Multimed Tools Appl (2020) 79:11069–11082
https://doi.org/10.1007/s11042-018-6177-0

Improved wavelet-based image watermarking through SPIHT

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Received: 16 March 2018 / Revised: 1 May 2018 / Accepted: 21 May 2018 /
Published online: 2 June 2018

Abstract This paper presents an improved watermarking algorithm using discrete wavelet transform (DWT), discrete cosine transforms (DCT) and singular value decomposition (SVD). Further, robustness and security of algorithm is enhanced by set partitioning in hierarchical tree (SPIHT) and Arnold transform, respectively. The experimental results evident that proposed method is imperceptible and robust against various form of attacks and found superior to other similar technique under consideration.

Keywords DWT · DCT · SVD · SPIHT · Arnold transform · Robustness

1 Introduction

Internet has become the popular channel for each user to download, transmit multimedia data like images and video [15]. Digital data can easily be tampered or manipulated. However, attackers can copy, store, delete or modify digital data easily. This leads to unauthorized use of digital data/media. To protect the digital contents from unauthorized user/use(s), some notable mechanism is required. Recently, integrity and confidentiality of media contents is maintained by using efficient watermarking technique [15]. In this technique, some type of watermark (digital data) is embedded within cover media for the purpose of authentications, copyright and annotation. The potential applications of watermarking are chip and hardware security, E-governance, Copyright protection, digital library, real time audio/video applications,

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healthcare, fingerprinting, forensic and many more. In addition, watermarking techniques save the bandwidth requirements during transmission of huge image or its related data.

2 Related work

Some important contributions of work in this area as reported by the potential researchers are presented below.

An adaptive watermarking technique using DCT and SVD for e-governance application is proposed in [8]. Genetic algorithm is used to optimize the gain factor of masking. The method not only avoided the false positive problem but also robust to several attacks. In [18], authors have proposed a robust and imperceptible watermarking technique using combination of most demanding transform techniques i.e. DWT, DCT and SVD. Experiment results have shown that proposed technique has better NC values as compared to other methods [7, 9] under common watermarking attacks. Singh et al. [17] have introduced a robust multiple watermarking using transform domain techniques. For better security, multiple watermarks are hidden into same media file simultaneously. Before embedding, the text watermark is encrypted by simple encryption technique. Various experimental tests have been performed and indicate it is robust for various form of attacks. DWT and DCT based improved watermarking method is proposed by Ghazvini in [4]. Further, GA is used to optimize the performance of embedding and recovery parameters. Experimental results have shown that the method recovered the hidden watermark against attacks. Ali et al. [1] have discussed a lossless watermarking approach. The robustness and security of the method is achieved through combining different transform domain techniques and visual cryptography. The normalized correlation (NC) values are obtained superior to some previous published work [12, 22, 23].

A secure and highly robust watermarking technique through Fibonacci-Lucas transformation and multi-objective evolutionary optimizer (MEO) is presented by Gunjal and Mali [5]. The method has excellent embedding capacity and obtained high NC value for most of the considered attacks. Further, the results demonstrations clearly indicate that the method is superior to other similar techniques under consideration [2, 3, 10, 11]. In [16], method achieved the robustness and security through SPIHT and Chinese remainder theorem (CRT) encryption algorithm. The performance comparisons with several other method [13, 14] have shown that the superiority of the method. Similar other robust watermarking techniques are presented in [7, 9, 13, 14, 20].

3 Major contribution of work

In this paper, the major contribution of the work as follows:

- Research concluded that the performance of hybrid transforms based watermarking technique (fusion of DWT, DCT and SVD) found superior to the technique using DWT, DCT or SVD separately or combination of any two (DWT-DCT, DWT-SVD or DCT-SVD) [17]. The considered transform techniques (DWT, DCT and SCD) have its own merits and demerits [19]. The DWT is one of the popular methods for sub-band image coding. The high energy compaction property of DCT and SVD make it suitable watermarking. We can present the useful data in very few frequency coefficients if the

DWT coefficients are transformed by DCT [24]. Further, the popular demerits of SVD is false positive problem can be easily removed by the solution as provided in [6, 21]

