

Novel Digital Image Watermarking in SWT+SVD Domain

Nikhil Purohit, M. Chennakrishna and K. Manikantan

Abstract In this paper, Digital Watermarking is carried out in the frequency domain and the technique proposed uses single level Stationary Wavelet Transform (SWT) along with Singular Value Decomposition (SVD). SWT is used over other transformations because of its non-decimation and shift invariance property. The singular values of SWT transformed watermark image is embedded into the singularly decomposed HH sub-band (sub-image) of R, G or B channel of a Host color image. The experimental results of watermarked images shows increase in Peak Signal to Noise Ratio (PSNR) and the extracted watermark image is highly correlated with the original watermark for various types attacks.

Keywords Digital watermarking · Stationary wavelet transform · Singular value decomposition · Peak signal to noise ratio

1 Introduction

Digital watermarking is used extensively in this digital era wherein the sensitive information is merged with a carrier which acts like a camouflage and only the proper decoding algorithm is able to extract the information which is hidden inside the carrier. It is also used for various applications like authentication, copyright protection [1], information hiding [2], broadcast monitoring, content identification [3] and filtering i.e. for instance if a person is watching a movie scene, pop ups like promotions and advertisements are triggered by identifying the content being watched.

N. Purohit · M. Chennakrishna · K. Manikantan (✉)
Department of Electronics and Communication Engineering,
M S Ramaiah Institute of Technology, Bangalore 560 054, India
e-mail: kmanikantan2009@gmail.com

N. Purohit
e-mail: ramesh.nikhil89@gmail.com

M. Chennakrishna
e-mail: chennakrishna150@gmail.com

Similarly, it is also used for content blocking by recognising a specific part of the content. Hence watermarking is widely used for security purposes. The information can be in the form an image, video or audio and corresponding to it the carrier is chosen [4–6]. The multimedia industry are still facing a lot of challenges and trying find algorithms that are more robust and the watermarks which cannot be removed or altered, thereby eliminating piracy. Watermark can be visible or invisible [7] depending on the application.

2 Problem Definition and Contribution

Watermarking in the frequency domain [8, 9] is preferred since it alters the coefficients obtained after using different transformations rather than pixels which is done in spatial domain [10]. Many techniques and combinations have been implemented using DWT, DFT and SVD based [11–14]. But the PSNR values obtained are very low even though the correlation between the original and the extracted watermark is better. To improve the PSNR values this paper proposes.

SWT+SVD domain watermarking using HH sub-band:

Combination of SWT and SVD technique is used to embed the information into the host image and the use of HH sub-band instead of LL, HL, LH sub-bands provides better PSNR values for R, G and B channels.

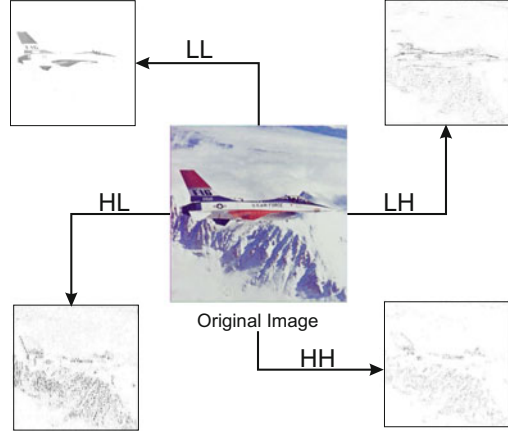
3 Fundamental Concepts

This section provides the basic ideas about the mathematical functions used in the proposed algorithm, they are described as follows

3.1 Stationary Wavelet Transform (SWT)

The single level two dimensional SWT [15] disintegrates the image into four sub-bands (sub-images) each having size same as that of the original image as shown in Fig. 1, i.e. LL, LH, HL, HH. It is also known as undecimated transform since there is no downsampling of the images. LL is the approximate image of input image it is low frequency sub-band. LH sub-band, HL sub-band and HH sub-band gives the horizontal, vertical and diagonal features of original image respectively. These sub-bands are used for integrating the watermark.

