Image Watermarking Using Slantlet Transform

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Abstract— **Watermarking robustness is one of the major characteristics that influence the performance and applications of digital image watermarking. For copyright protection, the watermarking robustness must be increased without significantly degrading the visual quality of the host image. For this purpose, a watermarking algorithm is proposed in this paper. The proposed algorithm is based on wavelet-like transform, known as Slantlet Transform (SLT). The basic idea is to decompose the original image using SLT; a binary watermark is then embedded in the high frequency sub-bands. The embedding process is done by modifying horizontal and vertical high frequency coefficients in a content-based manner. A comparison is made between the proposed embedding method and other embedding methods in terms of Peak Signal to Noise Ratio (PSNR). A second comparison is made for the proposed embedding method based on different transforms (i.e. SLT and DWT) in terms of PSNR. The Normalized Correlation (NC) value between the original watermark and the extracted watermark after applying different attacks is calculated to test the robustness of the proposed method. From the first comparison, the results show that the proposed embedding method yields better imperceptibility. The results of the second comparison demonstrate that the proposed algorithm can achieve better robustness and imperceptibility.**

Keywords-component; Digital image watermarking; robust watermarking; Discrete Wavelet Transform (DWT); Slantlet Transform (SLT); Peak Signal to Noise Ratio (PSNR); Normalized Correlation(NC).

I. INTRODUCTION

The use of information technology and the internet is increasing day after another. Nowadays it is convenient for people to transmit digital data and information through internet. However, there is a fear of using that information by unauthorized people like hackers. Security in digital communication is an important issue, digital watermarking is one of the methods used to protect digital information. Different applications can make use of digital watermarking; one of these applications is copyright protection.

Digital watermark is a pattern of bits inserted into a digital image, audio, or video file that identifies the file's copyright information. The watermark embedding is done by special designed algorithms. The basic requirements of watermarking techniques are: Imperceptibility, Robustness, Capacity and Security. The watermark will be imperceptible if the watermarking process does not degrade the visual quality of the host image and it will be invisible if the difference between the original image and the watermarked image cannot be distinguished. The robustness means that the original watermark has the ability to withstand image distortions and modifications. There are two types of watermarking attacks: signal processing attacks and geometric attacks. Many researches are carried out in the direction of increasing robustness against these types of attacks [1, 2]. After different attacks on the watermarked image, the watermark is distorted, but still can be extracted from the image. The capacity means the amount of the information that can be stored in an image. If more than one watermark is embedded into an image, then the capacity is the sum of all individual watermarks payloads. The security of watermarking process is necessary to resist malicious attacks, where a secret key is used to determine the value of the watermark and to decide the locations where the watermark is embedded.

Embedding watermarks can be done by changing the image pixels directly and this case is called embedding in the Spatial domain. Another domain can be used for embedding watermarks that is the Transform domain; in this case, the original image is pre-processed before embedding a watermark. The pre-processing involves converting the image to the desired domain such as Discrete Fourier Transform (DFT), Discrete Cosine Transform (DCT) or Discrete Wavelet Transform (DWT). In [3] a DFT-based digital image watermarking system was proposed for the purpose of copyright protection. The DCT was also applied in digital image watermarking systems, in [4, 5] the image is transformed using discrete cosine transform and the watermark was embedded in the frequency coefficients. The discrete wavelet transform typically provides higher image imperceptibility and more robust to image manipulations [6]. A large number of researches were directed towards image watermarking using wavelet transforms. As examples the robust image watermarking schemes based on wavelet transform were proposed in [7, 8]. A study of the effect of wavelet families on watermarking was done in [9].

In order to improve the performance of digital watermarking process, different transforms were used. In [10] a hybrid transform (DWT-DCT) was proposed to increase the robustness of common DWT and DCT methods. In [11] the Slantlet Transform (SLT) coefficients have been used instead of the wavelet transform coefficients for data embedding. It was confirmed through the experimental results that the application of the SLT gives better image quality of stego-images. In [12] the SLT was used for data compression. The comparison results with the DCT and DWT based approaches proved that the SLT gives better performance.