- We obtained the excellent ‘NC’ values through popular transform domain techniques and SPIHT. Our experimental results (From Tables 1, 2, 3, 4, 5, 6, 7 and 8) clearly shown the method is embedding the watermark imperceptibly and recovered the hidden watermark nearly original one. SPIHT [16] is used to generate embedded compressed bit string which can be used for storage /or bandwidth efficient transmission. Further, SPIHT technique provides exact rate control i.e. any bit rate (compression ratio) can be set by user to reconstruct original images.
- The performance of the method is carried out by several experimental tests. Further, NC values are found better than other similar approaches under consideration [7, 9, 18].
- For better confidentiality, watermark image is scrambled by Arnold transform [26]. This is hard to recover watermark for attackers even after extraction.
- Our watermarking technique save the bandwidth requirements and the hidden watermark is also suitable for able archiving and data retrieval [19].

4 Proposed SPIHT based watermarking method in transform domain

The detail watermarking embedding, and extraction technique is shown in Fig. 1a-b. The proposed technique is based on most demanding and popular transform domain techniques (DWT, DCT, and SVD) and SPIHT. Barbara and logo image are considered as cover and watermark image, respectively. In embedding process, the host image is decomposed by DWT. The DCT is applied on selected sub-band of DWT. SVD is applied on obtained DCT coefficients of the cover image. Watermark image is first scrambled by using the Arnold transform and then scrambled image is transformed by DCT and SVD. Finally, the scrambled and transformed watermark image is embedded into the cover image. Further, SPIHT encoding is applied on watermarked image which result in compressed watermarked image. The hidden watermark recovered process is same as embedding but in reverse order.

5 Experimental results

Our method is implemented using MATLAB version 13. In our experiment, the cover image size of 512 × 512 and watermark image of size just half of the cover image i.e. 256× 256 are used for testing In our experiments, the significant distortion between cover and watermarked

Table 1 PSNR, NC and SSIM values at varying gain factors

Gain(K)	PSNR (in dB)	NC	SSIM
0.01	38.47	0.9422	0.999954
0.08	35.35	0.9935	0.997615
0.09	34.68	0.9950	0.997003
0.1	34.02	0.9962	0.996330
0.17	30.07	0.9984	0.989905
0.3	25.31	0.9990	0.971311

Table 2 NC and SSIM values under different attacks

Attacks	Noise variation	NC	SSIM (after attacks)
Salt & Pepper with different Noise density	0.001	0.9969	0.985077
	0.003	0.9853	0.97658
	0.005	0.9713	0.968246
	0.01	0.9424	0.949458
	0.02	0.8959	0.912951
	0.1	0.7005	0.677389
	0.5	0.5810	0.190452
Gaussian Noise	Var = 0.001	0.9874	0.978836
	Var = 0.003	0.9502	0.95878
	Var = 0.005	0.9219	0.939639
	Var = 0.01	0.8569	0.895718
	Var = 0.02	0.7906	0.81776
JPEG compression with different quality factor	10	0.9969	0.979408
	30	0.9987	0.986209
	60	0.9988	0.987701
	80	0.9990	0.989342
	100	0.9992	0.989325
Cropping	(20 20,400,480)	0.8970	0.789895
	(250300550700)	0.8952	0.789895
Rotation	300	0.9984	0.295227
	500	0.9984	0.260456
	700	0.9984	0.353285
	1000	0.9984	0.393222
Scaling attacks	(×0.5)	0.5563	0.707554
	(×1.5)	0.5227	0.812598
Sharpening Mask attack	0.1	0.9297	0.946208
	0.3	0.9306	0.94849
	0.5	0.9313	0.950011
	0.7	0.9318	0.951043
Median Filter Attack	(4 4)	0.9528	0.976881
	(10 10)	0.9578	0.960935
	(20 20)	0.7936	0.923243
	(50 50)	0.7936	0.923243
Histogram		0.6736	0.719232

image is measured by Peak Signal to Noise Ratio (PSNR) and **Structure similarity index** (SSIM) [19]. The Similarity between original and extracted/recovered watermark image is measured by NC [19]. In addition, our results are compared with previously reported watermarking techniques. The cover, watermark and corresponding watermarked images are illustrated in Fig. 2. Figure 3 shows the attacked watermarked and recovered watermark images. Without any attack, the performance (as estimated in form of PSNR, SSIM and

