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A Chaos Based Non-Blind Digital Image Watermarking in Wavelet Transform Domain

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Abstract: Digital Image Watermarking is used to protect images from illegitimate access. Two techniques are merged to enhance the imperceptivity of the image i.e Singular Value Decomposition (SVD) and Redundant Discrete Wavelet Transform (RDWT) and in YCbCr color space by creating different chaos in the watermark image. This technique can help to embed more number of watermark bits in the colored host image to enhance the safety and robustness of the watermarks. The embedding capacity was increased by using the idea of watermark in watermark. Hence, the security was increased by embedding the encrypted watermarks in the host image. This results in an additional level of security for watermarking. For instance, if the attacker hacked the watermarked image, still he will not be able to identify the watermark because it is encrypted using chaotic map and hence the ownership remained secure. The proposed technique was tested in contradiction of multiple geometrical attacks (median filtering, noise addition, cropping etc.) and hence resulted in the better extraction of the watermark. The increase in performance can be evaluated using results of multiple parameters i.e Mean Square Error (MSE), Peak Signal-to-noise Ratio (PSNR), Normalized Correlation (NC) and Root Mean Square Error (RMSE).

Keywords: Non-Blind, Chaotic behavior, Geometrical attacks, YCbCr color space.

I. INTRODUCTION

Watermarking is a method that is used to protect the ownership of the users from attackers. It mainly deals with security-oriented applications, copyright protection or other ownership authentication, and hence it will affect the survival of watermark i.e containing both positive and negative influences [1]. In case of secure watermarking, the hidden data will be reachable only at the leakage of a substantial removal of the quality of the cover image. While expecting malicious manipulations, it is to be noted that foes are aware of the watermarking algorithm and therefore they can visualize different watermarking removal steps. The security lies on key choice[5].

Digital Watermarking is better than digital signatures as the metadata is inserted in the cover signal of any kind of hypermedia file in a very particular manner that it does not require extra bandwidth. For history, reliability and genuineness of a digital content provides guarantee over the consumption of digital signatures [5]. Header part of the article is consumed for appending of digital signature. Hence this appending requires extra bandwidth resulting in overhead. Cryptography is an entirely dissimilar practice. Cryptography merely delivers safety through encryption and decryption. Still, encryption does not support the vendor observing the way of a genuine client to see the information when decrypted. Hence, results in no guarantee after decryption. As shown in the figure 1, in such a case, illegal copies of the digital content can be made by the Customers. In contrast to cryptography, even after watermarks are decoded, the content remained protected.

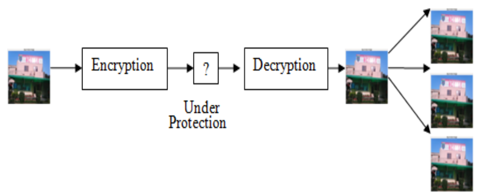

Fig 1: Cryptography cannot prevent replication of digital images

II. PREVIOUS TECHNIQUES

To enhance the security of the images, an additional factor was introduced named as Singular Value Decomposition (SVD). Mostly two commonly techniques are DWT-DCT and DWT-SVD. The combination of two or more techniques is also called "fusion" or "hybrid".

A. Discrete Wavelet Transform

Discrete Wavelet Transform is abbreviated as DWT. The transformation is done on sampled data, e.g. values in an array are transformed into wavelet coefficients. The reverse process is used to convert the wavelet coefficients into the actual data that was sampled and hence it is known as Inverse Discrete Wavelet Transformation (IDWT). DWT divide the image into 4 bands i.e "LL, LH, HL and HH" [6].

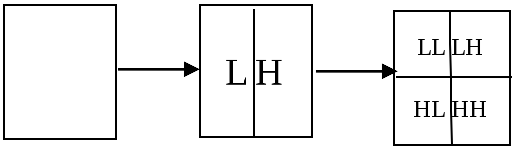

Fig 2: One level DWT decomposition step

The categorization of an image is done in two ways i.e high-pass and low-pass. Firstly, rows are filtered. Finally, the down- sampling is done on both filters by dividing into two again [16]. Figure 3 represents the 1-level DWT of the two dimensional image

