

Geometric Robust Multimodal Biometric Watermarking Scheme for Copyright Protection of Digital Images

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ABSTRACT

This paper proposes a copyright protection system using multimodal biometrics for content protection of digital images. Two biometric traits, one physiological (face) and one behavioral (offline handwritten signature) of the legitimate owner are used as watermarks. These watermarks are embedded at different levels of resolution to the high frequency wavelet coefficients through optimal control of the embedding factor. Experimental evaluation confirms the imperceptibility and robustness of the scheme against a family of typical image distortions functions like Jpeg Compression, filtering etc as well as geometric attacks such as scaling, rotation and combined attacks.

General Terms

Pattern Recognition, Digital Rights Management, Copyright Protection.

Keywords

multimodal biometrics, lifting wavelet transform, biorthogonal wavelets, structural similarity index measure.

1. INTRODUCTION

“A picture is worth a thousand words”, this famous anecdote specifies the amount of information that a picture is capable of conveying. Technological advancements in acquisition, processing and storage have made it possible to capture, store and disseminate life-like images, at the same time raised the threat of manipulation, altering or permanent tampering of this data. There is hence a need felt to provide an authentication data within this image data to ensure the originality and copyright protection. This process of adding small distortions to image by exploiting the redundancy in image data and the fact that Human Visual System is also insensitive to such distortions is called watermarking. Watermarking is the best remedy for protecting and preserving the rightful ownership of any useful data. The image coefficients can be perturbed either spatially or after the image has been transformed in frequency domain. While the former technique involves random selection of subsets of host image for the purpose of watermark insertion, the latter inserts the same into the coefficients of the transformed image. The most common image transforms used are Discrete Fourier Transform (DFT), Discrete Cosine Transform (DCT) or Discrete Wavelet Transform (DWT).

Biometric watermarking is a watermarking technique in which a biometric trait of a person like fingerprint, face, voice or iris is used as the watermark. As biometric traits are unique to an individual, their use as watermarks offer an enhanced

access control mechanism, and serve as stronger deterrents to piracy.

This paper proposes a copyright protection using multimodal biometrics for content protection of digital images. Two biometric traits, one physiological (face) and one behavioral (offline handwritten signature) of the legitimate owner are used as watermarks. These watermarks are embedded at different levels of resolution to the high frequency wavelet coefficients through optimal control of the embedding factor. Experimental evaluation confirms the imperceptibility and robustness of the scheme against a family of typical image distortions functions like Jpeg Compression, filtering, scaling. The rest of this paper is organized as follows. Section II reviews biometric watermarking implementations for image data and the concept of lifting wavelet transform. Section III outlines the proposed algorithm framework. Section IV illustrates the optimization of embedding factor. The experimental results and discussions are presented in Section V. The paper is summed up and concluded in Section VI.

2. RELATED WORK

2.1 Literature review

Biometric digital watermarking was primarily proposed by A.K.Jain and his research team. Jain and Umut [1] proposed multimedia content protection framework that is based on biometric data of the users. Kundur and Hatzinakos [2] were the pioneers in suggesting a watermarking model using biorthogonal wavelets based on embedding a watermark in detail wavelet coefficients of the host image. The model proposed was robust against numerous signal distortions, however it was non-blind. Yang [3] in his paper simulates under a spread-spectrum watermarking framework where a Gaussian distributed watermark is injected into the largest wavelet coefficients to find the best biorthogonal wavelet filter for multi resolution image watermarking. The performance of seven integer biorthogonal wavelet bases is evaluated and it is observed that the 917-F wavelet provides a substantial edge“ when all detail sub bands are eligible for watermarking. The effect of using even-length and odd length biorthogonal wavelets for watermarking have been discussed in [4] and [5] respectively. Both these techniques were robust against several attacks, but were presented for the sake of detecting the presence of a watermark not for extracting it. M.Vasta[6] presented a novel biometric watermarking algorithm for improving the recognition accuracy and protecting the face and fingerprint images from tampering. He made use of multi resolution DWT to embed face image in a finger print image. V-Support Vector Machine is exploited to enhance the quality of the extracted face image. Low et al. [7] proposed to adaptively fuse Least Significant Bit (LSB) and

Discrete Wavelet Transform (DWT)-based approaches into a unison framework, which to be known as LSB-DWT scheme. The performance of LSB-DWT scheme is validated against simulated frequency and geometric attacks. Namboodiri, Jain [8] presented an LSB-based biometric watermarking scheme where a digital document was spatially watermarked with online handwritten signature. Reddy et al. [9] proposed a method in which the authors used a gray scale logo as watermark. Further, they used the model of Barni et al. [10] to calculate the weight factors for wavelet coefficients of the host image. They extracted watermark from the distorted image by taking into consideration the distortion caused by the attacks. Fig 1 presents a generic biometric watermark extraction and embedding algorithm.

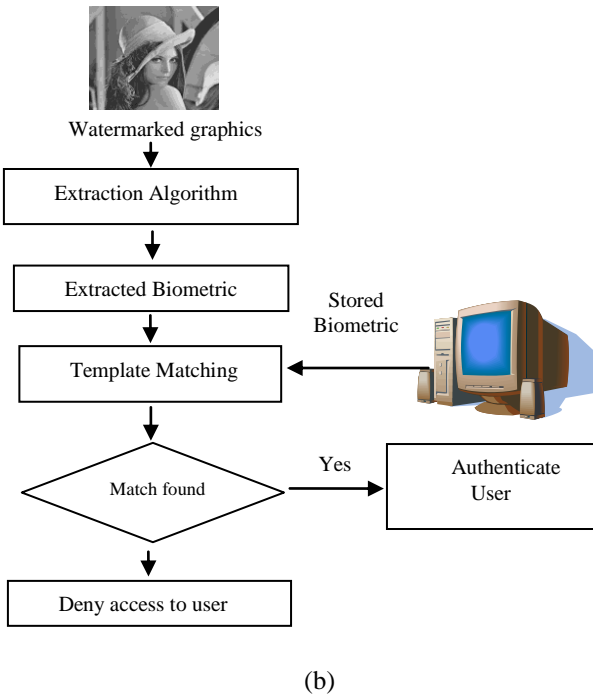
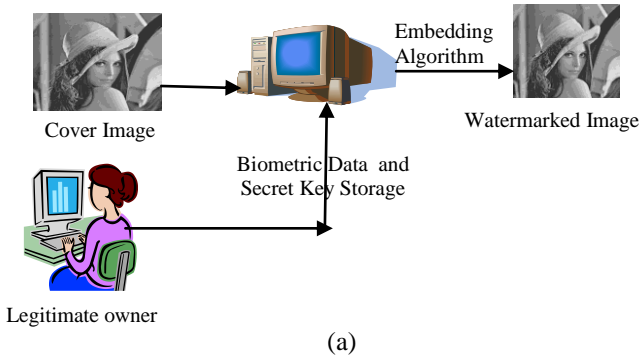


Fig 1: (a) Generic biometric watermark embedding (b) Generic biometric watermark extraction and authentication.