Fig. 1 Decomposition of the image into four components (LH, HL and HH sub-images are in negative form for better clarity) when SWT is applied



3.2 Singular Value Decomposition (SVD)

Singular value decomposition (SVD) [16] uses a rectangular matrix of an image ($m \times n$) where m is the number rows and n is the number of columns of the image. The mathematical equation for SVD is given below

$$A = U_{n \times n} \times S_{m \times n} \times V_{m \times m}^T \quad (1)$$

where U is the left singular vector, V is the right singular vector and S is diagonal matrix and it is singular. The U and V matrix are orthogonal to each other. The mathematical equation is given below

$$U \times U^T = I_{n \times n} \quad (2)$$

$$V \times V^T = I_{m \times m} \quad (3)$$

The S matrix is in descending order and it is always real. If A matrix is real, then U and V are also real. SVD can be calculated by finding eigenvector and eigenvalue of $A^T A$ and $A A^T$. The eigenvector $A^T A$ is given by columns of U and eigenvalue is given by columns of V .

4 Proposed SWT+SVD Domain Watermarking Using HH Sub-band

The combination of SWT+SVD along with their properties serve as a good alternative over other transforms. The host is separated into R, G and B channels and to one of the channels 2D-SWT (single level) is applied. The HH sub-band is chosen since it

gives better results compared to other sub-bands. Then it is decomposed using SVD. Similarly the HH sub-band of the watermark is also obtained by applying SWT and then the singular matrix is obtained by applying SVD. The singular values of the host images and the watermark images are combined and then inserted back into the selected host channel using ISWT and all the separated channels are combined to obtain the final watermarked image.

4.1 Watermark Embedding

Figure 2 shows the block diagram of the embedding process. The steps involved are as follows

1. The color host image is split into the individual channels (Red, Green and Blue).
2. To any one of the channels the 2D-SWT (single level) of SYM4 wavelet family is applied.
3. Among the different sub-bands obtained from SWT, the HH sub-band is selected.
4. SVD is applied to the HH sub-image to decompose it into U , S and V matrices

$$A = U \times S \times V^T \quad (4)$$

where A is the HH sub-image.

5. Similarly 2D-SWT (single level) of SYM4 wavelet family is applied to grey scale watermark image and SVD is applied to the HH sub-image to decompose it into U_1 , S_1 and V_1 matrices

$$B = U_1 \times S_1 \times V_1^T \quad (5)$$

6. Insert the S_1 matrix into the S matrix using a scalar quantity α i.e. indirectly the insertion of the watermark is done.

$$S_2 = S + \alpha S_1 \quad (6)$$

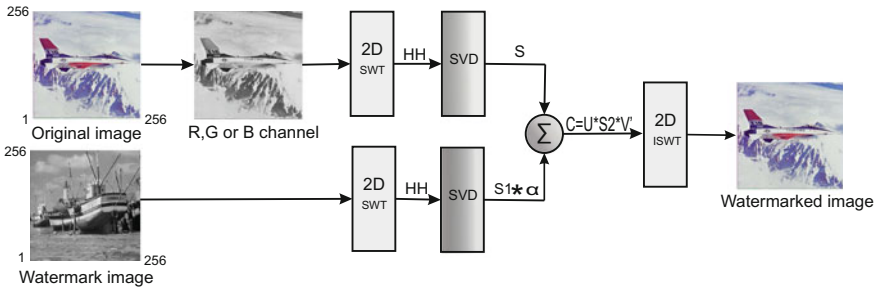


Fig. 2 Block diagram for the embedding process

where α is scaling factor which determines the strength of the watermark over the host image.

7. Combine the newly obtained S_2 with U and V matrices obtained from Eq. 4 as shown in Eq. 7

$$C = U \times S_2 \times V \quad (7)$$

8. The transformed HH sub-image C is combined with unaltered sub-images (LL, LH and HL) of the host image by applying ISWT to obtain the complete image of the selected channel.
9. The resultant channel obtained is concatenated with the other two channels and the resulting image obtained is the required watermarked image.

4.2 Watermark Extraction

Figure 3 shows the block diagram of the extraction process. The steps involved are as follows

1. The watermarked image is split into R, G or B channel.
2. Level one 2D-SWT (SYM4) is applied to the channel into which the watermark was embedded.
3. SVD is applied to the HH sub-band since the watermark is present in this sub-band and corresponding U , S and V matrices are obtained.

$$A^* = U^* \times S^* \times V^{*T} \quad (8)$$

where A^* is the HH sub-image.