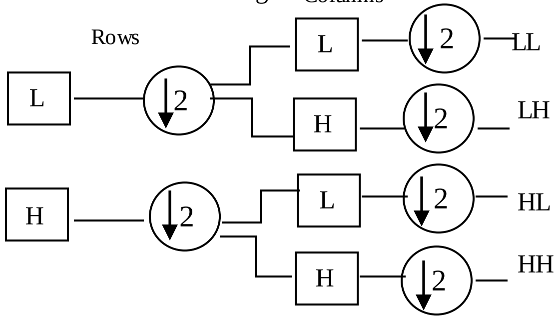

Fig 3: One DWT decomposition step(2D)

Low-pass filtering results in LL subband containing irregular portrayal of the image and contains both the rows and columns. Hence, diagonals relied in high-frequency components and considered as high-pass filtered in both directions (fig 3). Low-Low subband is referred as "approximation subband". The LH and HL images are the resultant in alternate directions. LH depends on horizontal edges which contain mostly vertical information, while. HL contains vertical edges that represent the horizontal detail information [7]. All these subbands HL, LH and HH except LL are referred as "detail subbands" [20].Following figures shows the pyramidal decomposition in 2-level DWT.

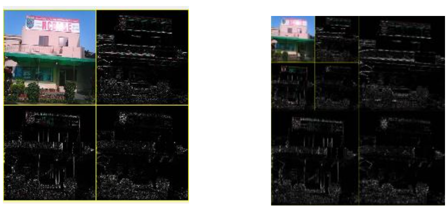

Fig 4: Pyramidal Decomposition of Host image (NCBAE.jpg) at level 1 and 2 ((LL subband)

The extracted watermark in DWT results in the distortion of the pixels. This issue is resolved in RDWT (Redundant/Shift-invariant Discrete Wavelet Transform) and also referred as un-decimated DWT, over-complete DWT [5].

B. SVD (Singular Value Decomposition)

It is a mathematical concept that is commonly used in matrices i.e factorization of a real matrix as well as complex matrix. It has several applications in different arenas of the image processing [4]. It is considered as a linear algebra transform. SVD of an image A is shown having dimension in the arrangement of N*N and it is written as follows:

$$A=USV^T$$

Where,

S defines "diagonal matrix or singular matrix" having positive values of matrix A.

U, V are "orthogonal matrices" that defines the geometrical specifications of the original image are basically specified. Right singular matrix, i.e., V defines the vertical properties of actual host or watermark image and Left singular matrix, i.e. U defines horizontal properties of the host or watermark image.

Usually compression, data hiding, noise reduction and watermarking are done using SVD. Following are the main properties of SVD used in digital watermarking scheme.

- Small variations will not affect the robustness of the image.
- Singular Values added a factor of high stability in an image so various attacks does not affect the scheme.

C. Alpha Blending

Alpha Blending Technique is involved in Watermarking [9].It acts as a key used for embedding an image into the host and then extract it back from the watermarked image from the equations given below.

- For Watermarking Embedding:

S_wimg=(beta*S_img1)+(alpha*S_img2);

- For Watermarking Extraction,

S_ewat = (S_wimg - alpha*S_img1)/beta;

Where,
S_wimg =Watermarked Image,
LL= Subband of the Original Image,
S_img2=Watermark Image,
S_ewat =Extracted Watermark Image

α = the scaling factor of the actual image
ß = the scaling factor of the watermark image

D. Chaotic Transformation (Chaos)

The substitution-permutation of the watermark image is carried out by using Logistic map transform [3].It is also considered as the visage alteration. For 3D image, this transformation is defined as

$$x_{n+1} = r\, x_n (1-x_n)$$

Where

r = positive constant
x_n = vertical and horizontal coordinates(watermark image)
x_{n+1} = after scrambling, vertical and horizontal coordinates (watermark image)

After scrambling the image by Logistic map transformation, watermark image will be restored using this equation [17].

E. YCbCr Color Space:

In place of RGB, YCbCr color space is used. It is a one of the commonly used color space that acts as an element of the color image pipeline in images & video schemes. The luma component was considered as Y. It depicts the intensity and Chroma components for red and blue are Cr and Cb respectively. This is an approach of embedding RGB info and not considered an absolute color space. Conversion of RGB color space to YCbCr can be done by using the comparisons below:

$$Y = 0.29R + 0.587G + 0.114B$$
$$Cb = 0.596R - 0.272G - 0.321B$$
$$Cr = 0.212R - 0.532G - 0.311B$$

III. PROPOSED ALGORITHM FOR COLORED IMAGES (RDWT-SVD-CHAOS)

A. Watermark Embedding:

Embedding of the Watermark image is done into the host or cover image [19]. Then Chaos are added according to Logistic map in watermark image by using permutation and hence resulted in an enhanced PSNR value [3][4].

