

Alpha	Domains		
	DCT(8bit)	DCT(16bit)	DWT(8bit)
1	19.685	250	250
2	39.120	250	250
3	57.550	250	250
4	11.389	47.676	250
5	7.870	38.252	250

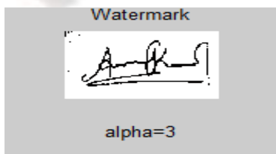
As the alpha value increases the PSNR value is getting reduced i.e. the quality of the image is getting reduced. In the case of DWT it is seen that the PSNR value is not that much reduced when the alpha increases. Table 2 shows the PSNR value of the retrieved signature. The performance of DCT (8bit) is poor when compared to DCT (16bit) and DWT. The original signature can be retrieved for all alpha values changing from 1 to 5 in the case of DWT where the PSNR is a high value of about 250 which does not shows any significant difference from the original image. In the case of DCT (16bit) signature can be retrieved without error only when the alpha values are 1, 2, and 3. For values alpha= 4 and alpha = 5 the image quality is reduced.



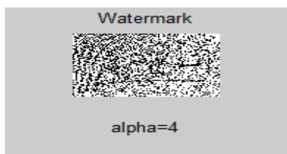
(a)



(b)



(c)



(d)

Fig.3 Retrieved signatures after the removal of watermark from DCT (8bit) domain for different values of alpha (a) alpha=1(b) alpha=2 (c) alpha=3 (d) alpha =4

Fig.3, fig.4 and fig. 5 show the retrieved watermark from DCT (8bit), DCT (16bit) and DWT respectively for different values of alpha. It is clear from the images that the watermark can be retrieved perfectly in DWT domain than in DCT domain.

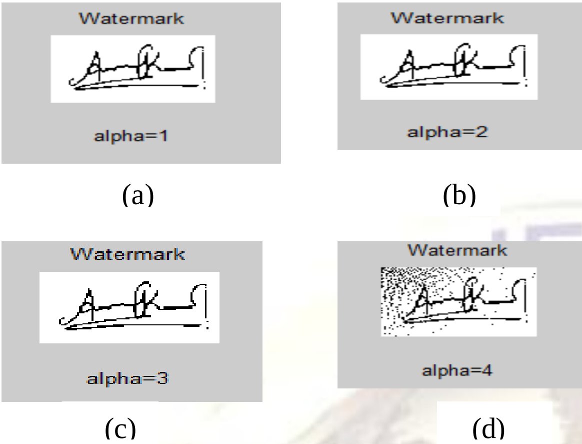


Fig.4 Retrieved signatures after the removal of watermark from DCT (16bit) domain for different values of alpha (a) alpha=1(b) alpha=2 (c) alpha=3 (d) alpha =4.

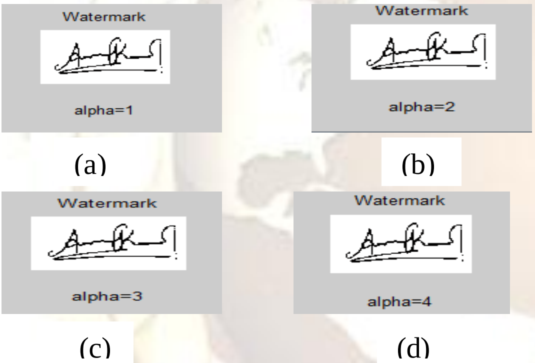


Fig.5 Retrieved signatures after the removal of watermark from DWT domain for different values of alpha (a) alpha=1(b) alpha=2 (c) alpha=3 (d) alpha = 4

For DCT (8bit) it is inferred from the fig.3 that, when the alpha = 3 the watermark can be retrieved with PSNR value 57.55. In the case of DCT (16 bit) shown in fig.4, it is seen that for alpha values 1, 2 and 3 the watermark is reconstructed with PSNR values 250, that is the original watermark is perfectly reconstructed. From fig.5 it is seen that the watermark can be retrieved perfectly for all values of alpha i.e.in this case the watermark is embedded in the DWT domain. Table 3 shows the PSNR variation of the original and reconstructed image. From the table it is clear that the image quality is high for DWT when compared to DCT. MSE is calculated for watermarking in different domains, it is found that the mean square error will be less for DWT as compared to DCT (8bit), DCT (16bit) i.e. the fig.6 to fig.8 shows the MSE of DCT (8bit), DCT (16bit) and DWT.