In this paper, we propose a watermarking algorithm based on Slantlet transform and a content-based embedding method. The purpose of the proposed method is to obtain better image quality and increase the robustness.

The organization of the paper is as follows. In section II, the SLT is introduced and its properties and features are outlined. Section III contains a comparison between wavelet transform and slantlet transform. In section IV, the algorithm of the proposed system is explained. Section V presents the results. The conclusion of the work is in section VI.

II. SLANTLET TRANSFORM

The discrete wavelet transform (DWT) can be implemented using filter bank iteration; however, this does not give a discrete-time basis that is optimal with respect to time-localization. For this reason, the Slantlet Transform (SLT) has been proposed in [13]. As explained by the author of [13], the SLT is an equivalent form of the DWT with two-zero moments and improved time-localization. The SLT filterbank is implemented in the form of parallel structure, different filters has been used for each scale instead of filter iteration for each level. The length of SLT filters is shorter than those of the equivalent DWT. Slantlet transforms scale dilation factor is exactly two while the DWT filters can approximately provide a scale dilation factor of two. The SLT filterbank implementation is done by considering the usual iterated DWT filterbank and an equivalent form [13], which is shown in Fig.1. The SLT filterbank shown in Fig. (1.c) is based on the second structure that is shown in Fig. (1.b) but it will be obtained by different filters that are not products. The filters can be calculated using the SLT equations that are derived in [13]. When the product form is not necessary it will be possible to design filters of shorter length while satisfying orthogonality and zero moment conditions [13].

The filters of the Slantlet filterbank for scale i are $g_i(n)$, $f_i(n)$ and $h_i(n)$ which analyze a signal the length of the filters for scale i will be proportional to 2^i. All the details are available in [13].

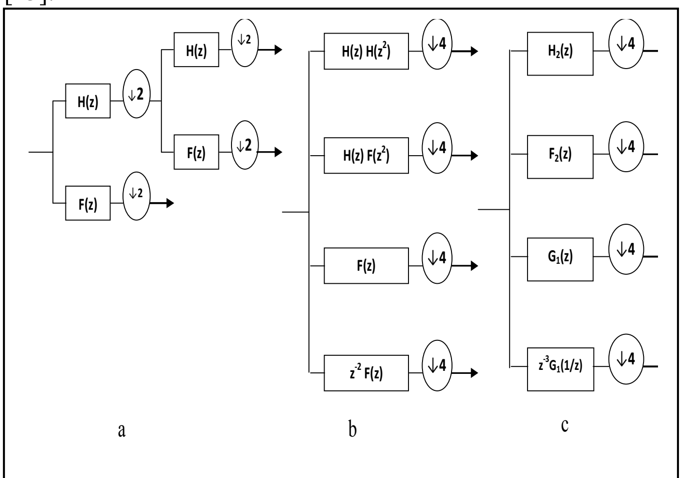


Figure 1. a. 2-scale iterated filterbank DWT. b. Equivalent structure of DWT filterbank . c. 2-scale SLT filterbank.

III. WAVELET VS SLANTLET

Wavelet transforms have been widely used in the areas of signal and image processing for de-noising, compression, feature detection, steganography and watermarking for the past several years. One of its inherent properties of multiresolution representation is akin to the operation of the human visual system (HVS). It offers a relatively efficient representation of piecewise smooth signals and is an efficient tool for the application that needs multiresolution analysis. It provides short windows at high frequencies and long windows at low frequencies. One of its disadvantages is that for a fixed number of zero moments, it cannot yield a discrete-time basis that is optimal with respect to time localization [14].