Table 3 Performance of Proposed method for various cover and watermark image at gain factor $k = 0.09$ without any attack

Cover image	Watermark image	PSNR (in dB)	SSIM	NC
Barbara	Baboon	32.82	0.994922	0.9846
Lena	Cameraman	30.00	0.993811	0.9965
Boat	Finger	30.13	0.992587	0.9846
Barbara	Juit logo	28.55	0.992088	0.9973
MRI	Thorax	34.68	0.995857	0.9950

Table 4 Performance under varying bit rate

Cover image/watermark image	Bit Rate (bpp)	PSNR (in dB)	SSIM	NC
Lena/Baboon	0.25	32.73	0.992862	0.9705
	0.5	35.03	0.995941	0.9911
	1	36.21	0.996982	0.9892
	1.5	36.55	0.997233	0.9885
	2	36.59	0.997262	0.9896
	2.5	36.70	0.997341	0.9896
	3	36.72	0.997355	0.9902
Barbara/ Baboon	0.25	26.65	0.976750	0.8812
	0.5	29.91	0.989215	0.9827
	1	33.22	0.995107	0.9815
	1.5	34.38	0.996312	0.9878
	2	34.69	0.996582	0.9933
	2.5	34.95	0.996793	0.9933
	3	35.02	0.996845	0.9937
Boat/ Baboon	0.25	29.10	0.982170	0.9491
	0.5	31.76	0.990536	0.9875
	1	33.75	0.994158	0.9860
	1.5	34.46	0.995089	0.9895
	2	34.76	0.995445	0.9902
	2.5	34.82	0.995515	0.9918
	3	34.93	0.995629	0.9918

NC) is evaluated at several gain as shown in Table 1. We have obtained best PSNR value = 38.47 dB at gain factor (k) = 0.01. However, the best NC value is noted as 0.9984 at gain factor = 0.17. However, our lower PSNR value is 25.31 dB at gain factor 0.3 and NC value is 0.9422 at $k = 0.01$. This indication means the method is robust at high gain and no any significant distortion between cover and watermarked image at low gain values.

We have determined the NC and SSIM performance of our method at gain = 0.17 as presented in Table 2. The results clearly indicated that the method obtained high NC values, at the same time; SSIM values are also high for several attacks. From Table 2, the best NC and SSIM value is 0.9992 and 0.989342 against JPEG compression attacks, respectively. However, our lower NC and SSIM value is 0.5227 for scaling attack and 0.260456 for rotation attack, respectively.

Table 3 shows the performance (as determined in terms of PSNR, SSIM and NC) of our method for different cover and watermark image at gain = 0.09. From Table 3, the best NC value is obtained as 0.9973 for Barbara - Juit logo image. However, lower NC value is 0.9846 for Boat– Finger and Barbara – Baboon images. Out of the presented PSNR values in this table, the best PSNR value is 34.68 dB for MRI -Thorax image. However, lower PSNR value is 28.55 dB for Barbara image where logo image is used as watermark. Table 4 shows PSNR, SSIM and NC values are obtained by our method for different cover/watermark images at varying bit rate using $k = 0.07$. With 'Lena' image, maximum PSNR, SSIM and NC values (at bit rate = 3) are 36.72 dB, 0.997355 and 0.9902, respectively. However, minimum PSNR, SSIM and NC values (at bit rate 0.25) are 32.73 dB, 0.992862 and 0.9705, respectively. For 'Barbara' image, maximum PSNR, SSIM and NC values (at bit rate = 3) are 35.02 dB, 0.996845 and 0.9937, respectively. However minimum PSNR, SSIM and NC values (at bit rate = 0.25) are 26.65 dB, 0.976750 and 0.8812, respectively. For cover image Boat, best PSNR, SSIM and NC values (at bit rate 0.3) are 34.93 dB, 0.995629 and 0.9918, respectively. However, minimum PSNR, SSIM and NC values (at bit rate 0.25) are 29.10 dB, 0.982170 and

Table 5 Comparing PSNR, SSIM and NC of proposed method with Shivani et al., Said et al., and Senapati et al.