4. The difference of the singular matrix S^* of the watermarked image and the singular matrix S of original RGB image will fetch back the singular matrix of the

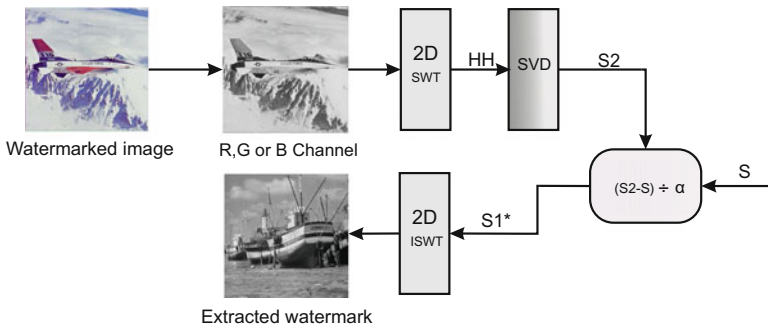


Fig. 3 Block diagram for the extraction process

watermark i.e. the separation of the watermark is done from the watermarked image. It is given by Eq. 9

$$S_1^* = \frac{(S^* - S)}{\alpha} \quad (9)$$

5. The new sub-image B^* is formed by multiplying S_1 with the U_1 and V_1 matrices obtained from Eq. 5

$$B^* = U_1 \times S_1^* \times V_1^T \quad (10)$$

where B^* is the HH sub-image of the extracted watermark.

6. This sub-image is combined with the unaltered LL, LH and HL sub-images of the watermark image to obtain the complete image by applying ISWT.
7. The obtained image almost matches the watermark image which was embedded during the embedding process. Correlation between the two images can be found to determine their resemblance.

5 Experimental Results and Analysis

The evaluation of the proposed algorithm is done by calculating the PSNR and also by finding correlation between watermark image before embedding and the watermark image obtained after the extraction. The MATLAB tool [17] is used for the evaluation of the algorithm. Table 1 shows the PSNR values for different combinations of host and the watermark images each of size 256×256 pixels. The PSNR is calculated using Eq. 11.

Table 1 PSNR values obtained for the watermarked image, after embedding the watermark image into R, G and B channels in dB

Host	Watermark	PSNR_R	PSNR_G	PSNR_B
Lena	Cameraman	97.52	95.96	96.80
Pepper	Airplane	99.75	97.58	99.45
Airplane	Boat	97.96	95.95	99.56
Baboon	Hunter	90.79	88.51	88.57
Tulips	House	103.34	99.14	101.98
Barbara	Livingroom	91.27	92.01	92.13
Plane	Barbara	96.27	96.17	96.31
Map	Butterfly	90.67	90.87	90.26
Lena	Mysail	97.58	96.03	96.87

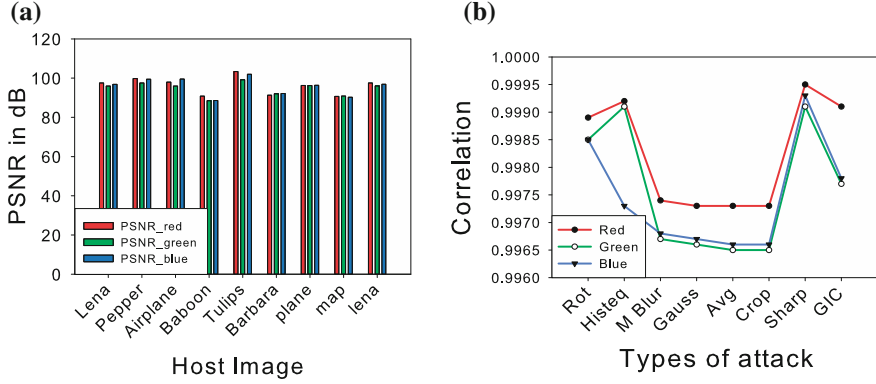


Fig. 4 a PSNR values for all three channels b Correlation coefficients for different types of attacks

$$PSNR = 20 \log_{10} \left(\frac{255}{RMSE} \right) \quad (11)$$

where RMSE is the root mean square error, $I(i, j)$ is the original image and the $\bar{I}(i, j)$ is the watermarked image.

$$RMSE = \sqrt{\frac{1}{MN} \left(\sum_{i=1}^M \sum_{j=1}^N (I(i, j) - \bar{I}(i, j))^2 \right)} \quad (12)$$