2.2 Lifting Wavelet Transform Using Biorthogonal Wavelets

In the proposed algorithm, lifting scheme proposed by Swelden [11] has been used for multiresolution decomposition of the host image. Computation of LWT can be carried out either using convolution based (filter bank) procedures or lifting based procedures. The lifting wavelet

transform is widely used in signal processing because of its efficient implementation with low memory and computational complexity [12]. Figure 2 depicts the process of lifting wavelet transform and inverse lifting wavelet transform

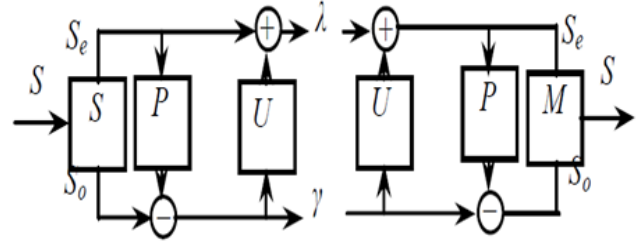


Fig 2: Basic block diagram of lifting wavelet transform

The lifting algorithm consists of three phases: Split, Predict and Update. The 2-D image $f(x, y)$ passes through the following steps to obtain the wavelet coefficients.

- Split: $f_e(x, y) = f(x, 2y)$ (1)

- $f_o(x, y) = f(x, 2y + 1)$ (2)

- Predict: $\gamma(x, y) = f_o(x, y) - P[f_e(x, y)]$ (3)

- Update: $\lambda(x, y) = f_e(x, y) + U(x, y)$ (4)

The lifting wavelet transform used in the present context has been strengthened by using biorthogonal wavelet transform. A biorthogonal wavelet is a wavelet where the associated wavelet transform is invertible but not necessarily orthogonal. Designing biorthogonal wavelets allows more degrees of freedom than orthogonal wavelets. One additional degree of freedom is the possibility to construct symmetric wavelet functions [13].

The property of perfect reconstruction and symmetric wavelet functions exist in biorthogonal wavelets because they have two sets of low pass filters (for reconstruction), and high pass filters (for decomposition). Another advantageous property of biorthogonal over orthogonal wavelets is that they have higher embedding capacity if they are used to decompose the image into different channels. In the case of Biorthogonal wavelet, rather than a single scaling function there is a dual scaling function and mother wavelet.

$$\phi_k^n(x) = 2^{\frac{n}{2}} \phi(2^n x - k) \quad (5)$$

$$\psi_k^n(x) = 2^{\frac{n}{2}} \psi(2^n x - k) \quad (6)$$

The correlation is calculated between the embedded watermarks and the image decomposition coefficients obtained using classical LWT and Biorthogonal LWT. The Biorthogonal LWT provides lower correlation with the embedded watermarks due to the complementary information present in two wavelet systems that offers better directional selectivity compared to classical transform.

3. PROPOSED METHOD

In the proposed algorithm, the classic Cox's digital watermarking [13] algorithm concept has been suitably modified to embed two biometric traits i.e. an offline handwritten signature and a face image of the owner of digital image. The host image is decomposed using lifting wavelet transform using biorthogonal wavelets as described in [14]. The watermarks are embedded at different levels of resolution hence providing geometric attack resilience to the proposed algorithm. The biometric images used are gray

scale images and which are binarized using algorithm described in [15].

3.1 Watermark Embedding

The following steps are followed for the watermark embedding.

- Let $I_{original}$ be the host image of size $M \times N$.
- Let wm_1 and wm_2 be the signature watermark and face watermark of length $(M_s \times N_s)$ and $(M_f \times N_f)$ respectively. The feature vectors are generated after binarization by converting the watermarks into a 1D array of size $((M_s \times N_s), 1)$ and $((M_f \times N_f), 1)$ resp.
- Secret key K_1 is entered to generate pseudorandom sequences for signature watermark insertion.
- For embedding the signature image, the Lifting Wavelet Transform $I_{lwt(i,j)}$ of the host image is calculated for level 2 decomposition, sub-bands of size $\frac{N}{2^2} \times \frac{N}{2^2}$ are obtained.
- The horizontal detailed band is used for watermark insertion as embedding in the approximation band causes more perceptible changes to the watermarked image. The watermark is embedded as follows:

```

for i = 1: length(wm1)
    random_seq_1
        = round(2 * (rand(M/4, N/4)
            - 0.5));
    if (wm1(i) == 0)

```

$$HH_2 = HH_2 + k * random_seq_1;$$

end
end

k is the strength factor used for embedding. Any visible effect, such as blocking, due to manipulation of these wavelet coefficients is controlled using parameter optimization method as described in the subsequent section. Experimentally it has been observed that this factor must be < 1 .

- Secret key K_2 is entered to generate pseudorandom sequences for face watermark insertion.
- For embedding the face image, the Lifting Wavelet Transform $I_{lwt(i,j)}$ of the host image is calculated for level 3 decomposition, sub-bands of size $\frac{N}{2^3} \times \frac{N}{2^3}$ are obtained.
- The level 3 horizontal detailed band is used for embedding the face image as follows:

```

for i = 1: length(wm2)
    random_seq_2
        = round(2 * (rand(M/8, N/8)
            - 0.5));
    if (wm2(i) == 0)
        HH3 = HH3 + k * random_seq_2;
    end
end

```

- The watermarked image I_{wm} is obtained by applying inverse LWT twice as shown in fig 3.