Cover image	Bit Rate (bpp)	Methods	PSNR (in dB)	SSIM	NC
Lena	0.25	[16]	30.93	0.8982	0.3201
		[13]	31.24	0.9075	0.1317
		[14]	30.93	0.8974	0.3032
		Our	32.73	0.9929	0.9705
	0.5	[16]	31.36	0.9292	0.9804
		[13]	31.10	0.9167	0.9848
		[14]	31.31	0.9301	0.9828
		Our	35.03	0.9959	0.9911
	1	[16]	31.13	0.9617	0.9804
		[13]	33.87	0.9600	0.9801
		[14]	34.02	0.9621	0.9797
		Our	36.20	0.9970	0.9892
	1.5	[16]	34.40	0.9676	0.9149
		[13]	34.35	0.9658	0.9227
		[14]	34.76	0.9677	0.9180
		Our	36.54	0.9972	0.9885
	2	[16]	34.90	0.9693	0.9257
		[13]	34.83	0.9686	0.9298
		[14]	34.76	0.9677	0.9180
		Our	36.58	0.9973	0.9896
	2.5	[16]	35.44	0.9740	0.9598
		[13]	35.41	0.9738	0.9510
		[14]	35.33	0.9733	0.9517
		Our	36.70	0.9973	0.9896
	3	[16]	35.65	0.9739	0.9558
		[13]	35.65	0.9724	0.9490
		[14]	35.52	0.9744	0.9480
		Our	36.72	0.9974	0.9902
	Lossless at 3.5	[16]	36.00	0.9750	0.9831
		[13]	35.83	0.9762	0.9841
		[14]	35.68	0.9754	0.9747
		Our	36.77	0.9975	0.9903

0.9491, respectively. Therefore, we noticed that the performance of the method is increases at high bit rate.

In Table 5, we are comparing the performance of our method with similar reported methods [13, 14, 16]. Our method offered maximum and minimum PSNR value are 36.77 dB (at bit rate = 3.5) and 32.73 dB (at bit rate = 0.25), respectively. However, maximum PSNR value (at lossless compression) obtained by Shivani et al. [16], Said et al. [13] and Senapati et al. [14] techniques are 36 dB, 35.83 dB, 35.68 dB, respectively. Further, our method offered maximum and minimum SSIM values (at bit rate 0.25) are 0.9975 and 0.9929, respectively. However, maximum SSIM values offered by the method presented in [13, 14, 16] are 0.9750, 0.9762 and

Table 6 Comparing robustness of the proposed method with Shivani et al.

Attacks	Crop	Noise	Sharpening	Invert	Histogram equalization
NC value [16]	0.7158	0.7208	0.5034	0.9771	0.5415
NC value (Proposed method)	0.9416	0.7255	0.7397	0.9873	0.8165
Improvement (%)	31.55	0.65	46.94	1.04	50.78

Table 7 Comparing the robustness of the proposed method with Singh et al. at different gain