1. Read the color cover or host image (RGB)
2. By altering the color space, RGB Color Image is converted into three different channels Y, Cb, and Cr.
3. Sub-divide the image using 4-level RDWT into LL^4, LH^4, HL^4 and HH^4 subbands on Y channel.
4. Select HH^4 band and perform SVD, results in
   U_img1, S_img1, V _img1.
5. Take Color watermark image, and separate R Channel from RGB Watermark Image.
6. Apply Random permutation (Ranperm) Method using Logistic map Transform to Scramble the R Channel.
7. Extract G Channel from Watermark (RGB).
8. Apply Ranperm Method using Logistic map Transform to Scramble the G Channel.
9. From watermark image, extract B Channel from RGB.
10. Apply Ranperm Method using Logistic map Transform to Scramble the B Color Channel.
11. 3L- RDWT is applied on the R Channel that was scrambled using chaos and hence the image is divided into WLL^3, WLH^3, WHL^3 and WHH^3.
12. On WHH^3 band ,SVD is applied that results in
    U_wimg2, S_wimg2, V _wimg2
13. Insert watermark into the host by adding two constants alpha and beta :

    S_wimg = (ß *S_img1) + (α *S_wimg2)
    where α and ß are scaling factor
    wimg = U_img1* S_wimg *V_img1

14. Apply inverse 4-Level RDWT on wimg to get Y Channel of the Watermarked Image.
15. To get back RGB watermarked image, merge Y, Cb and Cr color channels.

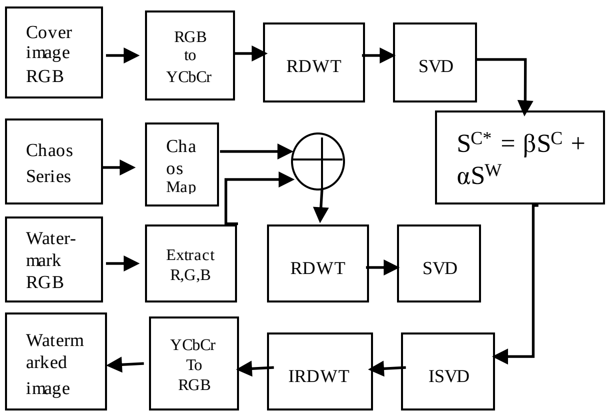

Fig 5: Steps for Embedding the Watermark image Using RDWT-SVD-Chaos

B. Watermark Extraction:

The inverse of the embedding process is the Extraction process. Processing starts from converting the color space from RGB to YCbCr and extract Y channel from both of them. The decomposition is performed on the watermarked image and cover image. By consuming inverse redundant discrete wavelet transform, watermark can be extracted. The extracted watermark has high value of PSNR and NC value that depicts more robustness as compared to existing techniques and it almost retains its value by applying different attacks [21]. Cover image is subtracted from the watermarked image and the scale factor is divided to extract the watermark. Substitution (unscrambling) is then performed to bring the watermark image back. It is noticed that by increasing the values of scale factors, extracted watermark becomes blur. This schemes enhances the PSNR value of the extracted watermark image and made it more robust.