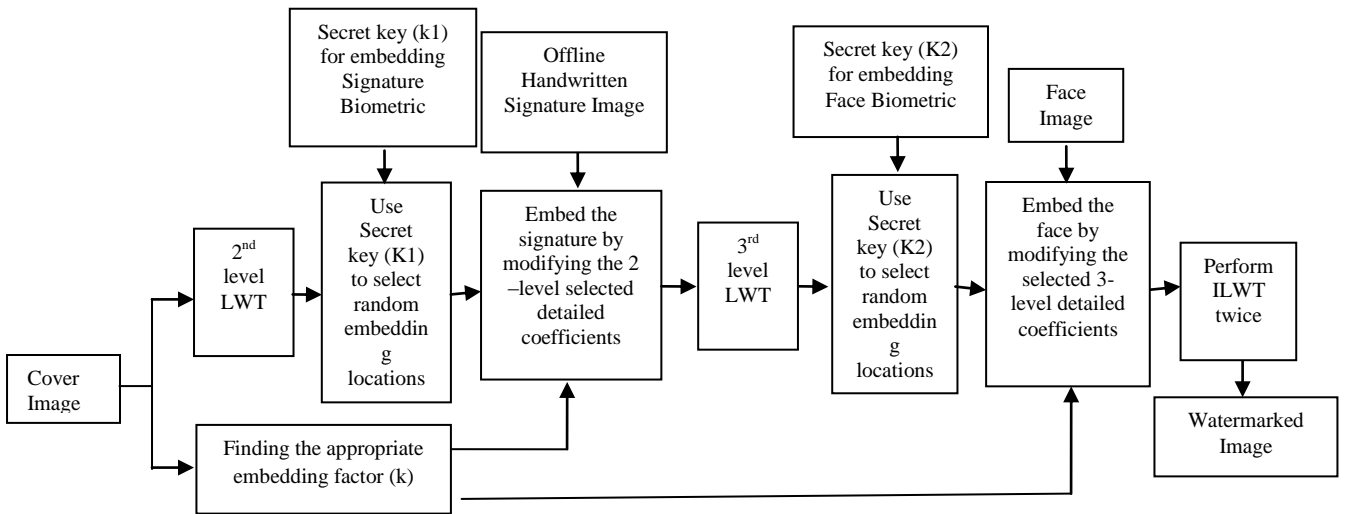


Fig 3: Block Diagram of proposed watermarking embedding scheme.

3.2 Watermark Extraction

The extraction process uses the correlation detector to recover the embedded watermarks by using the same secret keys for random sequence generation as were used for embedding. Face watermark is initially extracted after the user has entered the secret key K_2 as follows:

```

for (i = 1: length(wm2))
    random_seq_2
        = round(2 * (rand(M/8, N/8)
            - 0.5));

```

$$correlation_face(i) = corr2(HH_3, random_seq_2);$$

```

if (correlation_face(i) > std(correlation_HH3))
    wm2(i) = 0;

```

else $wm_2(i) = 1;$

end

The extraction process uses the correlation detector to recover the embedded watermarks by using the same secret keys for random sequence generation as were used for embedding.

Signature watermark is extracted after the user has entered the secret key K_1 as follows:

```

for (i = 1: length(wm1))

```

```

random_seq_1
= round(2 * (rand(M/4, N/4)
- 0.5));

correlationsignature (i)
= corr2(HH2, random_seq_1);
end

if (correlationsignature(i)
> std(correlation_HH2))
wm1 (i) = 0;
else wm1 (i) = 1;
end

```

The same is depicted in fig. 4.

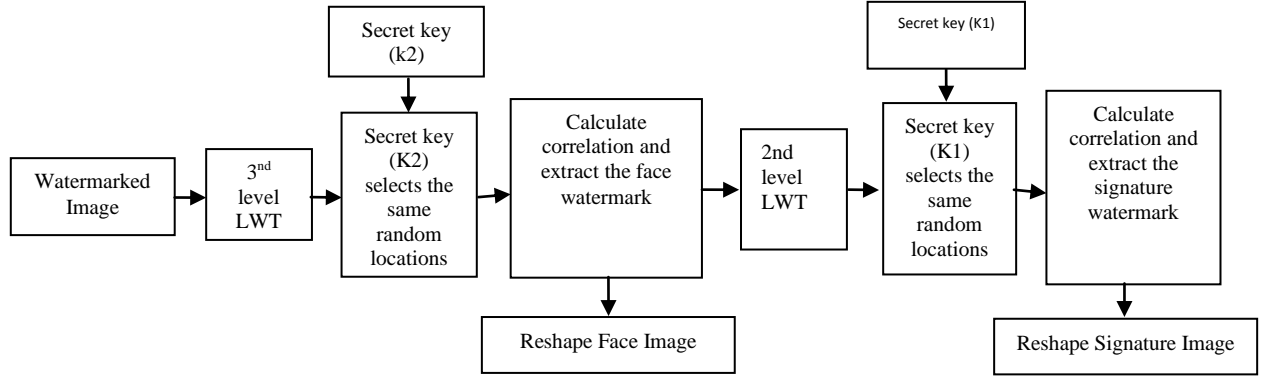


Fig 4: Block Diagram of proposed watermarking extraction scheme.

4. EMBEDDING FACTOR OPTIMIZATION

The embedding factor k is of vital significance to any watermarking scheme. Its value has a direct implication on the following two factors

- 1) Robustness: As k increases, the algorithm becomes more resilient to attacks and hence more robust.
- 2) Imperceptibility: As k increases, the image becomes more distorted and hence imperceptibility is not achieved.

Due to this trade-off, a multi objective optimization technique is used to select appropriate strength factor so as to maintain imperceptibility with improved attack resilience. To show the effect of k on image distortions, the performance evaluation of the method has been done using image quality determination metric Structural Similarity Index Measure (SSIM) [16]. While PSNR is a commonly used metric, SSIM index is an advanced method for measuring the similarity between two images. SSIM is designed to improve on traditional methods like PSNR and MSE by modelling image distortion as a combination of three factors considering the properties of Human Visual System (HVS). These three factors are loss of correlation, luminance distortion and contrast distortion.

Let $I_{original} = x$ be the original image and $I_{wm} = y$ be the manipulated (either watermarked or attacked image), the SSIM quality index is defined as

$$SSIM(x, y) = \frac{(2\mu_x\mu_y + C_1)(2\sigma_{xy} + C_2)}{(\mu_x^2 + \mu_y^2 + C_1)(\sigma_x^2 + \sigma_y^2 + C_2)} \quad (8)$$

$\mu_x, \mu_y, \sigma_x^2, \sigma_y^2$ are the mean value and variances of x and y respectively and

$$\sigma_{xy} = \frac{1}{N-1} \sum_{i=1}^N (x_i - \mu_x)(y_i - \mu_y) \quad (9)$$

N = Number of samples. Parameters C_1 and C_2 are defined as

$$C_1 = (K_1 l)^2, \quad C_2 = (K_2 l)^2$$

l is the dynamic range of the pixel values (for gray scale images it ranges from 0-255) and $K_1, K_2 < 1$ are small

constants. The standard value for K_1 is taken as 0.01 while for K_2 , it is 0.03. The image perceptual comparison is best when the size of x and y is the same. In practice, one usually requires a single overall quality measure of the entire image. We use a mean SSIM (MSSIM) index to evaluate the overall image quality.

$$MSSIM = \frac{1}{M} \sum_{j=1}^M SSIM(x_j, y_j) \quad (10)$$

Thus the parameter optimization will be achieved using two objective functions $f_i(k) = 1 - SSIM(k)$ and $f_r(k)$. $f_i(k)$ shows the effect of k on imperceptibility while $f_r(k)$ shows the impact of k on attack resilience and is calculated as the error probability function described as

$$P_{error} = \frac{1}{2} P_{error|0} + \frac{1}{2} P_{error|1} \quad (11)$$

Both the functions have a contrasting nature while the imperceptibility increases monotonically with k , robustness is monotonically decreasing. Thus the aim is to find an optimum value of k so as to minimize both the functions. The goal attainment method given in [18] provides a solution to find optimum k value according to SSIM which gives satisfactory level of attack resilience. In this approach the value $0.5 < k < 0.7$ is found to be optimal for most of the images.