Attacks	Gain(K)	Noise density	NC value [18]	NC value (Our)	Improvement (%)
Pepper and Noise attack	0.9	0.01	0.9962	0.9984	0.22
		0.02	0.9917	0.9960	0.43
		0.03	0.9869	0.9914	0.46
		0.06	0.9641	0.9726	0.88
		0.08	0.9468	0.9568	1.06
	0.7	0.01	0.9961	0.9984	0.23
		0.02	0.9910	0.9943	0.33
		0.03	0.9823	0.9890	0.68
		0.06	0.9508	0.9637	1.36
		0.08	0.9277	0.9424	1.58
	0.5	0.01	0.9948	0.9981	0.33
		0.02	0.9855	0.9913	0.59
		0.03	0.9719	0.9684	−0.69
		0.06	0.8430	0.9430	11.86
		0.08	0.8892	0.9126	2.63
Speckle attack	0.9	0.01	0.9981	0.9983	0.02
		0.02	0.9906	0.9961	0.56
		0.03	0.9849	0.9927	0.79
		0.06	0.9631	0.9778	1.53
		0.08	0.9458	0.9640	1.92
	0.7	0.01	0.9948	0.9980	0.32
		0.02	0.9896	0.9952	0.57
		0.03	0.9818	0.9901	0.85
		0.06	0.9409	0.9679	2.87
		0.08	0.9275	0.9500	2.43
	0.5	0.01	0.9944	0.9978	0.34
		0.02	0.9848	0.9921	0.74
		0.03	0.9724	0.9830	1.09
		0.06	0.9262	0.9498	2.55
		0.08	0.8918	0.9245	3.67
Gaussian attack	0.9	0.01	0.9872	0.9925	0.54
	0.7	0.01	0.9841	0.9896	0.56
	0.5	0.01	0.9752	0.9831	0.81
Poisson attack	0.9		0.9981	0.9988	0.07
	0.7		0.9974	0.9991	0.17
	0.5		0.9973	0.9992	0.19

0.9754, respectively. From Table 5, our method offered maximum and minimum NC values are 0.9903 and 0.9705, respectively. However, maximum NC values offered by the method presented in [13, 14, 16] are 0.9831,0.9841 and 0.9747 respectively at same rate. We are further comparing robustness of our method with other recent published work [16] as shown in Table 6. From this Table, the NC value obtained by our method is 0.9416 for cropping attack. However, the NC value obtained by the [16] is 0.7158 under same attack. The other NC values

Table 8 Comparing the robustness of the proposed method with Singh et al., Khan et al. and Harish et al

Various attack	NC value [18]	NC value [9]	NC value [7]	NC value (Proposed method)
Gaussian noise	0.9872	0.9762	0.9690	0.9925
Salt and pepper noise	0.9962	0.9894	0.8940	0.9984
Poisson noise	0.9981	0.9981	0.9390	0.9992
Speckle noise	0.9981	0.9981	0.9890	0.9983