Selesnick [13] proposed Slantlet transform (SLT) in 1999, which can provide better time localization. The filterbank defined by him for SLT employs a similar parallel structure like DWT providing exactly a scale dilation factor of 2. Slantlet filters are piecewise linear filters which can be applied with shorter supports maintaining the features of DWT. Like DWT, Slantlet filters are orthogonal, provides octave-band characteristics and multiresolution decomposition. They also have the same number of zero moments like DWT [14]. Panda and Meher [12] have proved that the SLT is a better candidate for signal compression as compared to the conventional DCT and DWT based methods. They have observed that the SLT based algorithm can retain a higher percentage of energy after compression compared to the DWT approach.

SLT had been used in medical image processing for the classification of magnetic resonance (MR) human brain images. In [15] the Slantlet transform was applied to the intensity histogram signal for each 2-D MR image. After obtaining these feature vectors, they used a neural network based binary classifier to classify the image as an image from a normal brain or from abnormal brain. In [16] a Slantlet transform based method was presented for image fingerprints. In this paper, the phase information was extracted from Slantlet transform domain for image fingerprints. Better performance was verified in the experiments as compared to a previous method.

IV. RESEARCH METHODOLOGY

This section contains two parts. The first part describes the embedding method adapted from [17]. The second part explains the experiments carried out to verify the performance of the proposed algorithm.

A. Proposed embedding and extracting method

1) Watermark embedding

The procedure of the watermark embedding process is shown in Fig. 2; the process can be explained in the following steps:

- Step 1: Decompose the original image into subbands using 2D-SLT. The SLT coefficients of Lena image are shown in Fig. 3.
- Step 2: Select the horizontal and vertical high frequency coefficients. The horizontal and vertical

coefficients of the 1st level are HL1 and LH1, respectively, the horizontal and vertical coefficients of the 2nd level are HL2 and LH2, respectively, as shown in Fig. 3.

- Step 3: Embed the binary watermark by modifying the selected coefficients in a content-based manner. In [17] a content-based embedding method has been used. To embed a watermark bit first the corresponding horizontal and vertical high frequency coefficients must be selected. If the watermark bit is w(x,y) then the corresponding horizontal and vertical high frequency coefficients that have the same coordinates are denoted by HL(x,y) and LH(x,y), respectively. The watermark bit w(x,y) is embedded by manually changing the value of the difference between HL(x,y) and LH(x,y). The rules of wavelet coefficient modification are as follows:

$$If\ w(x,y) = 1\ and\ D_1 = HL(x,y) - LH(x,y) < T,$$

(T is a threshold to control watermark invisibility), increase HL(x,y) while decrease LH(x,y) by inserting the watermark.

$$\begin{cases} HL'(x,y) = HL(x,y) + \dfrac{(T - D1)}{2} \\ LH'(x,y) = LH(x,y) - \dfrac{(T - D1)}{2} \end{cases}$$

$$Else\ if\ D_1 = HL(x,y) - LH(x,y) \geq T, do\ nothing;$$

$$If\ w(x,y) = 0\ and\ D_2 = LH(x,y) - HL(x,y) < T,$$

similar operation is done.

$$\begin{cases} HL'(x,y) = HL(x,y) - \dfrac{(T - D2)}{2} \\ LH'(x,y) = LH(x,y) + \dfrac{(T - D2)}{2} \end{cases}$$

$$Else\ if\ D_2 = LH(x,y) - HL(x,y) \geq T, do\ nothing.$$

- Step 4: Replace the original horizontal and vertical high frequency coefficients with the modified coefficients.

- Step 5: Apply inverse 2D-SLT to obtain the watermarked image.

2) Watermark extraction

The watermark extraction process is done as follows:

- Step 1: Decompose the watermarked image into subbands using 2D-SLT.

- Step 2: Select the horizontal and vertical high frequency coefficients.