5. EXPERIMENTAL RESULTS AND DISCUSSIONS

5.1 Experimental Setup

It is important to evaluate an image watermark algorithm on many different images. Images should cover a broad range of contents and types. The proposed technique has been tested on standard evaluation images for watermarking algorithms. To evaluate the performance of the proposed watermarking algorithm, MATLAB platform is used. The standard Yale database for 50 face images has been used and a signature database consisting of signatures of 50 users has been used for experimental purposes.

Fig 5 shows the original image as well as watermarked image and the original as well as extracted watermarks. In all

the above images, the same face and signature image has been used as a watermark.

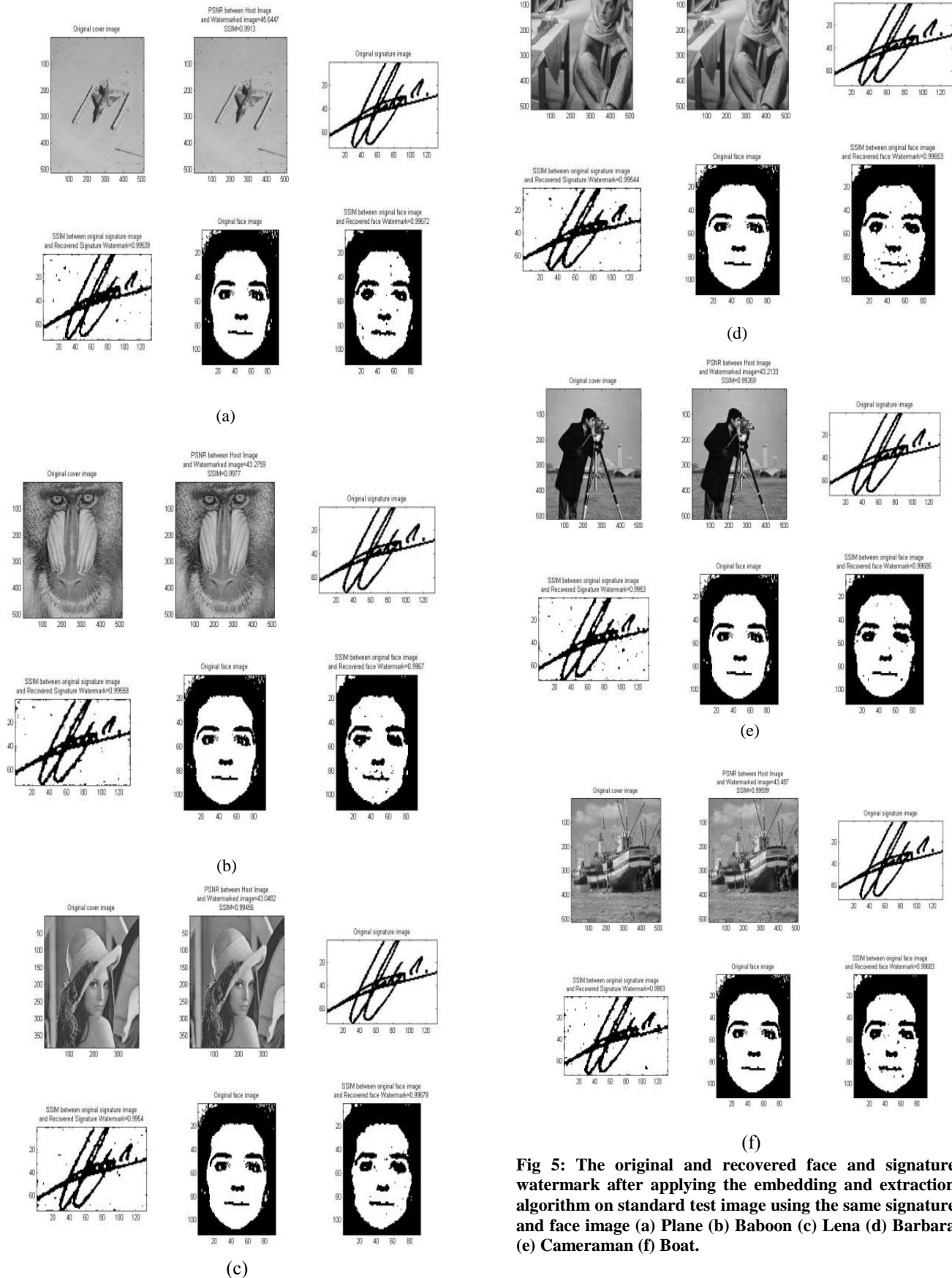


Fig 5: The original and recovered face and signature watermark after applying the embedding and extraction algorithm on standard test image using the same signature and face image (a) Plane (b) Baboon (c) Lena (d) Barbara (e) Cameraman (f) Boat.

5.2 Robustness Tests under StirMark Attacks

The robustness of the proposed algorithm has been tested against the benchmark StirMark [17] attack. These attacks include common signal processing attacks like median filtering, Gaussian noise addition, Jpeg Compression, or geometric attacks like resizing, rotation or a combination of both.

5.2.1 Median filtering

The most common signal processing attack in digital image is filtering. Table I shows the MSSIM values for the extracted face and signature watermarks, after applying median filter of varying filter lengths. It can be observed that even after the degradations caused in the images, the recovered watermarks are very much recognizable. Some results for the same are shown in fig 6.