Table 3 PSNR comparison of original and retrieved image in different domains

Alpha	Domains		
	DCT(8bit)	DCT(16bit)	DWT
1	146.329	250	250
2	130.793	137.193	130.074
3	121.683	125.624	127.968
4	85.571	85.625	115.971
5	59.684	59.680	115.003

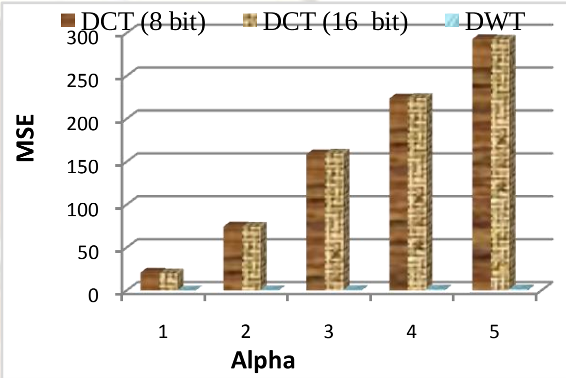


Fig.6 MSE comparison of original and watermarked image for different domains

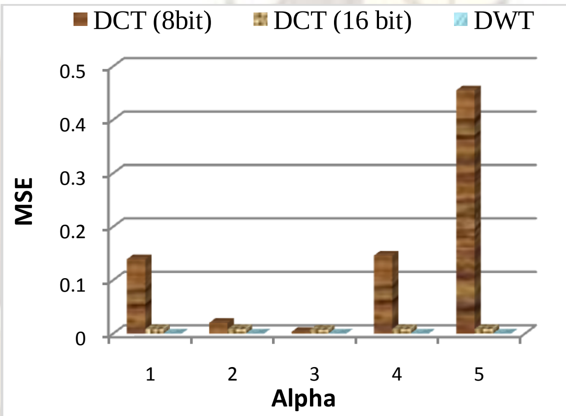


Fig.7 MSE comparisons of original signature and retrieved signature for different domains

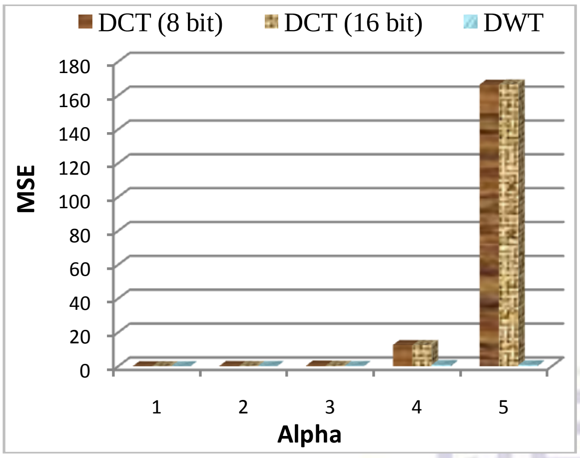


Fig.8 MSE comparison of original and retrieved image for different domains

From the above results it is clear that DWT performs much better than DCT (8bit) and DCT (16 bit). So DWT is taken as the domain for watermarking for further experiments.