- Step 3: Extract the watermark from the selected coefficients as follows:

  The selected horizontal and vertical coefficients are HL'(x,y) and LH'(x,y), respectively, the watermark bit w'(x,y) can be extracted by [17]:

$$w'(x,y) = \begin{cases} 1, & if\ HL'(x,y) \geq LH'(x,y) \\ 0, & if\ LH'(x,y) \geq HL'(x,y) \end{cases}$$

Figure 2. Watermark embedding scheme

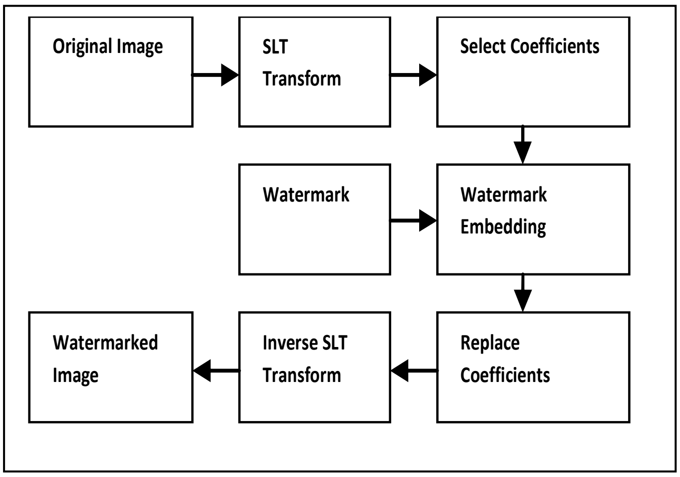
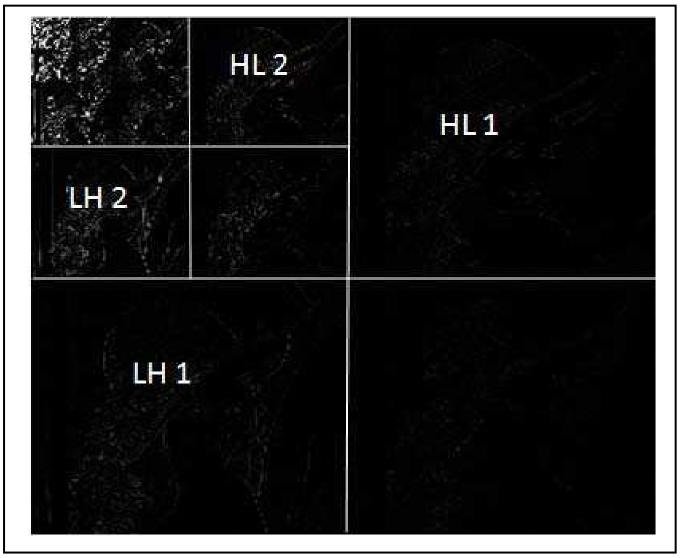


Figure 3. 2D-SLT coefficients for Lena image



B. The following experiments are carried out to verify the performance of the proposed algorithm:

1) In [11], the authors used two different embedding methods (Least Significant Bit (LSB) embedding method and Threshold embedding method) with the SLT and a comparison between the SLT scheme and DWT scheme was made. In their experiments, the data were embedded into the HL, LH, and HH subbands of the 1st level SLT coefficients. In our experiments, we used a different embedding method (content-based embedding method) and the data were embedded in the HL and LH subbands of the 1st level and the 2nd level of the SLT coefficients, we compare the proposed embedding method with the two embedding methods described in [11]. To test the image quality after the watermarking process PSNR will be calculated using the same test image, threshold values and the payloads that are already used in [11].

2) In this experiment, the performance of the proposed embedding method based on the two different transforms (i.e. SLT and DWT) is studied. Two copies of a binary watermark (64 X 64) are embedded to increase the robustness. One copy of watermark is embedded in the horizontal and vertical coefficients of each level of two-level transformation. The watermark used in this work is shown in Fig. 4. The SLT-based scheme will be compared with DWT-based scheme using the same embedding method in terms of PSNR between the original image and the watermarked image. The test will be done using standard grayscale images (512 X 512 pixels). To test the robustness of the two schemes several attacks and modifications have been used. The performance after the attacks is compared using the NC between the original watermark and the extracted one after the attack.

