Comparison of Bit Error Rate Performance Measure of Robust Watermarking Scheme Based On Self-Fractional Fourier Functions, Empirical Mode Decomposition and Cyclic Encoding

J. B. Sharma*, K.K. Sharma **, Vineet Sahula***
*(Department of Electronics & Communication Engineering, Malaviya National Institute of Technology, Jaipur, Rajasthan, India)
** (Department of Electronics & Communication Engineering, Malaviya National Institute of Technology, Jaipur, Rajasthan, India)

ABSTRACT

Recently watermarking scheme based on EMD and SFFF has been proposed. Robustness of watermarking schemes are compared using various performance parameters like bit error rate, normalized correlation and similarity. In this paper, robustness of watermarking scheme based on image decomposition using self-fractional Fourier functions and bivariate empirical mode decomposition with cyclic error correcting code is being compared using bit error rate performance measure. Simulation results shows that bit error rate (%) values are inline with similarity parameter values with lower computation complexity. Hence BER (%) can be used as performance measure.

Keywords **- Empirical mode decomposition (EMD), Fractional Fourier transform, Self-fractional Fourier transforms, Watermarking.**

I. INTRODUCTION

Digital watermarking is used to prove the ownership of digital data and to prevent illegal duplication and distribution of multimedia data. In digital robust watermarking a secret imperceptible signal is embedded into the original data in such a way that it remains present as long as the perceptible quality of the content is at an acceptable level [1]. Ownership claims are verified by extracting the watermark using detection algorithm and comparing the extracted watermark with the original watermark [1,2].

The watermarking schemes have been proposed in spatial domain as well as transform domains, where the spatial and transform coefficients of the image are modified either in multiplicative manner or in additive manner [1]-[5]. A significant number of robust watermarking schemes using discrete wavelet transform (DWT)[2,3], discrete cosine transform (DCT) [4], and Fast Fourier transform (FFT) [5], are proposed. Watermarking schemes based on fractional Fourier transform and the self fractional Fourier functions are proposed in [8,9]. Robust and blind watermarking schemes using wavelets and empirical mode decomposition are proposed in [11-13].

A dual watermarking scheme using SFFF decomposition combined with bivariate empirical mode decomposition (BiEMD) in [10]. In this robustness analysis and comparison of this scheme with other schemes using similarity performance measure has been presented.

In one bit robust watermarking correlation between extracted and original watermark is used as performance measure but in case of multi bit robust watermarking normalized correlation, similarity and bit error rate etc., are used as performance measures [15]. Various performance measures to verify the extracted watermark has been proposed in [6,7].

In this paper comparison and analysis of robustness of scheme proposed in [10] using bit error rate (BER) performance measure is presented.

The rest of the paper is organized as follows: In section II the comparison of BiEMD and SFFF based watermarking scheme is presented. Simulation results are presented in section section III, and the conclusions of work are given in section IV.

II. COMPARISON OF WATERMARKING SCHEME BASED ON BER MEASURE

In this section we compare the scheme proposed in [10] from the point of view of BER measure. BER measure of watermarking scheme using image decomposition with self-fractional Fourier functions and bivariate empirical mode decomposition, scheme using only SFFF alone based decomposition and scheme using only bivariate EMD alone based decomposition is computed. These schemes have already been compared for similarity measure in [10].

Bit error rate (BER) is defined as follows,

$$BER(\%) = \frac{EB}{TB} X100$$,

where TB is the number of original watermark bits, and EB is the number of incorrect bits in extracted watermark.

The watermarking scheme based on image decomposition using SFFFs and bivariate EMD (BiEMD) is reproduced for convenience of readers and shown in Fig. 1. More details can be seen in reference [10].