Table I: MSSIM results of extracted watermarks Median Filtering with different filter sizes attack

Image	3 x 3		5 x 5		7 x 7	
	Face	Signature	Face	Sign	Face	Sign
Barbara	0.99748	0.99568	0.99746	0.99609	0.99749	0.99583
Lena	0.99644	0.99536	0.99644	0.99518	0.99646	0.99539
Boat	0.99636	0.99627	0.99616	0.99578	0.99627	0.99631
Plane	0.99742	0.99632	0.99748	0.9965	0.99752	0.99605
Baboon	0.99618	0.99512	0.99616	0.99509	0.99604	0.99511

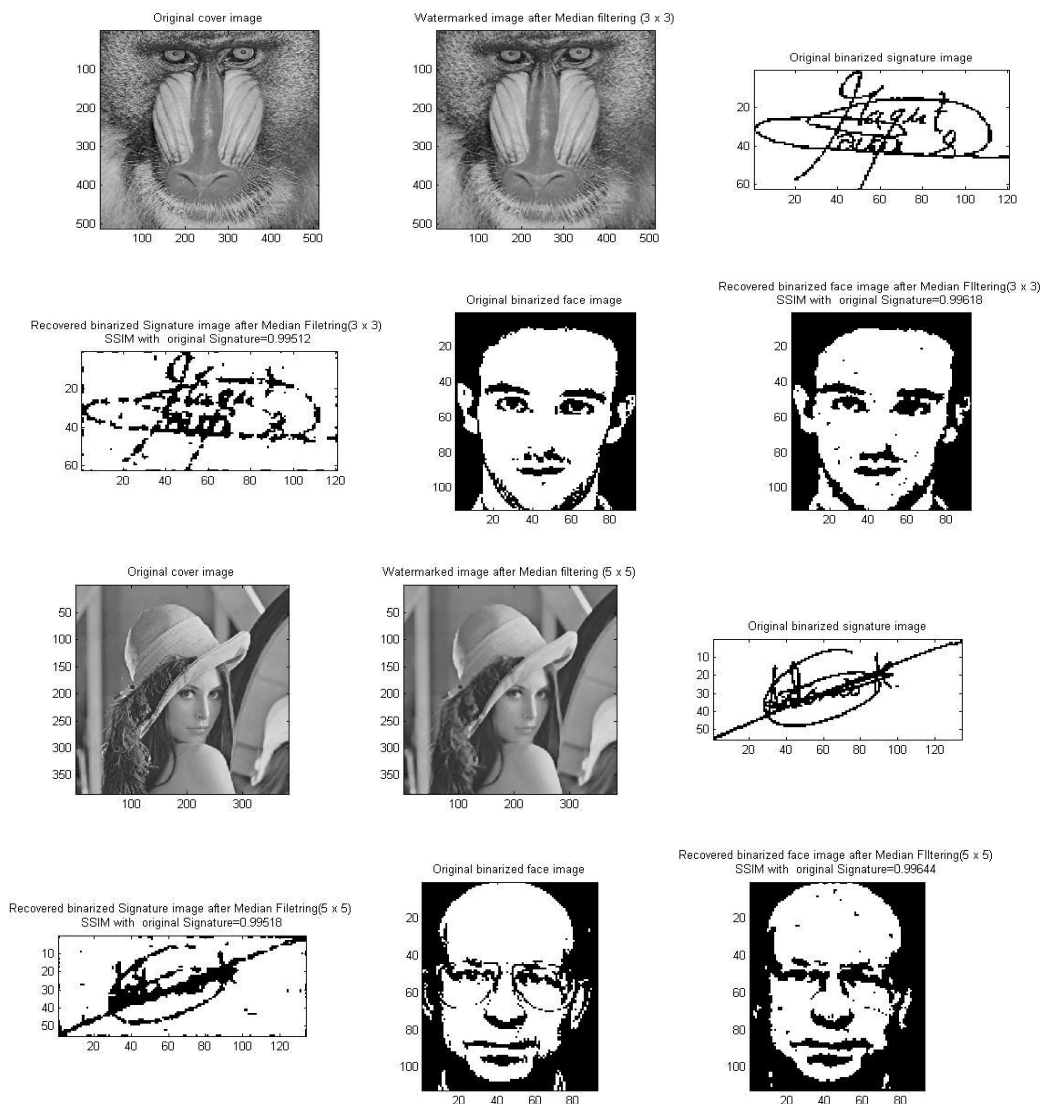


Fig 6: Extracted signature and face watermarks after median filtering on different images.

5.2.2 Gaussian noise

Noise is added to image to degrade its quality. Robustness against additive Gaussian noise is estimated by degrading the watermark image by randomly adding

Gaussian noise with mean 0 and variance 0.01. Table II shows the MSSIM values for various recovered watermarks while fig 7 shows the results pictorially.

Table II: MSSIM results of extracted watermarks Under Gaussian filtering Attack mean=0, variance=0.01

Image	Gaussian filtering	
	Face	Signature
Barbara	0.99671	0.99514
Lena	0.99753	0.99578
Boat	0.99597	0.99544
Plane	0.99753	0.99578
Baboon	0.99747	0.99512