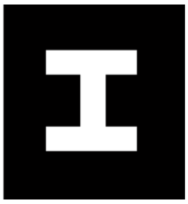


Figure 4. Binary watermark (64 X 64)

V. EXPERIMENTAL RESULTS AND DISCUSSION

1) In order to compare the image quality using our scheme and scheme in [11] the image used was (gray scale Lena image) with size (256 X 256). The results of comparison are shown in Table I and Table II. Table I contains a comparison with threshold embedding results. Table II contains a comparison with LSB embedding results. As we mentioned before we used the same threshold values and payload values that were used in [11] to make the comparison valid. In [11] the authors found that when the payload increased the efficiency of the SLT scheme decreased and DWT results will be better, however, when we compare the results of the DWT with the results of our method we found that our scheme still give better results than those in [11]. In Tables (I & II) our method did not change so when the threshold values and payload values stay the same the PSNR will be the same. This can be seen in the results when the threshold value is (3) and the payloads are (1673/3727/14026) the PSNR in our proposed method will be the same in both tables.

TABLE I. COMPARISON WITH THRESHOLD EMBEDDING

Threshold	Payload (data in bits)	PSNR (DWT) (in dB)[11]	PSNR (SLT) (in dB)[11]	PSNR (proposed method)(in dB)
3	36	25.2854	49.8573	69.6304
5	36	25.3310	44.6686	66.9861
7	36	25.3545	41.4534	65.0343
3	1673	27.7678	24.6087	43.1856
3	3727	26.8093	24.6042	37.6471
3	14026	26.8093	24.5749	32.8077

TABLE II. COMPARISON WITH LSB EMBEDDING

Threshold	Payload (data in bits)	PSNR (DWT) (in dB)[11]	PSNR (SLT) (in dB)[11]	PSNR (proposed method) (in dB)
3	44	26.2813	59.41	68.3299
5	44	26.3276	41.29	65.7342
7	44	25.3543	38.70	63.8429
3	1673	27.7678	25.8256	43.1856
3	3727	27.7620	25.8249	37.6471
3	14026	27.7418	24.9571	32.8077

2) The SLT scheme and the DWT scheme using the content-based embedding method were compared in terms of PSNR between the original image and the watermarked image. If only one copy of the watermark embedded the PSNR will be high as shown in Table III but in order to increase the robustness two copies of the watermark were embedded that makes the payload 8192 bits. There is a trade off between the threshold value and the PSNR so we used trial and error to choose the threshold. The threshold value that can give acceptable performance (high PSNR in the same time the watermark can be recovered correctly) is 1.7, which is obtained from the experiments. The watermarked Lena image using the proposed SLT scheme is shown in Fig. 5. The NC between the original watermark and the extracted watermark after no attack is also calculated. The results of the comparison are shown in Table IV. To test the robustness of these two schemes the NC between the original watermark and the extracted one (best recovered one) was calculated. Different attacks and modifications were used to test the schemes as shown in Table V; the results were calculated using two testing images (Lena image and Baboon image).

TABLE III. COMPARISON BETWEEN DWT AND SLT SCHEMES AFTER EMBEDDING ONE COPY OF WATERMARK

Image	PSNR (dB)		NC	
	WT	*SLT*	*WT*	*SLT*
Baboon	37.9709	39.1812	1	1
Barbara	48.7078	49.5751	1	1
boat	54.3156	54.5944	1	1
bridge	42.9244	43.9373	0.9991	0.9938
clown	54.1749	53.5066	0.9973	0.9973
couple	47.6006	48.3842	1	1
F16	45.6910	47.7576	1	1
girlface	57.7437	57.2832	1	1
Goldhill	50.9716	53.0576	1	1
houses	43.6943	43.7991	1	1
kiel	48.0345	48.0111	1	1
Lena	56.1535	56.7655	1	1
lighthouse	44.2474	45.4326	1	1
peppers	44.3410	46.3108	0.9694	0.9857
tank2	50.5969	51.5690	1	1
truck	49.6066	49.8867	1	1
trucks	46.4540	46.5645	1	1