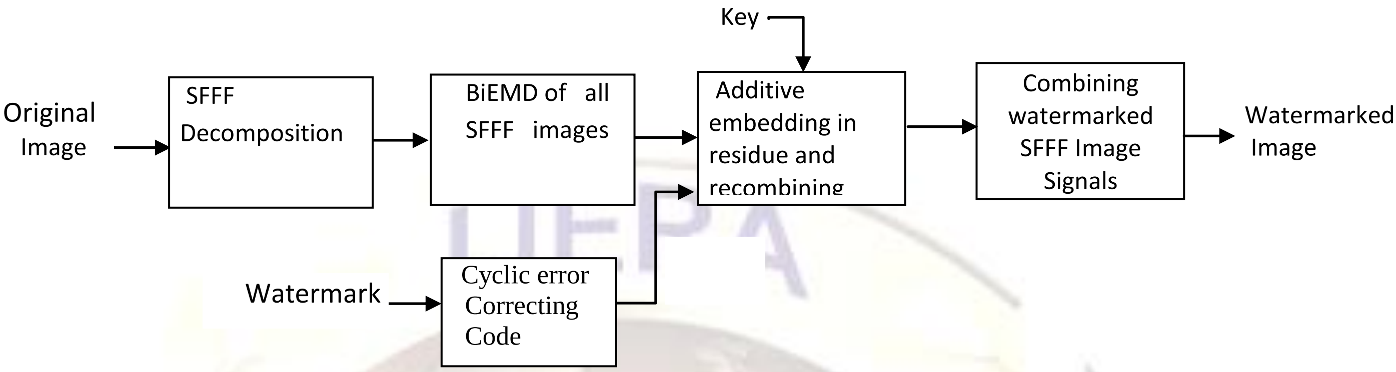


Fig.1 Block Diagram of watermarking scheme

III. SIMULATION RESULT

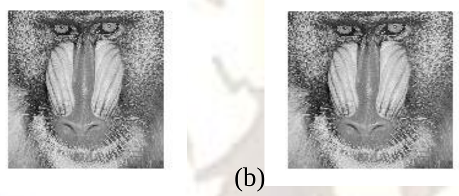
In this section computer simulation results performed using MATLAB, to verify the robustness of scheme proposed in [10], are presented. Baboon and Goldhill images (Figs. 3(a) and 4(a)) with two sets of watermark characters, shown in Figs. 5(a) and 5(b) are used to verify the robustness of scheme. BER (%) is computed for Goldhill image and WM2 watermark characters. The value of M is taken as four.

The input watermarks are encoded by (9, 8) systematic cyclic error correction code. The cyclic encoding scheme and $n = 9$ and $k = 8$ is selected due to simplicity and convenience of implementation.

Final watermarked images are shown in Figs. 3(b) and 4(b). Value of embedding constant is fixed to ensure invisibility and constant peak signal to noise ratio 42dB, for watermarked image. Watermark is recovered by decomposing watermarked image into SFFF images and SFFF images into IMFs and residue. The recovered original watermarks are shown in Figs. 6(a-b).

Simulations are also performed to compare the robustness of proposed SFFF and BiEMD based implementation of the watermarking scheme with only bivarite alone based implementation and only SFFF alone based implementation of watermarking scheme.

Bit error rate (BER) (%) between extracted watermark and original watermark is computed. Total 2216 bits are added in the watermark WM2 to the image Gldhill to perform the experimentation. Results for BER(%) for Goldhill image with watermark WM2 with different attacks are presented in table I-II and Figs 16((a)-(e)).

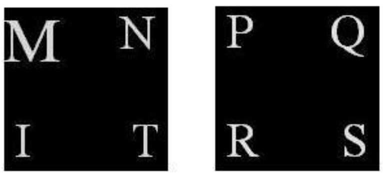


(a) (b)

Fig.2 (a) Baboon image (b) Watermarked image

(a) (b)

Fig. 3 (a) Goldhill image (b) Watermarked image



(a) WM1 (b) WM2

Fig.4 Original Watermarks

(a) (b)

Fig.5 Recovered watermark

A. Robustness Analysis: Robustness analysis of watermarking scheme is performed by analyzing the extracted watermark quality after applying attacks on watermarked image. Simulation results for various image processing attacks including noise addition, filtering, JPEG compression, sharpening, blurring, rotation to test the robustness of scheme proposed in [10] are presented in this section.

Baboon and Goldhill is used as cover image with WM1 (M, N, I, T) and WM2 (P,Q,R,S) watermark respectively. First attack on the image is applied by adding **white Gaussian noise** with SNR 25dB. Fig. 6 ((a),(c)) shows attacked images and fig. 6((b),(d)) shows recovered watermarks for SNR of 25 dB for Goldhill and Baboon image respectively.

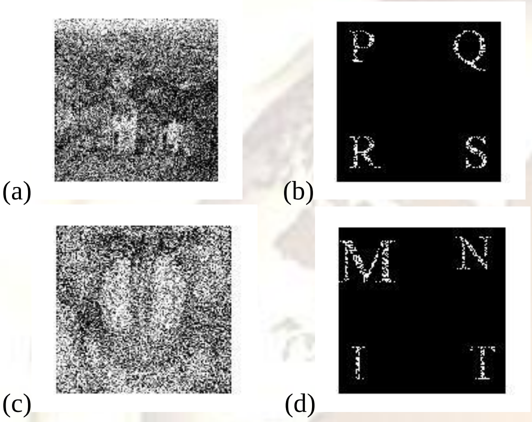


Fig.6 ((a) , (c)) Attacked image ((b),(d)) Recovered watermark with 25dB SNR

Salt and pepper noise: Fig. 8((a),(c)) shows attacked image obtained by mixing salt & pepper noise with sigma 0.2 for Goldhill and Baboon image respectively. Fig.8((b),(d)) shows recovered watermarks.