The correlation of the original watermark with the extracted watermark gives the information of how much the extracted watermark resembles the original watermark before embedding. Figure 4 shows the plot of PSNR values for different host images and correlation values obtained for different attacks. The correlation is calculated using Eq. 13.

$$corr(X, Y) = \frac{\sum_{i=1}^M \sum_{j=1}^N (X_{ij} - \bar{X})(Y_{ij} - \bar{Y})}{\sqrt{\left(\sum_{i=1}^M \sum_{j=1}^N (X_{ij} - \bar{X})^2 \sum_{i=1}^M \sum_{j=1}^N (Y_{ij} - \bar{Y})^2 \right)}} \quad (13)$$

To test whether the watermarking technique is reliable, various processing methods such as Cropping (Crop), Rotation (Rot), Gaussian Filter (Gauss), Histogram Equalization (Hist), Sharpening (Sharp), Average filter (Avg), Motion Blur (M Blur), Gamma Intensity Correction (GIC) have been applied. Tables 2, 3, 4 show the correlation values obtained for different channels after applying various attacks and Fig. 5 shows the corresponding watermarked images.

Table 2 Correlation coefficients obtained for watermark extracted from red channel after the application of various kinds of attacks

Host	Watermark	Rotate	Histeq	M blur	Gauss	Avg	Crop	Sharp	GIC
Lena	Cameraman	0.9993	0.9989	0.9982	0.9981	0.9981	0.9981	0.9990	0.9984
Pepper	Airplane	0.9998	0.9995	0.9990	0.9999	0.9989	0.9989	0.9995	0.9991
Airplane	Boat	0.9998	0.9999	0.9989	0.9989	0.9989	0.9989	0.9996	0.9991
Baboon	Hunter	0.9989	0.9992	0.9974	0.9973	0.9973	0.9973	0.9995	0.9981
Tulips	House	1.0000	0.9998	0.9996	0.9996	0.9996	0.9996	0.9998	0.9997
Barbara	Livingroom	0.9991	0.9992	0.9977	0.9977	0.9976	0.9976	0.9994	0.9984
Plane	Barbara	0.9982	0.9993	0.9969	0.9969	0.9968	0.9969	0.9984	0.9976
Map	Butterfly	0.9989	0.9989	0.9968	0.9967	0.9966	0.9967	0.9984	0.9972
Lena	Mysail	0.9999	0.9998	0.9991	0.9990	0.9989	0.9990	0.9999	0.9993

Table 3 Correlation coefficients obtained for watermark extracted from blue channel after the application of various kinds of attacks

Host	Watermark	Rotate	Histeq	M blur	Gauss	Avg	Crop	Sharp	GIC
Lena	Cameraman	0.9989	0.9988	0.9980	0.9980	0.9979	0.9979	0.9989	0.9985
Pepper	Airplane	0.9997	0.9994	0.9988	0.9988	0.9987	0.9987	0.9994	0.9994
Airplane	Boat	0.9998	0.9999	0.9988	0.9987	0.9987	0.9987	0.9995	0.9991
Baboon	Hunter	0.9985	0.9991	0.9967	0.9966	0.9965	0.9965	0.9991	0.9977
Tulips	House	0.9999	0.9998	0.9995	0.9995	0.9994	0.9994	0.9998	0.9997
Barbara	Livingroom	0.9991	0.9993	0.9979	0.9979	0.9978	0.9978	0.9993	0.9985
Plane	Barbara	0.9985	0.9993	0.9969	0.9969	0.9968	0.9969	0.9982	0.9975
Map	Butterfly	0.9988	0.9994	0.9968	0.9968	0.9967	0.9967	0.9983	0.9973
Lena	Mysail	0.9998	0.9998	0.9989	0.9988	0.9987	0.9987	0.9998	0.9995

Table 4 Correlation coefficients obtained for watermark extracted from blue channel after the application of various kinds of attacks