1. Read the host & Watermarked Image.
2. Convert Color Space from RGB to YCbCr for both the cover & Watermarked Image.
3. Perform 4-L RDWT on Y Channel of the host to split host image into LL^4, LH^4, HL^4 & HH^4.
4. Same 4-L RDWT is applied on Y Channel of Watermarked Image to split the Watermarked Image into $WMLL^4$, $WMLH^4$, $WMHL^4$ and $WMHH^4$.
5. Read the original Watermark Image (color).
6. Separate the channels of RGB watermark as R,G and B.
7. Apply Ranperm Method using Logistic map Transform for Scrambling R Channel.
8. Apply Ranperm Method using Logistic map Transform for Scrambling G Channel.
9. Apply Ranperm Method using Logistic map Transform for Scrambling B Channel.
10. Perform 3-L RDWT on shuffled R,G and B channel to split it into WLL^3, WLH^3, WHL^3 and WHH^3
11. On WHH^3 band, SVD is applied that results in
    U_img2, S_img2, V_img2
12. On HH^4 band ,SVD is applied that results in
    U_img1, S_img1, V _img1
13. On $WMHH^4$ band, SVD is applied that results in
    U_wimg3, S_wimg3, V _wimg3
14. Extraction of the watermark is done using alpha blending equation
    S_ewat = (S_img3 - α*S_img1)/ß
    Where α and ß are scaling factor
    Extracted watermark:
    ewat = U_img2*S_ewat*V_img2
15. Perform Inverse 4-L RDWT on ewat.
16. Perform Inverse-Ranperm Method for unscrambling the image we get from Step16.
17. Merge R, G and B Color Channels to get the original RGB Watermark.

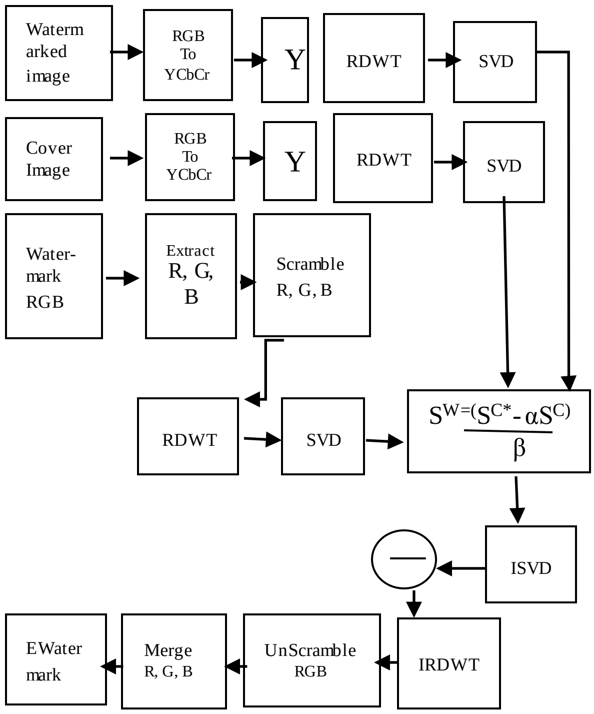

Fig 6: Steps for Extracting the Watermark image Using RDWT-SVD-Chaos

IV. SIMULATION RESULTS

To evaluate different parametric values, two different images are used for host as well as for watermarks for the proposed technique. Firstly, it is done on Lena.jpg and peppers.jpg and second is done on NCBAE.jpg and Baby.jpg. Here, JPEG image of RGB color space is used for both experiments having size 512×512, bit depth 24 and resolution 96×96 dpi[18]. In first experiment, Host image is lena.jpg and Watermark image is peppers.jpg. Experimentation was completed on same RGB images relying on extension of JPEG with size 512×512, resolution 1×1 dpi and bit depth 24. By comparing previous techniques to our proposed technique, the difference is shown by graphically representing the following extracted and embedded values of PSNR as shown in fig 7 and fig. 8. Table 1 and table 2 shows the estimated results (PSNR and NC) without attacks. Peak signal-to-noise ratio (PSNR) is specially used to check the imperceptibility of the host image after embedding of the watermarks and Normalized Correlation (NC) is used to identify the correlation between the original host and watermarked images.

$$\text{PSNR} = 10 \, . \log 10 \left(\frac{MAX2_1}{MSE} \right)$$

Table 3 shows the comparison in the values of watermarked and extracted watermark images. Table 4 and 5 shows the matrices results with attacks.