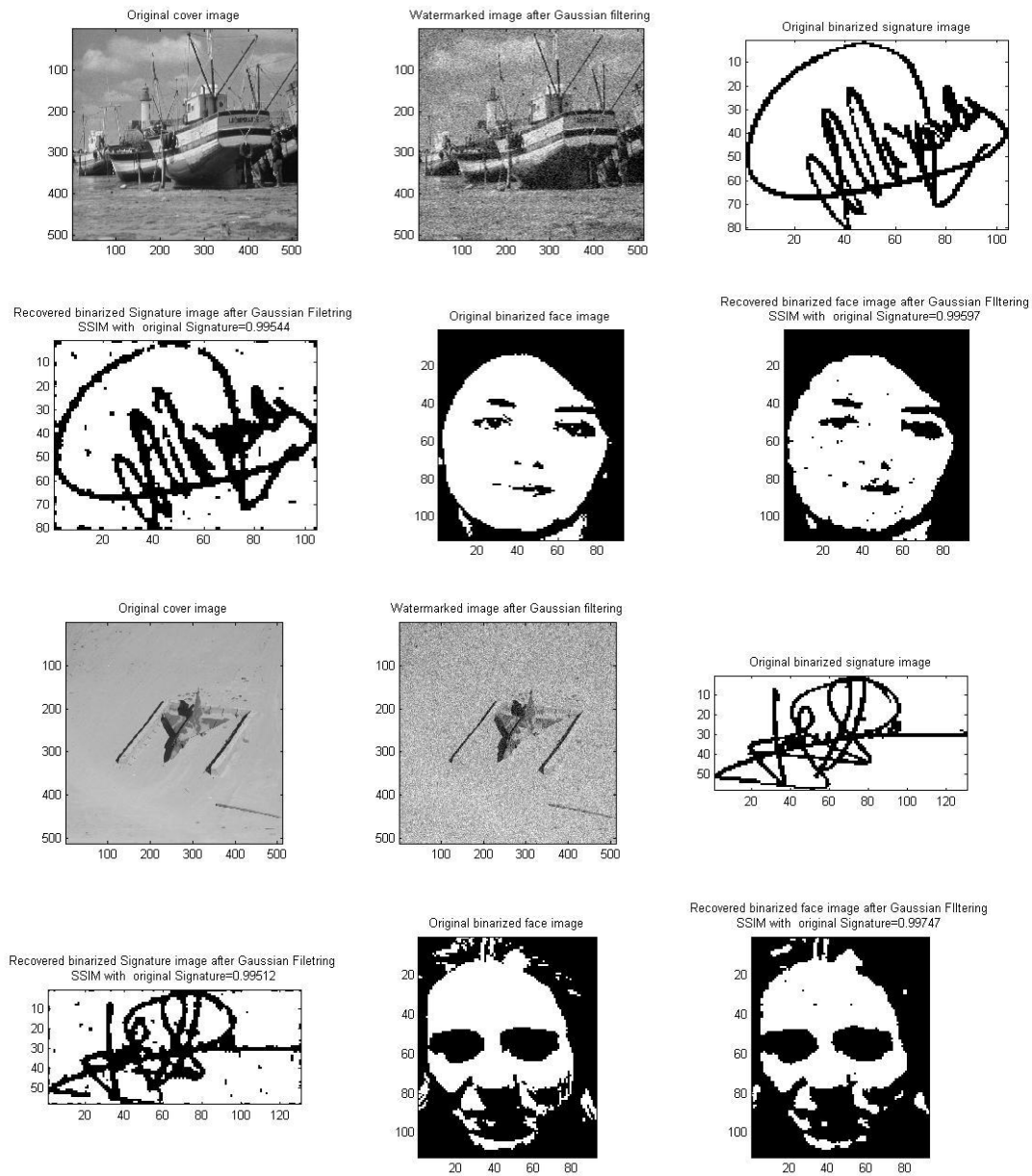


Fig 7: Extracted watermarks after addition of Gaussian noise to watermarked image

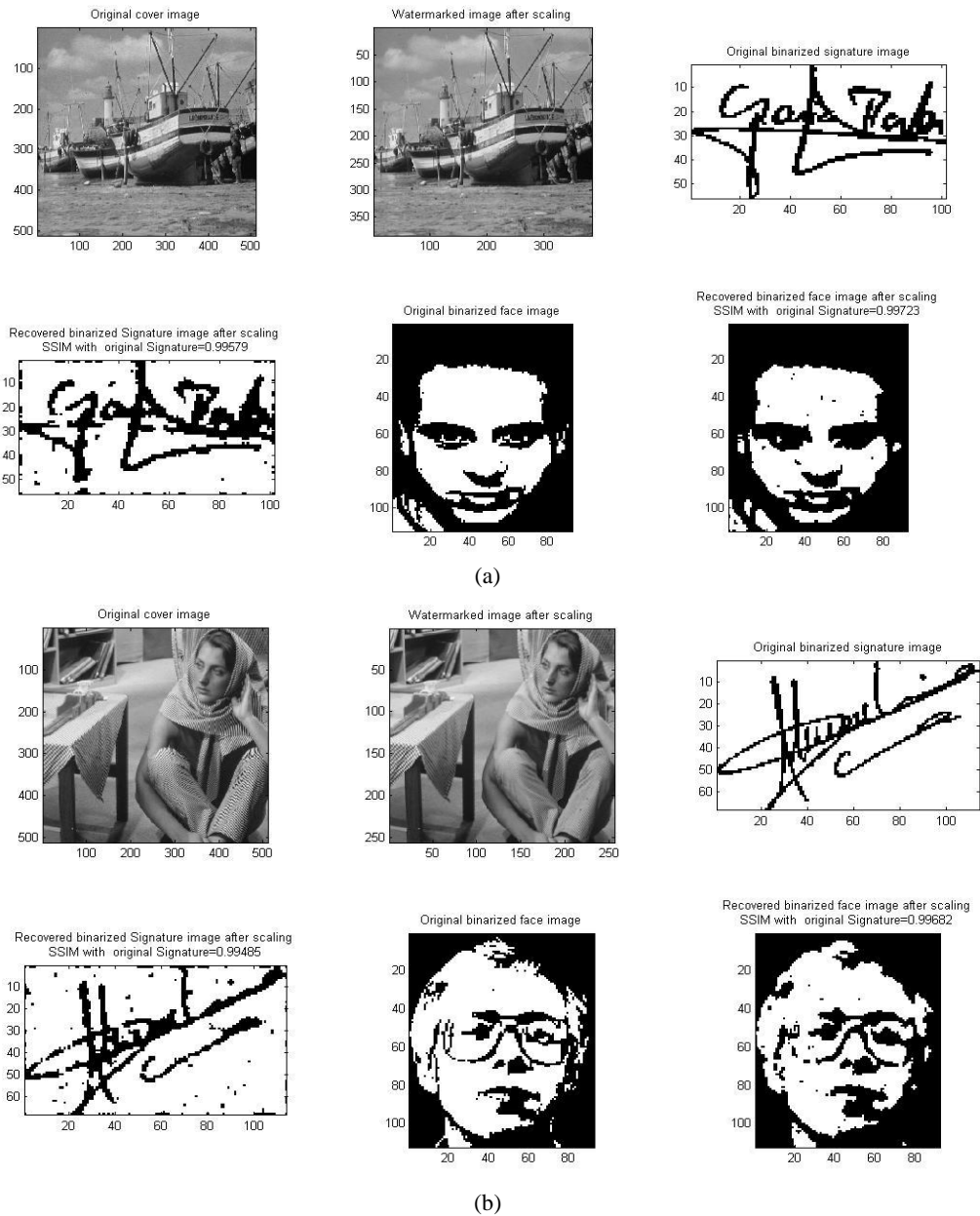
5.2.3 Scaling

The images were either cropped or resized.

Table III and fig 8 present the results of the effect of various scaling factors on the watermarked images.

Table III: MSSIM results of extracted watermarks under scaling Attack

Image	<u>Scaling Factor</u>							
	0.5		0.75		1.5		2.0	
	Face	Signature	Face	Signature	Face	Signature	Face	Signature
Barbara	0.99682	0.99485	0.99648	0.99552	0.9965	0.99528	0.99697	0.99503
Lena	0.99597	0.99539	0.99629	0.99619	0.99619	0.99569	0.99605	0.99535
Boat	0.99735	0.99523	0.99723	0.99741	0.99741	0.99587	0.99759	0.99566
Plane	0.99665	0.99526	0.99674	0.9966	0.9966	0.99505	0.9967	0.99547
Baboon	0.99562	0.99643	0.99595	0.99587	0.99587	0.99648	0.99583	0.99723