As a second step, the type of wavelet that is to be used has to be determined, for that three types of wavelets are considered Haar, db2, db4. Out of this Haar is found to give better performance than the others while retrieving the original image and also while retrieving the watermark. Table 4 and table 5 show the PSNR comparison of original vs. watermarked image and original vs. retrieved image. It is clear from the table that the quality of the retrieved image will be high in the case of Haar wavelet than that of db4 and db2. Fig.9 and fig.10 shows the MSE variation for the different wavelet used. The MSE is high in the case of db2 when compared to db 4 and haar wavelet. Haar wavelet is having the least MSE.

Table 4 PSNR comparison of original and watermarked image for different wavelets

Alpha	Wavelets		
	Haar	db2	db4
5	107.802	99.625	101.484
8	96.238	90.115	91.838
15	84.591	78.85	79.45

Table 5 PSNR comparison of original and retrieved image for different wavelets

Alpha	Wavelets		
	Haar	db2	db4
5	114.996	111.113	114.579
8	105.074	103.211	104.159
15	93.559	90.033	91.475

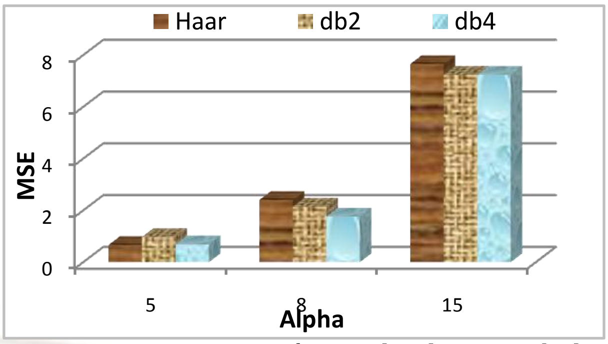


Fig .9 MSE comparison of original and watermarked image for different wavelets

Fig .11 to fig.13 shows the retrieved watermark for different wavelets, it is clear from the figure that the good quality watermark is obtained in the case of Haar wavelet, for db2 and db4 the image is degraded. For all the alpha values Haar wavelet is giving a good performance i.e. in all the cases the original watermark can be retrieved properly with a very good PSNR value. In the selection of wavelet only first level decomposition is considered and the watermark is embedded in the low frequency component.

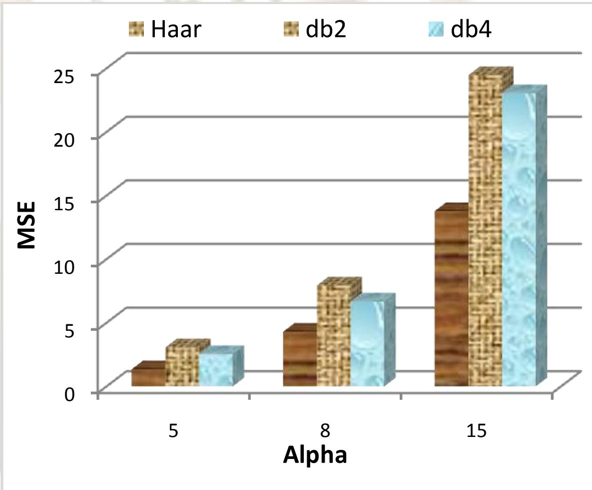
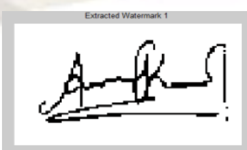
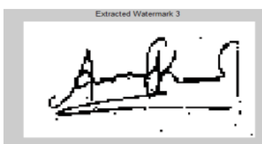


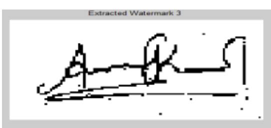
Fig.10 MSE comparison of original and retrieved image for different wavelet



(a)