Fig 7: a) Lena.jpg (host) b)Peppers.jpg(watermark) c) NCBAE.jpg (host) d) Baby.jpg (watermark)

Table. 1 Comparison of previous technique to Proposed technique (Embedding)

Embed Watermark Image	Makbol & Khoo RDWT-SVD (Grayscale)[8]	J. Munazah et al. RDWT-SVD (Colored)[19]	Gökçen Çetinel, RDWT-SVD+ Chaos(grayscale)[3]	RDWT-SVD with Chaotic (proposed for colored)
PSNR_RED	27.343 dB	32.969	93.3191 dB	56.5551
PSNR_GREEN		29.284		52.4980
PSNR_BLUE		31.376		56.2338
NC_R.	0.951	0.9596	0.9980	0.9990
NC_G.		0.9785		0.9992
NC_B.		0.9341		0.9987

Table. 2 Comparison of previous technique To proposed technique (Extraction)

Extract Watermark	Makbol & Khoo RDWT-SVD (Grayscale)[8]	J. Munazah et al. RDWT-SVD (Colored)[19]	Gökçen Çetinel RDWT-SVD+ Chaos [3]	RDWT-SVD with Chaotic (Proposed)
PSNR_RED	24.7136	23.324	Not given	60.928
PSNR_GREEN		29.011		60.877
PSNR_BLUE		23.616		58.345
NC_R.	0.7765	0.8942	Not given	0.9995
NC_G.		0.9287		0.9997
NC_B.		0.9219		0.9994

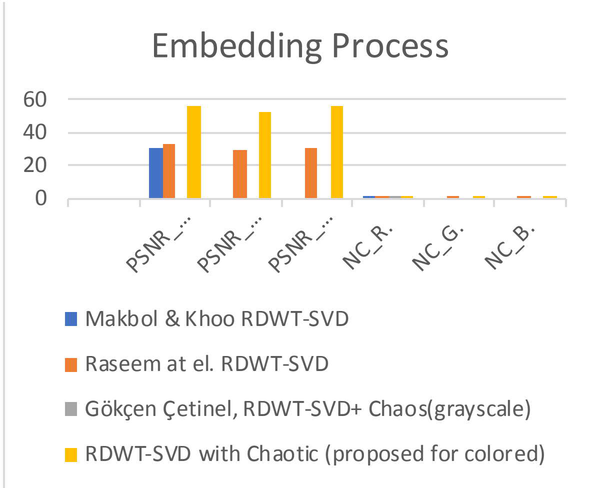

Fig 8: Comparison using Graphical Representation for Embedding (Table 1)

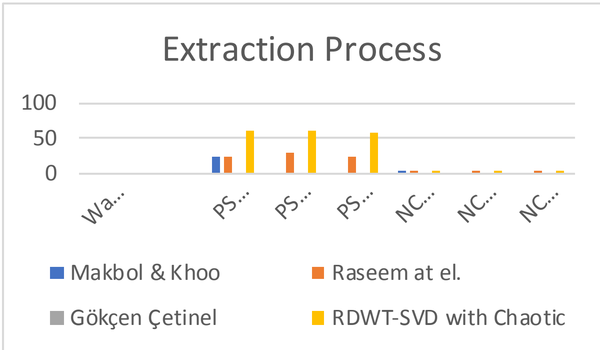

Fig 9: Comparison using Graphical Representation for Extraction (Table 2)

Table. 3 Comparison of different parameters for Host &watermarked and Watermark &Extracted Image

	NPCR	SSIM	MSE	PSNR	RMSE	NC
Host & Watermarked	0.106	0.999	0.22	54.67	0.47	1.0
Watermark &Extracted Image	0.023	0.999	0.06	60.87	0.47	1.0