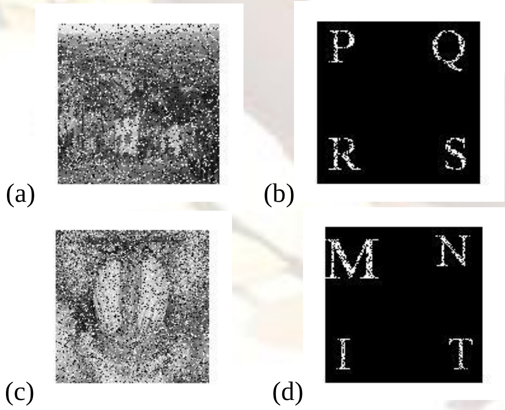


Fig.8 ((a),(c)) Attacked image ((b),(d))Recovered watermark with salt and pepper noise

JPEG compression Attack: attacked image is obtained by applying JPEG compression with quality factor Q=10 for Goldhill and Baboon image respectively. Fig. 9((a),(c)) shows attacked image and Fig.9((b),(d)) shows recovered watermark.

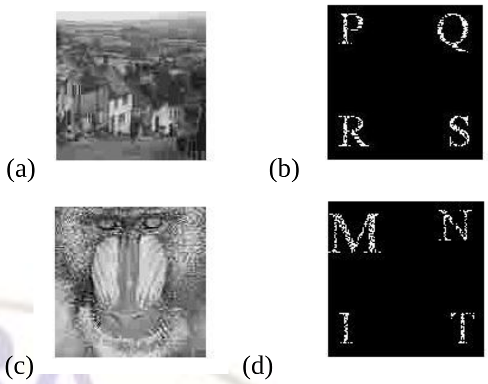


Fig.9 (a), (c) Attacked image (b),(d) Recovered watermark with Q=10

Filter attack: attacked image is obtained by applying median, Gaussian and wiener filtering with 5x5 window. Fig. 10((a),(c))-12((a),(c)) represent attacked image and Fig. 10((b),(d)-12((b),(d)) represent recovered watermark.

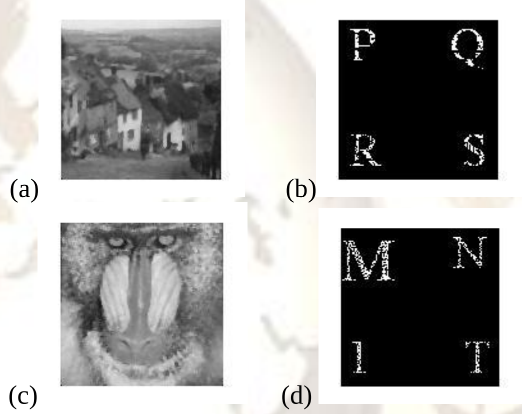


Fig.10 (a) median filter attacked image (b) recovered watermark for 5x5 window

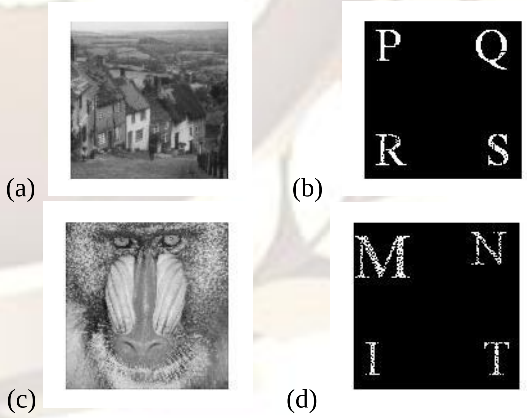


Fig.11 (a) Gaussian filter attacked image (b) Recovered watermark

Sharpening Attack: Attacked image is obtained by applying 50 % sharpening of watermarked image. The attacked image is shown in Fig. 13(a) and recovered watermark in Fig.13 (b).


(a)


(b)


(c)


(d)

Fig.13 (a) Attacked image (b) Recovered watermark

Blurring Attack: Blur of linear motion of camera by 20 pixels, with an angle of 45 in a counterclockwise direction is applied to obtain attacked image. The attacked image is shown in Fig. 14((a),(c)) and recovered watermark in 14((b),(d)).