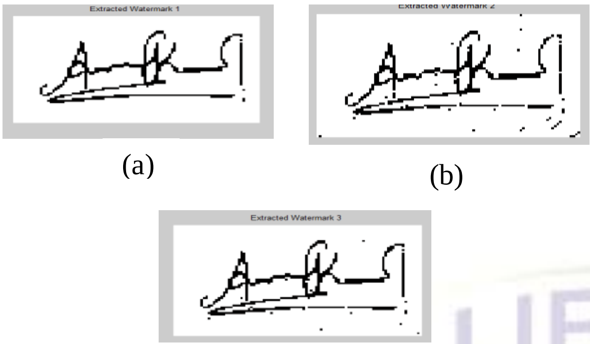


(b)



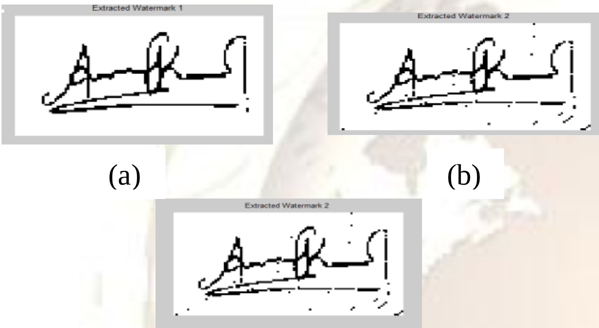
(c)

Fig. 11 Retrieved signature with alpha = 5 for different wavelets (a) Haar (b) db2 (c) db4



(a) (b) (c)

Fig. 12 Retrieved signature with alpha = 8 for different wavelets (a) Haar (b) db2 (c) db4



(a) (b) (c)

Fig. 13 Retrieved signature with alpha = 15 for different wavelets (a) Haar (b) db2 (c) db4

After selecting the wavelet, the watermarking is done for different decomposition levels of DWT, here the watermark used is the patient details as shown in fig .2 and it are found that level 3 decomposition gives better results when compared other levels. In the case of all other levels the retrieved watermark quality is degraded.

The watermark is retrieved perfectly when the alpha have some moderate values that is around 15. The comparison results of PSNR and MSE for alpha values 5, 8, 15 are shown in table 6 and 7 and fig 14 and fig.15 respectively. From all these results we can conclude that DWT using haar wavelet with a third level decomposition yields better result than DCT domain.

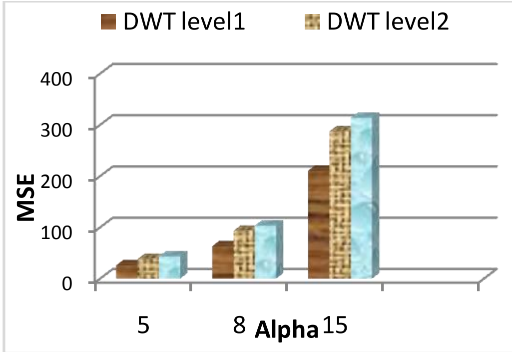


Fig.14 MSE comparison of original and watermarked image for different decomposition levels

Alpha	DWT level1	DWT level2	DWT level3
5	78.3340	74.435	73.191
8	69.389	65.485	64.439
15	57.336	54.221	53.341

Table 6 PSNR comparison of original and watermarked image for different decomposition levels

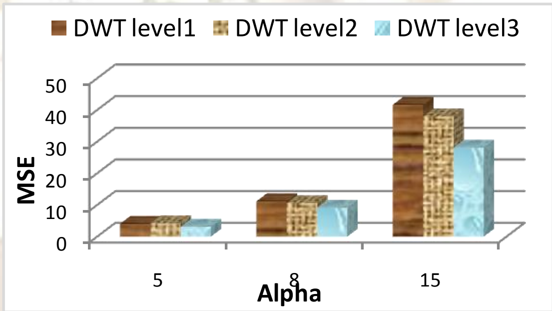


Fig.15 MSE comparison of original and retrieved image for different decomposition levels

Table 7 PSNR comparison of original and retrieved image for different decomposition levels

Alpha	DWT level1	DWT level2	DWT level3
5	85.9218	87.603	96.773
8	76.731	77.239	87.687
15	63.633	64.458	78.967