Fig 10: Visualization Test after Mean Filter

Fig 11: Visualization Test after Gaussian Filter

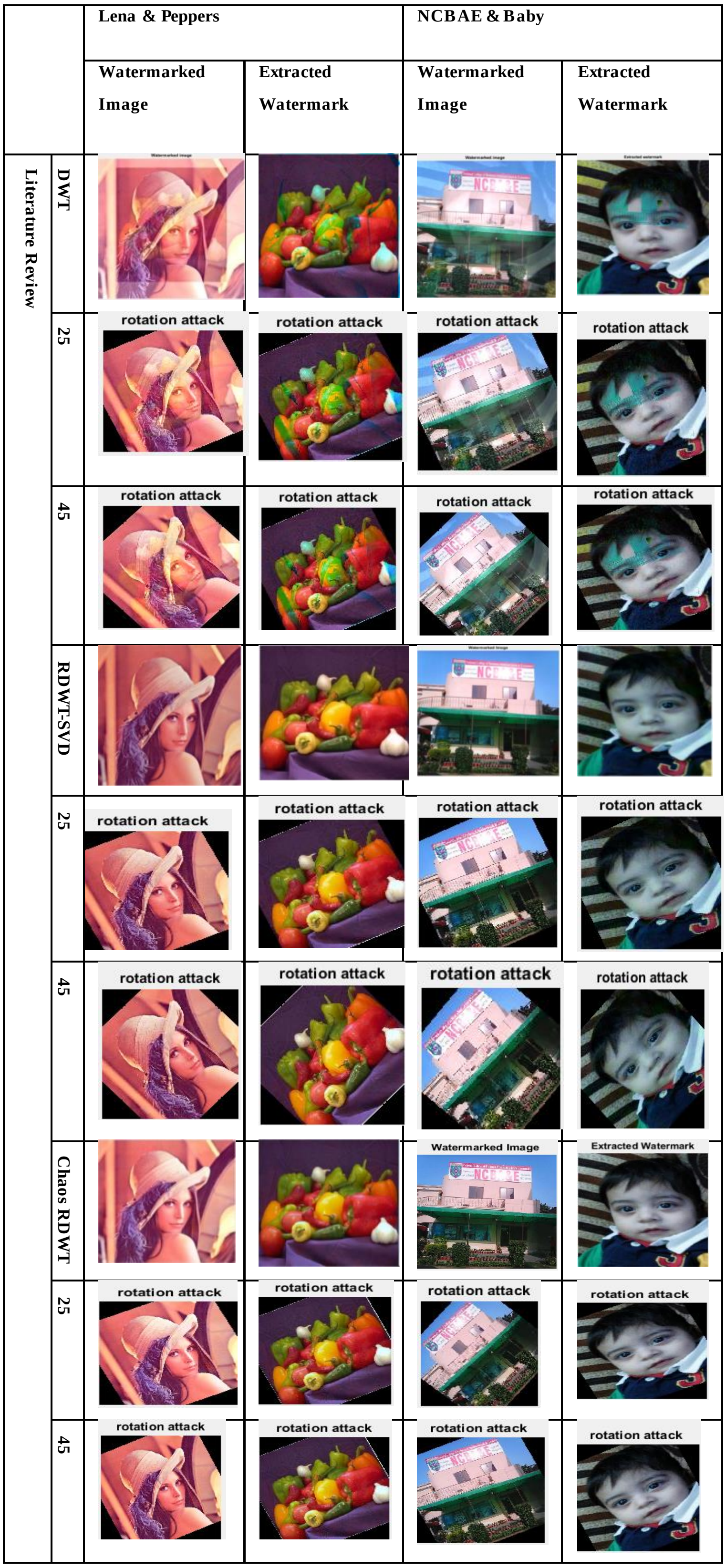

Fig 12: Visualization Test after Rotation Filter

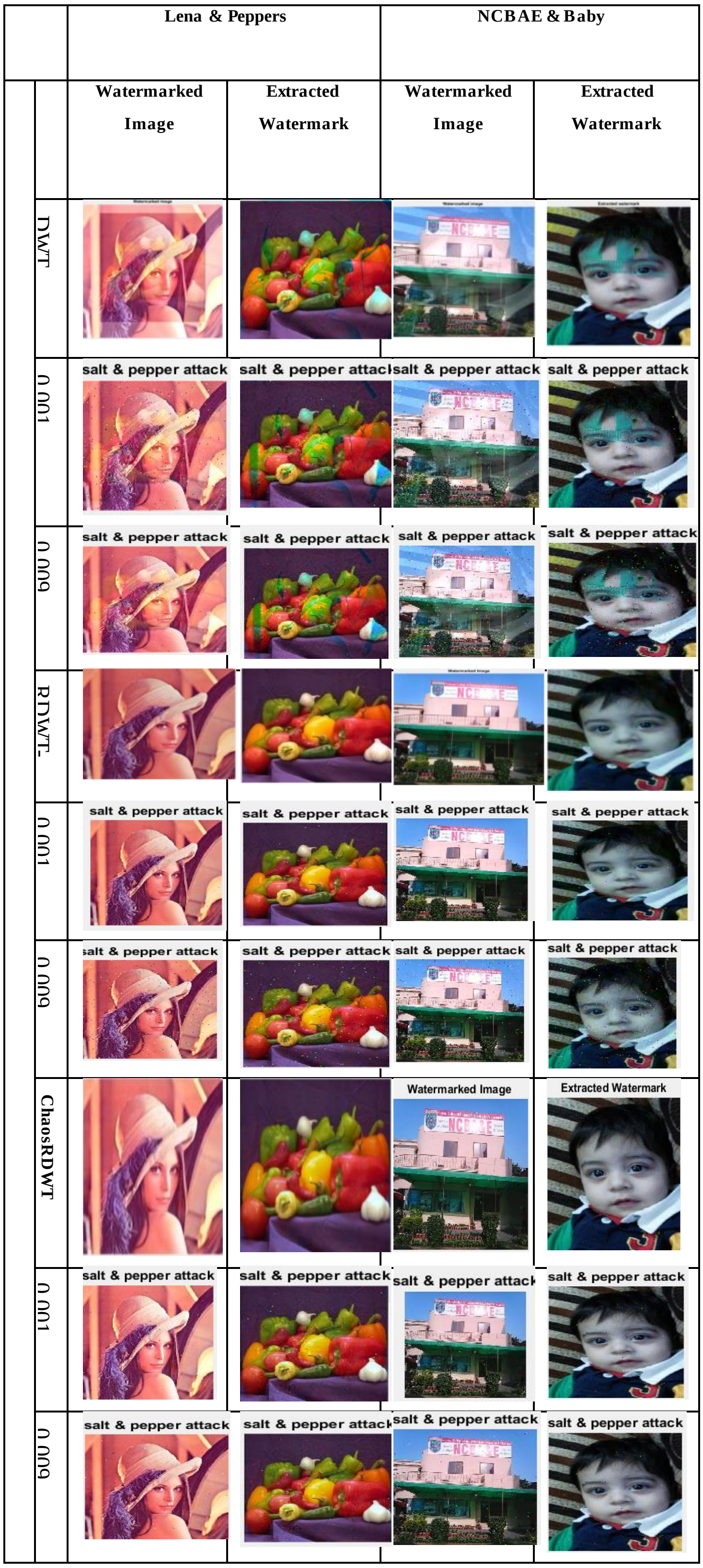

Fig 13: Visualization Test after Salt&pepper Attack

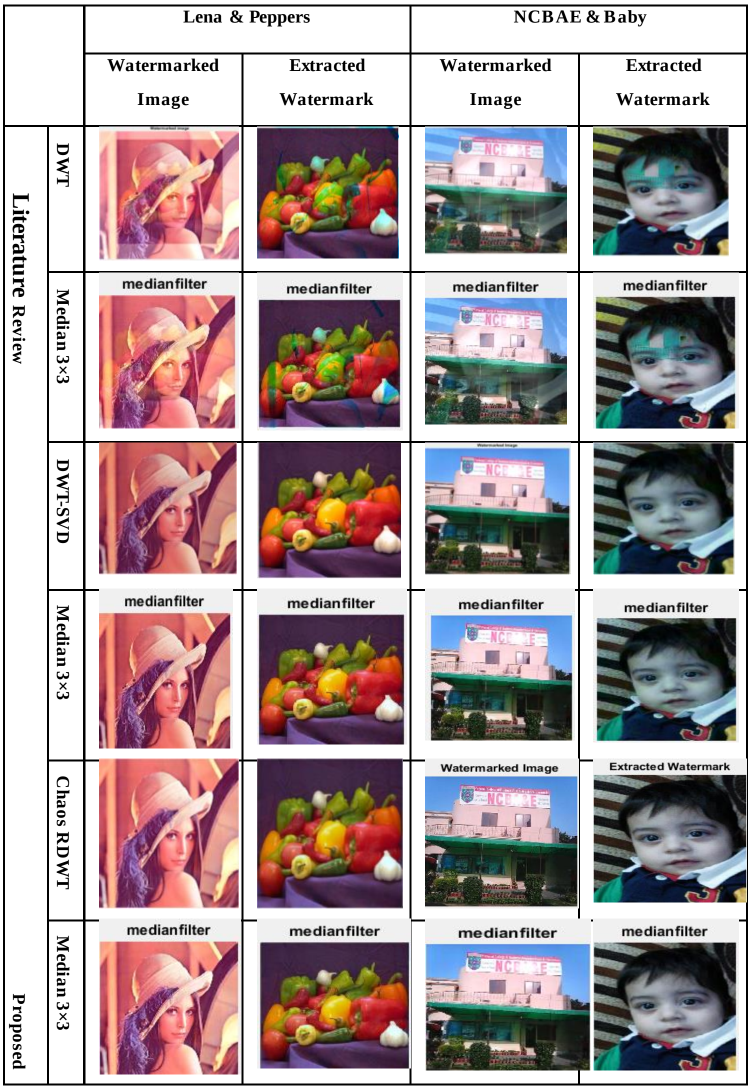

Fig 14: Visualization test for median filter

Different parameters are used to check the resistance against geometrical attacks[10][11].Their values indicate the robustuss of the watermark in the host image. PSNR(peak signal-to-noise ratio) is the main parameter to identify the resistance of original and the watermarked image. Highest the value of PSNR resulted in the more imperceptible behavior. Similarly, without MSE, PSNR cannot be calculated.

Some other parameters are also used i.e SSIM, used to check the similarity index in the original host and the embedded host as well as in watermark and extracted watermark.

$$(x, y) = \frac{(2\mu(x)\mu(y)+c1)(2\sigma(xy+C2))}{(\mu x_2+\mu y_2+c1)(\sigma 2_x+\sigma 2_y+c2)}$$

Similarly, NPCR is used to check the no of pixel change ratio by using given equation:

$$\mathrm{N}(c^1, c^2) = \sum_{i,j} \frac{D(i,j)}{T} \times 100\%$$

Table. 4 Values Recorded after applying different attacks on Watermarked Image