TABLE IV. COMPARISON BETWEEN DWT AND SLT SCHEMES AFTER EMBEDDING TWO COPIES OF WATERMARK

Image	**PSNR (dB)**		**NC**	
	WT	***SLT***	***WT***	***SLT***
Baboon	33.8753	34.4190	1	1
Barbara	40.4918	40.8894	1	1
boat	42.1212	42.5943	1	1
bridge	35.8239	36.8862	0.9991	0.9946
clown	42.1512	43.4253	0.9973	0.9973
couple	39.5646	40.1808	1	1
F16	37.1842	37.8527	1	1
girlface	44.2069	42.8538	1	1
Goldhill	40.9159	42.6061	1	1
houses	34.9013	35.6753	1	1
kiel	38.8207	38.3876	1	1
Lena	44.0473	43.7518	1	1
lighthouse	34.7280	34.3055	1	1
peppers	38.9893	39.7558	0.9694	0.9694
tank2	41.1434	41.7759	1	1
truck	42.0311	43.1119	1	1
trucks	39.3511	39.8029	1	1

TABLE V. COMPARISON BETWEEN NC AFTER ATTACKS

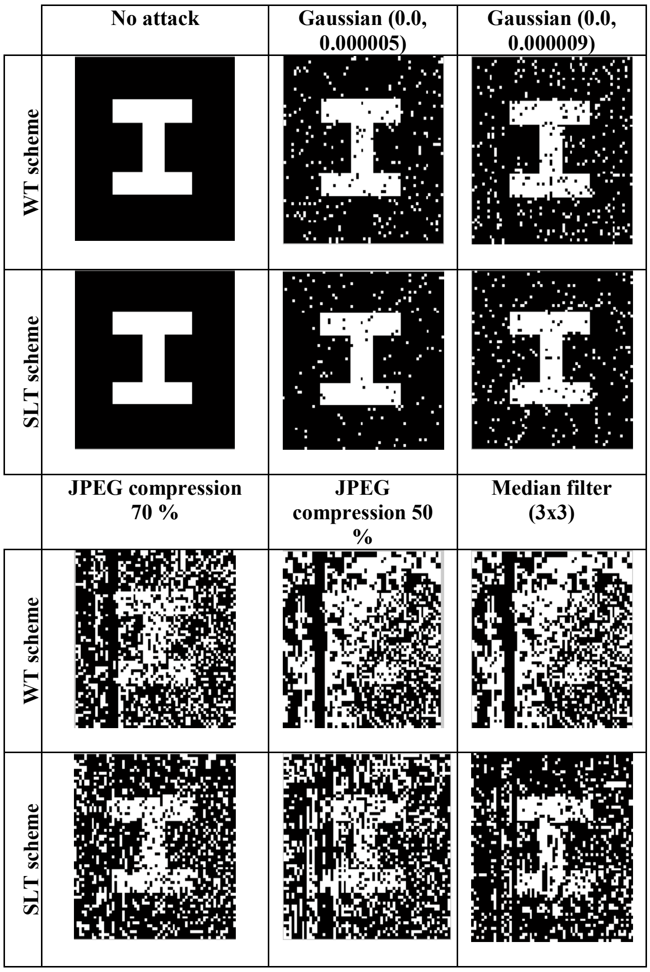
Attack	**Lena image**		**Baboon image**	
	NC WT	***NC SLT***	***NC WT***	***NC SLT***
Gaussian (0.0, 0.000005)	0.7926	0.8866	0.8591	0.9264
Gaussian (0.0, 0.000009)	0.7283	0.7993	0.7951	0.8466
JPEG compression quality 90 %	0.5795	0.7197	0.6095	0.6479
JPEG compression quality 70 %	0.3426	0.4390	0.4122	0.4538
JPEG compression quality 50 %	0.1912	0.3080	0.3354	0.3845
Median filter (3x3)	0.1233	0.4297	0.1022	0.3503
Wiener filter (3x3)	0.1258	0.4533	0.1565	0.4417
Histogram equalization	0.6867	0.8191	0.5604	0.5644
Rotate and crop 0.16°	0.4655	0.5929	0.4533	0.5607
Resize image scale 0.5	0.2325	0.5613	0.1855	0.4105
Resize image scale 2	0.5454	0.9761	0.1930	0.5925