VI.CONCLUSION

The various features of watermarking algorithms are discussed in this paper. The performance evaluation of embedding the watermark in DCT and DWT domains is analyzed taking PSNR and MSE as the evaluation parameters. It is found that DWT using haar wavelet performs quite better than DCT. Secondly the watermark embedding in different decomposition levels is analyzed and found out that the third level decomposition gives better results, i.e. about 24% reduction in MSE is obtained for third level DWT as compared to first level and a decrease of 23% is obtained for third level compared to second level decomposition. While increasing the level of decomposition further the retrieved image gets distorted. The future work has to be extended by evaluating the robustness of the watermarking algorithm against different types of attacks such as geometric attacks, compression attacks and modify further.

REFERENCES

[1] I Cox , M Miller , J.Bloom ,J. Fridrich , T.Kalker,"Digital Watermarking and Steganography", 2nd Ed. ISBN: 978-0123725851
[2] Y. Lim, C. Xu, D. D. Feng, "Web-based Image Authentication using Invisible Fragile Watermark", Proceedings of the Pan-Syndney area workshop on Visual Information Processing, Vol. 11, pp. 31-34, Sydney Australia, 2001.
[3] A. Wakatani, "Digital Watermarking for ROI Medical Images by Using Compressed Signature Image", Proceedings of the 35th International Conference on System Sciences, Vol 10 pp. 24-28 2002.
[4] B. M. Plantiz, A. J. Maeder, "A Study of Block-Based Medical Image Watermarking Using a Perceptual Similarity Metric", Proceedings of the Digital Imaging Computing: Techniques and Applications (DICTA 2005), 2005.
[5] A. Giakoumaki, S. Pavlopulos, D. Koutsouris, "Multiple Image Watermarking Applied to Health Information Management", IEEE Transactions on Information Technology in Bio-Medicine, Vol. 10, No. 4, October 2006.
[6] W. Gang, R. Ni, "A Fragile Watermarking Scheme for Medical Images", Proceedings of the 27th IEEE Annual Conference on Engineering in Medicine and Biology Shangai China September 2005.
[7] R. Raul et al., "Hiding scheme for medical images", Proc.17th International Conference on Electronics, Communications and Computers, ,pp. 32-32 August 2007.
[8] C.R. Piao, D.M. Woo, D.C. Park, S.S. Han, "Medical Image Authentication Using Hash Functions and Integer Wavelet Transform", 2008 Congress on Image and Signal Processing, (CISP-2008),
[9] Sanya, Hainan, China, the27th IEEE Annual Conference on Engineering in Medicine and Biology, Shanghai, China, pp.1-4, 2005.
[10] F.Y. Shih, Y.T. Wu, "Robust Watermarking and Compression for Medical Images based on Genetic Algorithms", Journal of Information Sciences, Elsevier, Vol. 175, No. 3, pp. 200-216, 2005.
[11] V. Fotopoulos, M. L. Stavrinou, A. N. Skodras, "Medical Image Authentication and Self-Correction through an Adaptive Reversible Watermarking Technique", Proceedings of 8th IEEE International Conference on Bio-Informatics and Bio-Engineering (BIBE-2008), pp. 1-5, October 2008.
[12] H.-K. Lee, H.-J. Kim, K.-R. Kwon, J. K. Lee,"ROI Medical Image Watermarking Using DWT and Bit plane", Asia Pacific Conference on Communications, Perth, Western Australia, 3-5, October 2005.
[13] J. M. Zain, L.P Baldwin, M. Clarke "Reversible watermarking for authentication of DICOM images" Proc. of the 26th Annual International Conference of the IEEE EMBS San Francisco, CA, USA, September 1-5, 2004
[14] Mohamed Ali Hajjaji, Abdellatif, El-bey,"A watermarking of Medical Image: Method Based LSB", Journal of Emerging Trends in Computing and Information Sciences, Vol.2, NO.12, December 2011