Watermarked Image	MSE	PSNR	RMSE	NC	NPCR	SSIM
S&P	18.60	35.43	4.313	0.99	0.001	0.983
Rotation	5895	10.42	76.78	0.32	0.982	0.400
Crop	112	13.13	12.7	0.61	0.654	0.761
Mean	73.09	29.49	8.544	0.98	0.920	0.939
Median	31.45	33.15	5.687	0.99	0.428	0.966
Guassian	4.89	41.23	2.221	0.99	0.418	0.998

Table. 5 Values Recorded after applying different attacks on Extracted Watermark Image

EWatermark Image Attacks	MSE	PSNR	RMSE	NC	NPCR	SSIM
S&P	23.99	34.32	4.8984	0.997	0.001	0.9909
Rotation	1053	7.905	102	0.054	0.994	0.1010
Crop	1791	18.13	9.78	0.612	0.654	0.7612
Mean	860	29.49	29.326	0.891	0.973	0.7186
Median	748	19.38	27.360	0.906	0.665	0.7777
Guassian	108	27.77	10.41	0.988	0.896	0.9714

V. CONCLUSION

RDWT-SVD-Chaos was tested against images of different dimensions i.e 256×256, 512×512. Images having high resolution and dpi resulted in high PSNR and NC values. Satisfactory exchange between fidelity and robustness was observed using this scheme. A non-blind image watermarking method for color images based on RDWT-SVD was introduced. To enhance the quality for embedding and extraction, an additional factor was introduced using "Chaotic behavior". This was termed as RDWT-SVD-Chaos technique. It showed more resistance against multiple attacks such as JPEG Compression, Guassian Noise, Scaling, Mean Filtering, Salt & Pepper Noise and Median Filtering. The performance of the RDWT-SVD-Chaos for watermarked image and extracted watermark was shown in the result's table. It uses stationary wavelets that increased the capacity produced by RDWT and resulted in no loss of imperceptibility. This technique was tested against dimension of 512×512 RGB images having different values of scaling factors, i.e "α = 0.1 and ß=0.5", independent of bit depth and same resolution for both watermark and host i.e 92dpi×92dpi then PSNR values for embedded and extracted images were 46.4680 and 49.1900 and were close to similarity. Similarly, experimentation was done using different resolution, 92×92 for host image and 72x72 for watermark image. PSNR values were increased for both the embedded image and the extracted image i.e 54.6781 and 60.8737 respectively using "Chaotic Behavior". The normalized correlation (NC) values for both images were found 1 that is the best level to check the similarity between two images. Hence it is concluded that robustness was improved for embedded image as well as for the extracted watermark image using the proposed scheme.

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