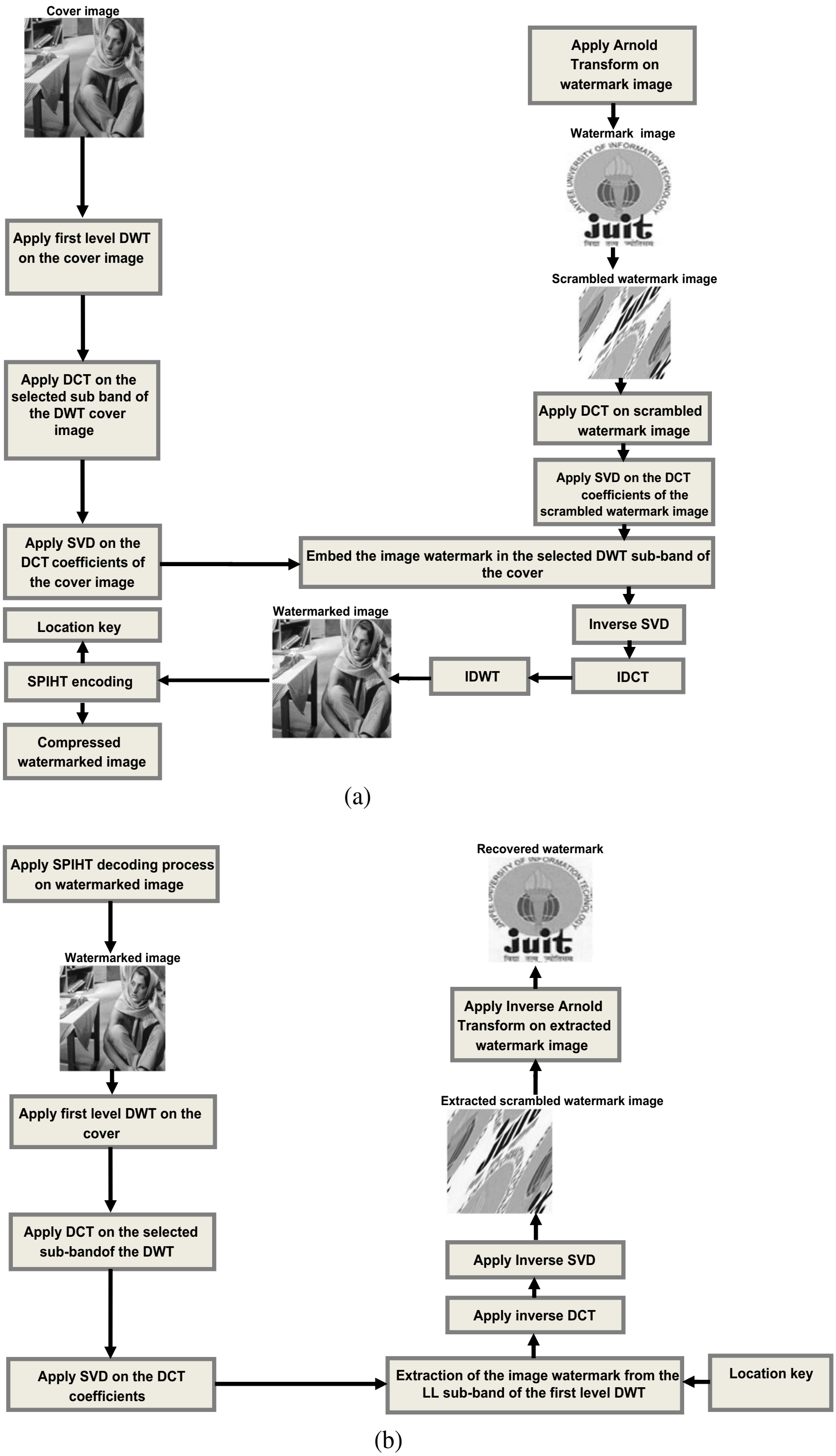

Fig. 1 Proposed method for **a** embedding and **b** extraction of watermark

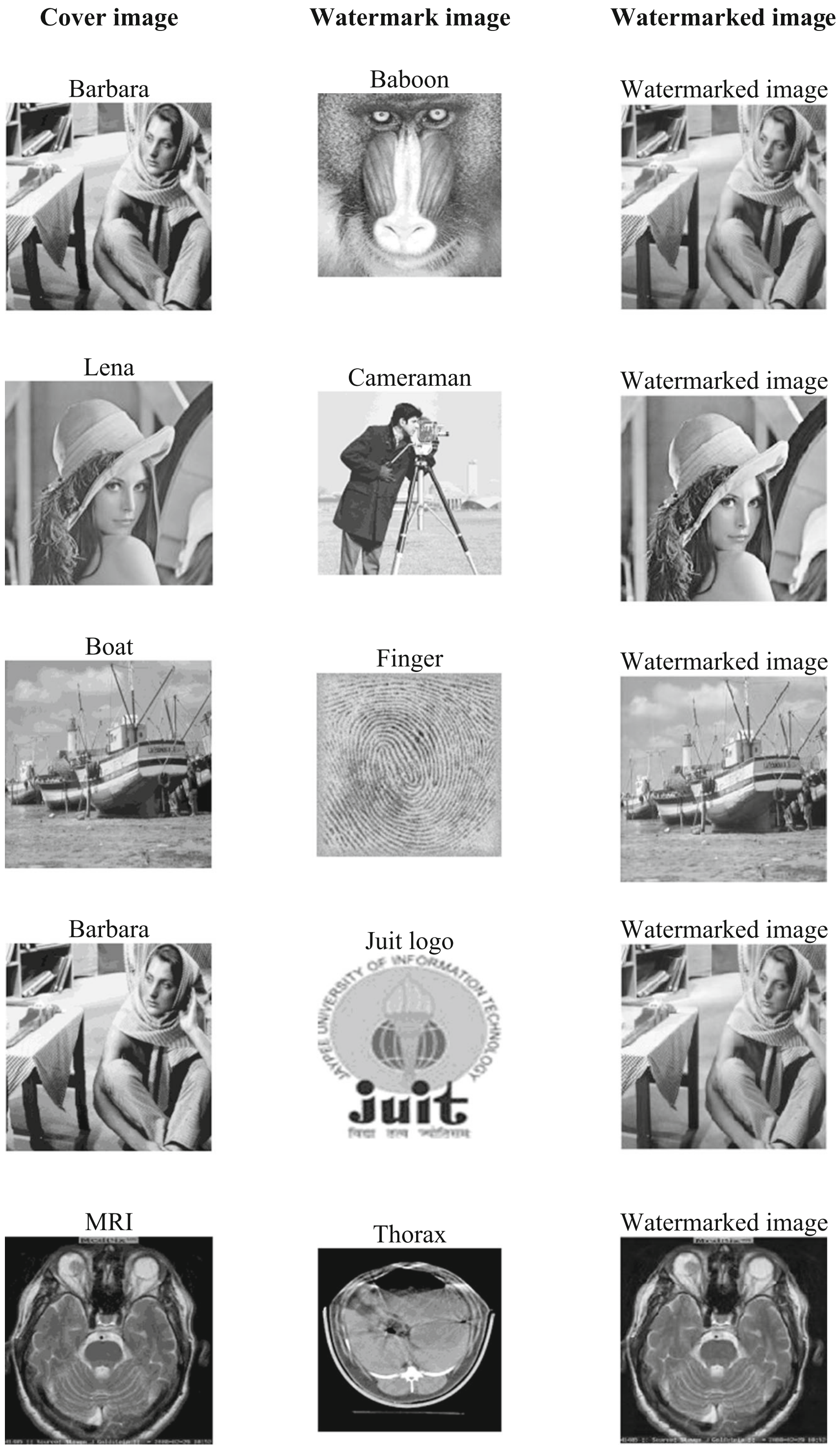

Fig. 2 Cover, watermark and watermarked images

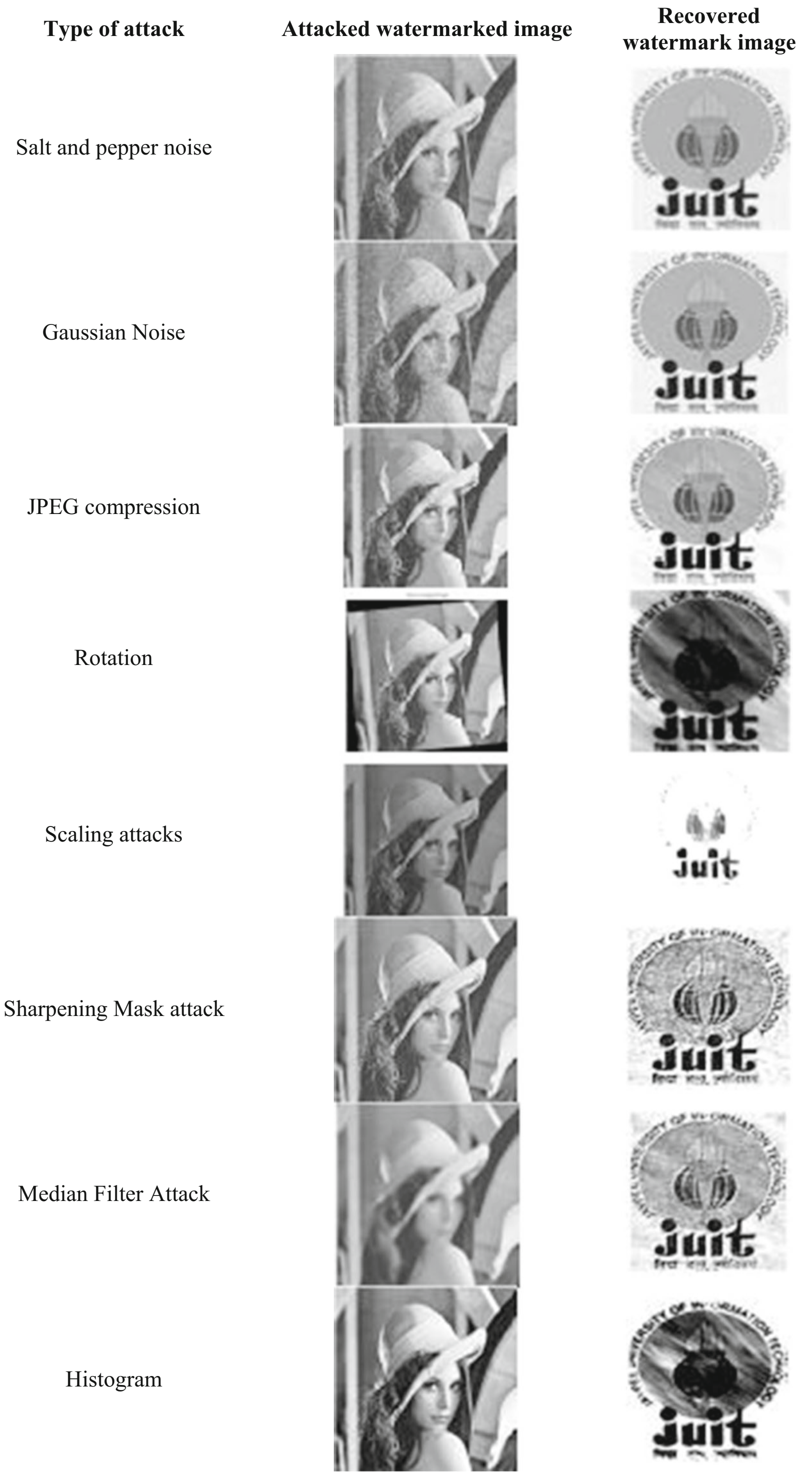

Fig. 3 Attacked watermarked and extracted watermarks image

Table 9 Subjective measure performance of our method

Gain(K)	Imperceptibility
0.01	Outstanding quality
0.08	Very good quality
0.1	Good quality
0.17	Acceptable quality
0.3	poor quality

presented in this Table indicate that our method is superior than [16]. From Table 6, our method offered up to 50.78% improvement in NC value as compared to [16].

Table 7 shows the comparison results of our method with previous reported method [18] for various attacks. Our method obtained the maximum and minimum NC values are 0.9992 (for Poisson attack) and 0.9126 (for pepper and noise attack) at gain = 0.5, respectively. However, best NC value offered by Singh et al. is = 0.9973 for Poisson attack at gain = 0.5. The minimum NC value obtained by Singh et al. is 