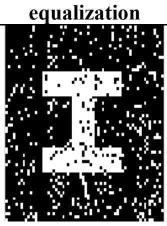
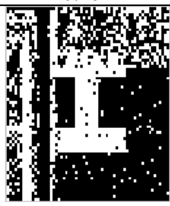
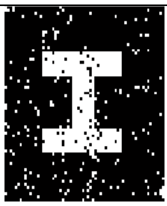
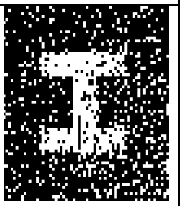
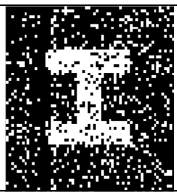
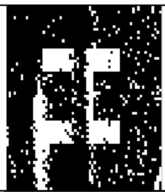
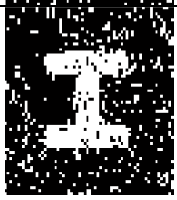
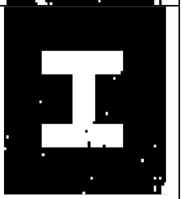
Figure 5. Watermarked Lena image after embedding 2 copies of (64x64) watermark using SLT scheme

The watermarks extracted after using the DWT scheme and the SLT scheme are shown in Table VI. These watermarks are extracted from the watermarked Lena image after different attacks.

The experimental results showed that the proposed method gives better image quality as compared with the results in [11]. This is shown in Table I and Table II. The comparison between the SLT scheme and DWT scheme using the same embedding method showed that the SLT scheme yields higher image quality and better robustness. In case of embedding one copy of the watermark image quality will be high (Table III) but in order to increase the probability of recovering the watermark a second copy of the watermark was embedded in the horizontal and vertical coefficients of the 2^{nd} level. After embedding a second copy of the watermark, image quality decreased (Table IV). The NC results (Table V) and the extracted watermarks after attacks (Table VI) prove that the watermark embedded in the SLT scheme is more robust than the watermark embedded in the DWT scheme. Since the coefficients of the SLT are different from the coefficients of the DWT the response of these coefficients to the attacks will be different so that the noise in the watermarks extracted from the SLT scheme is less than the noise in the watermarks extracted from the DWT scheme.

TABLE VI. THE WATERMARK EXTRACTED AFTER DIFFERENT ATTACKS



	Histogram equalization	Rotate and crop 0.16°	Resize image scale 0.5
WT scheme			
SLT scheme			
	JPEG compression 90%	**Wiener filter (3x3)**	**Resize image scale 2**
WT scheme			
SLT scheme			

VI. CONCLUSIONS

In this paper, a watermarking scheme is presented in order to achieve better image quality and robustness to some attacks. The main method is based on using SLT and embedding a binary watermark in the high frequency coefficients of the SLT using a content-based manner. The results prove that different embedding methods can give better performance for the same transform. In addition, the change of the transform with the same embedding method can give better results. For future work, other embedding methods can be tested to find out what is the most suitable embedding method with SLT.

REFERENCES

[1] P. Niu, X. Wang, H. Jin, M. Lu, "A feature-based robust digital image watermarking scheme using bandelet transform," Optics & Laser Technology Elsevir Ltd, vol. 43, no. 3, pp. 437-450, April 2011.