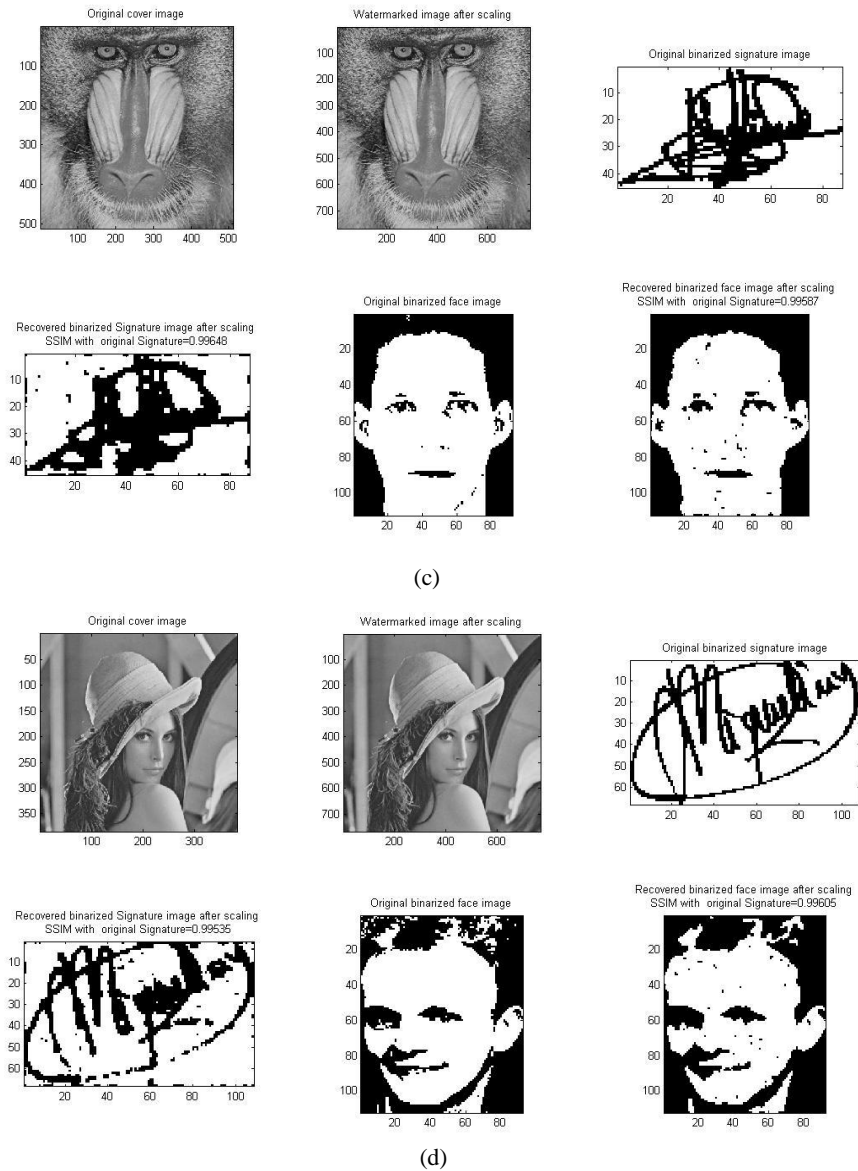


Fig 8: Effect of various scaling factors on the recovered watermarks (a) 0.5 (b) 0.75 (c) 1.5 (d) 2.0

5.2.4 JPEG Compression

Another most common manipulation in digital image is image compression. To check the robustness against Image Compression, the watermarked image is compressed using

JPEG compression for different compression ratios. MSSIM values for the extracted watermarks are depicted in Table IV and subsequently in fig 9.

Table IV: MSSIM results for JPEG Compression with varying Q-factor

Image	20		40		60		80		100	
	Face	Signature	Face	Signature	Face	Signature	Face	Signature	Face	Signature
Barbara	0.99593	0.99552	0.999596	0.99568	0.99587	0.99567	0.99591	0.99546	0.99594	0.99557
Lena	0.99739	0.99614	0.99743	0.99592	0.99738	0.99613	0.99736	0.99636	0.99736	0.99612
Boat	0.99743	0.99695	0.9976	0.99684	0.9976	0.99674	0.99758	0.99671	0.99756	0.99663
Plane	0.9972	0.99476	0.99714	0.99495	0.99714	0.99504	0.99708	0.99474	0.99713	0.99512
Baboon	0.99631	0.99545	0.99621	0.99521	0.99624	0.99521	0.99619	0.99516	0.9961	0.99517

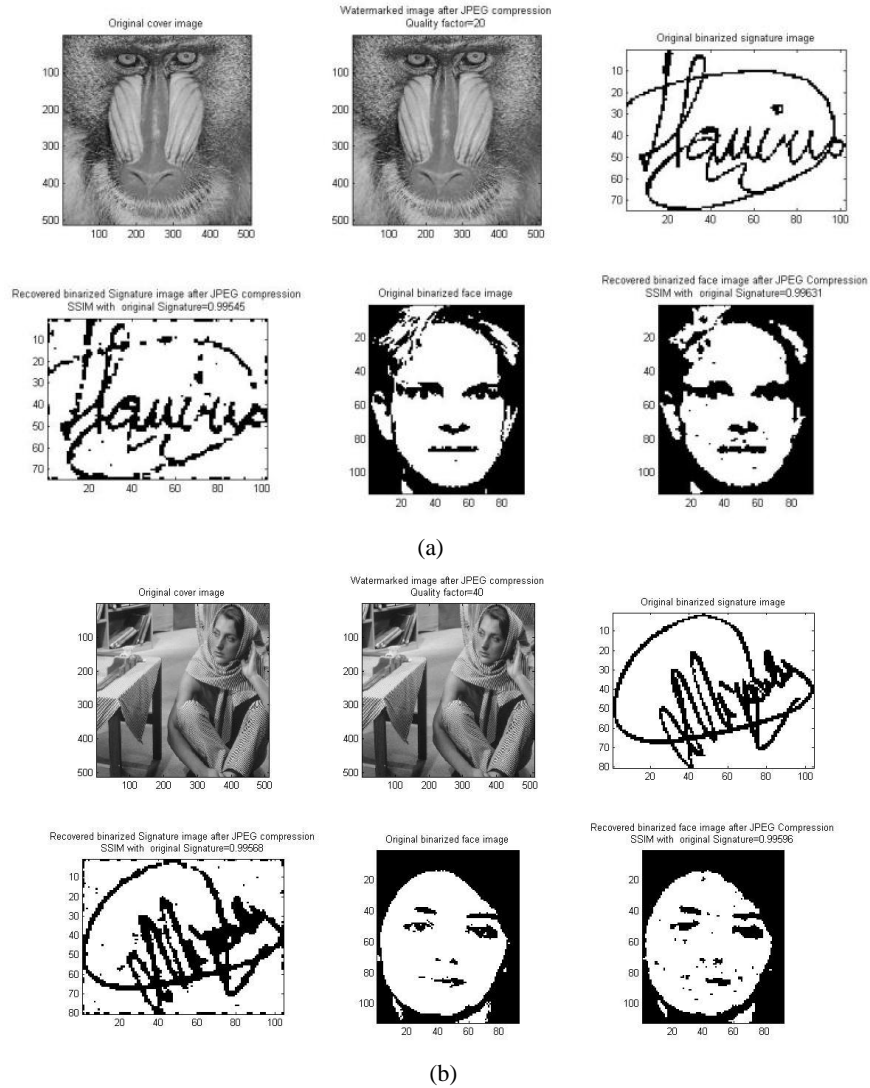


Fig 9: Extracted watermarks after JPEG Compression (a) Q-factor = 20 (b) Q- factor=40