0.8430 for pepper and noise attack. It is clearly noted from this table, our method offered up to 11.86% improvement in NC value as compared to similar reported technique [18].

Further, our method found superior to other similar technique [7, 9, 18] under consideration as shown in Table 8. From this Table, the best NC value obtained by our method is 0.9992 for Poisson noise. However, the NC values obtained by Singh et al., Khan et al. and Harish et al. are 0.9981, 0.9981 and 0.9390, respectively for same attack. The minimum NC value obtained by our method is 0.9925 for Gaussian noise. However, the NC values obtained by Singh et al., Khan et al. and Harish et al. are 0.9872, 0.9762 and 0.9690, respectively for same attack.

Table 9 shows the performance of our method with subjective measure [25]. It is noted from this table the significant distortion between cover and watermarked image is acceptable at all chosen gain factors except the gain = 0.3. At gain factor 0.3 visual quality of watermarked image is very poor. Therefore, our method offered better performance as compared to the methods reported in [7, 9, 13, 14, 16, 18]. The computational time of our method is 0.845 s.

6 Conclusions

An improved robust and secure watermarking algorithm in transform domain is presented. We achieved security and robustness of the algorithm through Arnold transform and set partitioning in hierarchical tree (SPIHT), respectively. The experimental results demonstrate that proposed method is robust and secure against various forms of attacks and found superior performance to other similar technique under consideration.

We would like to further determine the performance of the underlying technique for video watermarking, multiple watermarking, some new transform techniques and benchmark attacks. Further, the computational complexity of the method needs to be investigated separately in our future communication.

Acknowledgements The authors thank the potential reviewers for helpful and constructive comments that greatly contributed to improving this manuscript.

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