(a)


(b)


(c)


(d)

Fig.14 ((a),(c)) Attacked image ((b),(d)) Recovered watermark

Rotation Attack: Watermarked image is rotated between 2° to obtain attacked image. The attacked image is shown in Fig. 15((a),(c)) and recovered watermark in 15((b),(d)) for rotation 2 degrees .


(a)


(b)

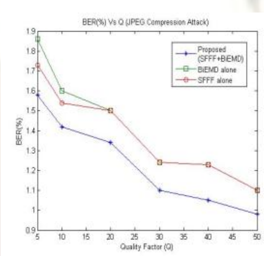

(c)


(d)

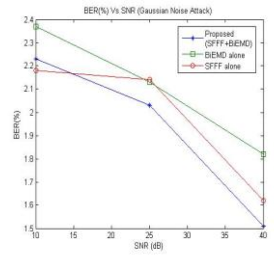
Fig.15 ((a),(c)) Attacked image ((b),(d)) Recovered watermark

B. Comparison of BER (%) measure and discussion: To compare the BER measure of bivariate EMD combined with SFFF decomposition based implementation of robust watermarking scheme with only SFFF decomposition based scheme and only bivariate EMD decomposition based scheme, same watermark encoded by systematic cyclic error correction code is embedded. That is the process used for embedding and detection is similar to [10]. Simulations are performed by embedding same watermark WM2 (P,Q,R,S) having total 2216 number of bits encoded by (9,8) cyclic error correcting code in goldhill image for all three schemes mentioned above. Strength of embedded watermark is measured by peak signal to noise ratio (PSNR) of watermarked image, and is taken as 42 dB for applying attack on above three schemes. Total 2216 number of bits are used in embedded watermark.

Computation results of bit error rate (BER), for above three mentioned schemes, under different attacks, are presented in table – I- II and Figure 16((a)-(e)).



(a)



(b)

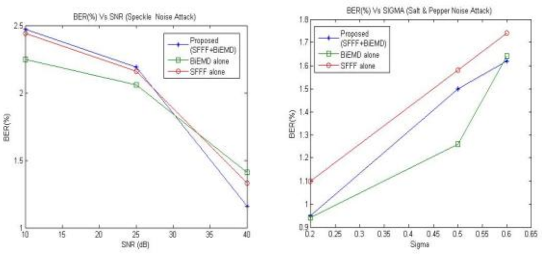
Table -I

BER for Goldhill image with (P,Q,R,S) watermark having total 2216 bits, PSNR: 42 dB

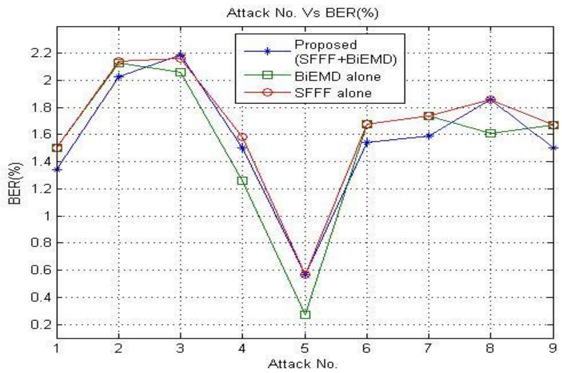
S.N.	Attack		SFFF + BiEMD	BiEMD alone	SFFF alone
1	JPEG	Q=5	1.58	1.86	1.73
		Q=10	1.42	1.60	1.54
		Q=20	1.34	1.50	1.50
		Q=30	1.10	1.24	1.24
		Q=40	1.05	1.23	1.23
		Q=50	0.98	1.10	1.10
2	Gaussian Noise	SNR=10dB	2.23	2.37	2.18
		SNR=25 dB	2.03	2.13	2.14
		SNR=40 dB	1.51	182	1.62
3	Speckle Noise	SNR=10 dB	2.47	2.25	2.44
		SNR=25 dB	2.19	2.06	2.16
		SNR=40 dB	1.16	1.41	1.33
4	Pulse & Pepper	SIG=0.2	0.95	0.94	1.10
		SIG=0.5	1.50	1.26	1.58
		SIG=0.6	1.62	1.64	1.74
5	Gaussian Filter	3x3	0.57	0.27	0.57
		5x5	0.57	0.27	0.57
		7x7	0.57	0.27	0.57
6	Median Filter	3X3	1.10	1.29	1.29
		5x5	1.54	1.68	1.68
		7x7	1.72	1.88	1.88
7	Weiner Filter	3x3	1.21	1.47	1.47
		5x5	1.59	1.74	1.74
		7x7	1.69	1.92	1.92
8	sharpening	-	1.86	1.61	1.86
9	Bluring1(5/65)	-	1.50	1.67	1.67
	Bluring1(20/45)	-	1.99	2.16	2.16