[2] K. Luo, X. Tian, "A New Robust Watermarking Scheme based on Wavelet Transform," Proceedings of the Cogress on Image and Signal Processing, 2008. CISP '08. vol. 1, pp. 312-316, 27-30 May 2008.

[3] C. Pun, "A novel DFT-based digital watermarking system for images," Proceedings of the 8th International Conference on Signal Processing, vol. 2, pp. 1245-1248, 16-20 November 2006.

[4] A. Lhab, H. Pirre, B. Wael, J. Graham, "Comparsion and Analysis of DCT-based Image Watermarking Algorithms," Book Chapter, Advances Techniques in Computing Sciences and Software Engineering, pp. 55-58, 2010.
DOI: 10.1007/978-90-481-3660-5_10.

[5] S. Kamble, S. Agarwal, V. K. Shrivastava, V. Maheshkar, "DCT based texture watermarking using GLCM," IEEE 2nd International Advance Computing Conference (IACC), pp. 185-189, 19-20 Feb. 2010.
DOI: 10.1109/IADCC.2010.5423014.

[6] S. k. Amirgholipour, A. R. Naghsh-Nilchi, "Robust Digital Image Watermarking Based on Joint DWT-DCT," International Journal of Digital Content Technology and its Applications (JDCTA), vol. 3,no.2, pp. 42-54, 2009.

[7] C. Temi, S. Choomchuay, A. Lasakul, "A Robust Image Watermarking using Multiresolution Analysis of Wavelet," IEEE International Symposium on Communications and Information Technology (ISCIT), vol. 1,pp. 623-626, 12-14 Oct. 2005.

[8] X. Zhang, K. Lo, J. Feng, D. Wang, "A Robust Image Watermarking Using Spatial-Frequency Feature of Wavelet Transform," Proceedings of the 5th International Conference on Signal Processing (ICSP), vol. 2, pp. 1100-1105, 21-25 Aug. 2000.

[9] E. Brannock, M. Weeks, R. Harrison, "The effect of Wavelet Families on Watermarking", Journal Of Computers, vol. 4, no. 6, pp. 554-566, June 2009.

[10] V. Fotopulos, A. Skodras, "A subband DCT Approach to Image Watermarking," Proceedings of the 10th European Signal Processing Conference, Tampere, Finland,pp. 1961-1964, 4-8 September 2000.

[11] S. Kumar, S. Muttoo, "Distortionless Data Hiding based on Slantlet Transform," International Conference on Multimedia Information Networking and Security, vol. 1, pp. 48-52, 18-20 November 2009.

[12] G. Panda, P. Dash, A. Pradhan, S. Meher, " Data Compression of Power Quality Events Using the Slantlet Transform," IEEE Transactions on Power Delivery, vol. 17, no. 2,pp. 662-667, April 2002.

[13] I. Selesnick, "The Slantlet Transform," IEEE Transactions on Signal Processing, vol. 47, no. 5, pp. 1304-1313, May 1999.

[14] S. Mutt, S. Kumar, "Secure Image Steganography based on Slantlet Transform," Proceedings of International Conference on Methods and Models in Computer Science, pp.1-7, 14-15 Dec. 2009.
DOI: 10.1109/ICM2CS.2009.5397983

[15] M. Maitra, A. Challerjee, "A Slantlet Transform based intelligent system for magnetic resonance brain image classification," Elsevier, Biomedical Signal Processing and Control, vol. 1, no. 4, pp. 299-306, October 2006.

[16] L. Yu, S. Sun, " Slantlet Transform based image fingerprints," Proceedings of the Third IASTED International Conference on Communication, Network and Information Security, Cambridge, MA, USA, pp.41-43, 9-11 October 2006.
ISBN 0-88986-636-8.

[17] L. Li, J. Qian, J. Pan, "Characteristic region based watermark embedding with RST invariance and high Capacity," International Journal of Electronics and Communications, vol. 65, no. 5, pp. 435-442, 2011.