5.2.5 Rotation

In the next experiment, the robustness of the proposed algorithm is tested against rotation attack. The proposed embedding approach is robust to rotation provided that one can compensate for the loss of synchronization. Table V and fig 10 shows the MSSIM values after the watermarked image was rotated in the range of (-5 degree to 5 degree).

5.2.6 Combined Attacks

In addition to the common individual attacks, the robustness of the algorithm was also tested against the combined attacks. The results of the same are presented in table VI.

Table V: MSSIM results of extracted watermarks under rotation attack

Image	Rotation Angle (Degrees)							
	-5		-1		1		5	
	Face	Signature	Face	Signature	Face	Signature	Face	Signature
Barbara	0.99744	0.99512	0.9974	0.99501	0.99719	0.99469	0.99735	0.99484
Lena	0.99659	0.99454	0.99613	0.99456	0.99641	0.99477	0.99624	0.9949
Boat	0.99669	0.99522	0.99661	0.99566	0.9964	0.99534	0.99666	0.99492
Plane	0.99705	0.99524	0.99711	0.99537	0.99697	0.99515	0.99696	0.99459
Baboon	0.99729	0.99553	0.99705	0.99539	0.99721	0.99512	0.99712	0.99499

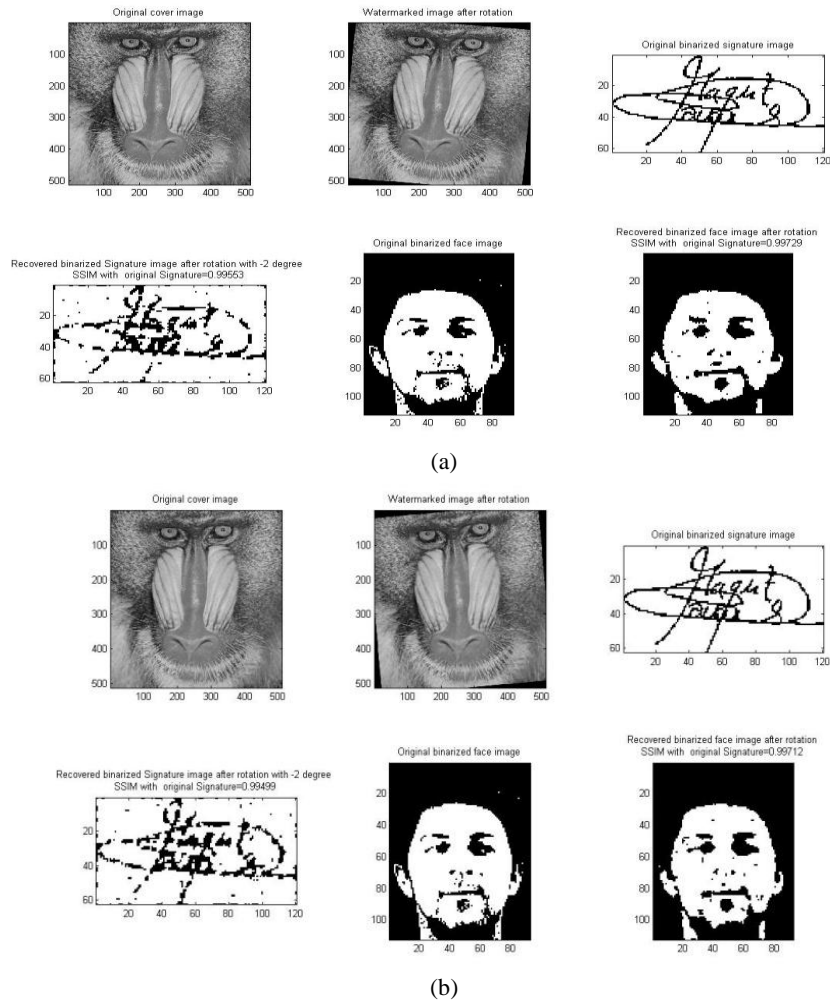
**Fig 10: Extracted watermarks after (a) -5 degree rotation (b) 5 degrees rotation**

Table VI: MSSIM results of extracted watermarks under Combined Attacks

Attack	Baboon		Barbara		Boat		Lena		Plane	
	Face	Sign	Face	Sign	Face	Sign	Face	Sign	Face	Sign
JPEG_20 + Scaling(0.5)	0.99584	0.99669	0.99682	0.99539	0.99618	0.99571	0.9963	0.99581	0.99702	0.99505
JPEG_20 + Scaling(2.0)	0.99583	0.99723	0.99697	0.99503	0.99759	0.9566	0.99605	0.99535	0.9967	0.99547
JPEG_20 + Med_filt (3x3)	0.99618	0.99512	0.99748	0.99568	0.99636	0.99627	0.99644	0.99536	0.99742	0.99632
JPEG_20 + Med_filt (5x5)	0.99616	0.99509	0.99746	0.99609	0.99628	0.9963	0.99644	0.99518	0.99752	0.99608
JPEG_20 + Med_filt (7x7)	0.99604	0.99511	0.99749	0.99583	0.99627	0.99631	0.99646	0.99539	0.99752	0.99605
JPEG_20 + Gaussian noise	0.99769	0.99487	0.99644	0.99581	0.99613	0.99581	0.99758	0.996	0.99733	0.99546

6. CONCLUSION

The paper presents a novel biometric multimodal watermarking algorithm using LWT. The watermark is embedded into the high frequency areas of the cover image using Watson's HVS criterion. Watermark detection is done using the correlation detector with the help of biorthogonal wavelets to make the recovery of the watermark better.

A delicate balance has been maintained in the trade-off between imperceptibility and robustness through the multi-objective optimization approach.

The robustness of the proposed method has been experimentally validated using the standard test benchmarks and the results are far more superior than any approach used for multimodal biometric embedding. The work can be further extended by incorporating pattern algorithms for the purpose of authentication of the extracted watermark.

7. REFERENCES

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