Table-II
Rotation Attack: BER(%)
(PSNR=42dB)

Angle	-2	-1	-0.5	0.5	1	2
SFFF+BIEMD	2.30	2.39	2.37	2.47	2.45`	2.53
BIEMD	2.30	2.39	2.37	2.47	2.45	2.53
SFFF	2.30	2.39	2.37	2.47	2.45	2.53



(c) (d)



(e)

Fig.16 Comparison of bit error rate (BER (%)) of extracted watermark under (a) JPEG compression attack (b) Gaussian noise attack (c) speckle noise attack (d) salt & pepper noise (e) All attacks.

BER (%) performance measures simulation results for scheme based on SFFF and BiEMD are following the trend of similarity parameter presented in [10], and proves the superior of scheme in comparison to other two schemes. Hence BER can also be used as performance measure.

IV. CONCLUSION

In this paper we have presented a bit error rate performance measure for analysis and comparison of the watermarking scheme proposed in [10]. Simulation results show that bit error rate (%) values are following same trend as similarity parameter values, with lower computation complexity. Hence BER (%) can also be used as performance measure.

REFERENCES

[1] I. Pits, “A method for Signature casting on Digital Images, Proc. of IEEE Conf. on Image Processing, 215-218 (1996)

[2] I. J. Cox, M. L. Miller, and A. L. McKellips, Watermarking as communications with side information. Proc. IEEE,7(87), 1127–1141, (1999)

[3] Barni, M., Bartiloni, F., Piva A. , Improved wavelet based watermarking through pixel wise masking. IEEE Transcations on Image Processing 10, 783–791 (2001)

[4] C. C. Wai, DCT-Based Image Watermarking Using Subsampling. IEEE Trans. on Multimedia, 5(1), pp. 34-38 (2003)

[5] J. O’Ruanaidh, W. Dowling, and F. Boland, “Phase Watermarking of Digital Images,” in Proceedings of IEEE International Conference on Image Processing, Vol. 3, pp. 239-242, Sep. 1996.

[6] M. Kuttera and F. A. P. Petitcolasb, A fair benchmark for image watermarking systems. Security and Watermarking of Multimedia Contents, vol. 3657, 25(1999).

[7] Jessica Fridrich, Miroslav Goljan, Comparing Robustness of Watermarking Techniques. Proc. of SPIE Vol. 3657 (Security and Watermarking of Multimedia Content), San Jose, Jan 25-27, 1999, pp. 214-225.

[8] I. Djurovic, S. Stankovic, and I. Pitas, Digital watermarking in the fractional Fourier transform domain. J. of Network and Computer Applications 24(4), 167-173 (2001)

[9] K. K. Sharma and Dharmendra Kumar Fageria , Watermarking based on image decomposition using self-fractional Fourier functions. Journal of Optics, 2(40),pp 45-50 (2011).

[10] J. B. Sharma, K.K. Sharma, Vineet Sahula, Digital Image Dual Watermarking using Self-Fractional Fourier Functions, Bivariate Empirical Mode Decomposition and Error Correcting Code. Accepted in Journal of Optics on 24 December 2012.

[11] N. Bi, Q. Sun, D. Huang, Z. Yang, and J. Huang, Robust image watermarking based on multiband wavelets and empirical mode decomposition. IEEE Trans. Image Proc. 8(16), pp. 1956–1996(2007)

[12] Taghia, Jalil, Doostari, Mohammad Ali, Taghia, Jalal, An Image Watermarking Method Based on Bidimensional Empirical Mode Decomposition. Congress on Image and Signal Processing,Volume: 5 pp. 674 – 678 (2008)

[13] Y. Lee, J. Nah, J. Kim, Digital Image Watermarking Using Bidimensional Empirical Mode Decomposition in Wavelet Domain. IEEE International Symposium on Multimedia (2009)

[14] A. P. Petitcolas, Watermarking schemes evaluation. IEEE Signal Processing Mag. 5(17), 58–64, (2000)

[15] Mohammad Ali Akhaee, S. Mohammad Ebrahim Sahraeian, Bulent Sankur, and Farokh Marvasti, Robust Scaling-Based Image Watermarking Using Maximum-Likelihood Decoder With Optimum Strength Factor, IEEE Transactions on Multimedia, Vol. 11, No. 5, Aug. 2009.