Host	Watermark	Rotate	Histeq	M blur	Gauss	Avg	Crop	Sharp	GIC
Lena	Cameraman	0.9988	0.9992	0.9981	0.9981	0.9980	0.9980	0.9980	0.9980
Pepper	Airplane	0.9997	0.9996	0.9989	0.9989	0.9989	0.9989	0.9989	0.9989
Airplane	Boat	0.9999	0.9999	0.9990	0.9990	0.9990	0.9990	0.9991	0.9990
Baboon	Hunter	0.9985	0.9973	0.9968	0.9967	0.9966	0.9966	0.9993	0.9978
Tulips	House	0.9998	1.0000	0.9996	0.9996	0.9996	0.9996	0.9998	0.9999
Barbara	Livingroom	0.9991	0.9991	0.9979	0.9979	0.9978	0.9977	0.9978	0.9978
Plane	Barbara	0.9988	0.9994	0.9969	0.9969	0.9969	0.9969	0.9984	0.9975
Map	Butterfly	0.9987	0.9998	0.9967	0.9966	0.9965	0.9966	0.9984	0.9973
Lena	Mysail	0.9998	1.0000	0.9990	0.9989	0.9988	0.9989	0.9999	0.9993

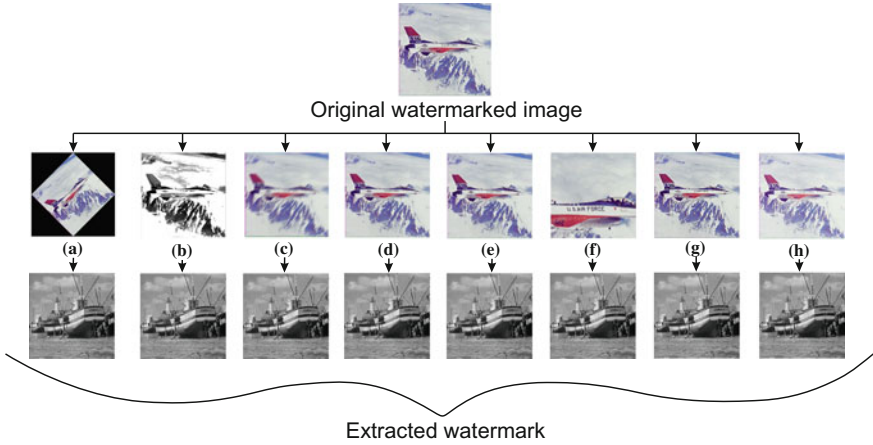


Fig. 5 **a** Rotated, **b** Histogram Equalised, **c** Motion Blurred, **d** Guassain filtered, **e** Average filtered, **f** Cropped, **g** Sharpened and **h** Gamma Intensity Corrected watermarked images

Table 5 Comparison of PSNR and correlation coefficients by proposed method with the DWT-DFT-SVD method by [14] for Airplane (Host) and Boat (watermark) image

Method	Channel	PSNR (dB)	Correlation coefficients		
			Rot	Hist	Sharp
As in [14]	Red	36.21	0.9905	0.9963	0.9889
	Green	33.06	0.9887	0.9970	0.9901
	Blue	37.33	0.9916	0.9924	0.9884
Proposed	Red	97.96	0.9998	0.9999	0.9996
	Green	95.95	0.9998	0.9999	0.9995
	Blue	99.56	0.9999	0.9999	0.9991

The PSNR and the correlation values obtained by proposed method is compared with DWT-DFT-SVD for watermarking in three different channels. Table 5 shows the comparison of PSNR and the correlation values with the method implemented by Ref. [14] and with the proposed method. The values obtained are better since the singular values of HH sub-band obtained from SWT is used instead of using singular values of HL sub-band obtained from DWT-DFT.

6 Conclusion

In this paper, the digital watermarking technique proposed uses combination of SWT+SVD which has been applied for nine different combinations of host and watermark images. The proposed technique was compared to the technique used

in Ref. [14] and the PSNR values obtained are superior. The main advantage of the SWT is that no downsampling is done after filtration which is not in case of DWT and the lack of shift invariance due to DWT is overcome by using SWT. Therefore increased PSNR values provide visually better quality watermarked images. Also in comparison with Ref. [14], the correlation coefficients obtained after applying for various kinds of attacks like rotate, crop, sharp etc are better. Therefore it is more robust and has more capability to withstand attacks that can cause information loss which is hidden inside the carrier and hence providing better security. Further this technique can be implemented for video watermarking and for embedding color watermark images.

References

1. Manjunatha Prasad, R., Shivaprakash Kollwad.: A Comprehensive Survey of Contemporary Researches in Watermarking for Copyright Protection of Digital Images. *International Journal of Computer Science and Network Security*, vol. 9, no. 4 (2009)
2. Shivani Khurana.: Watermarking and Information-Hiding. *International Journal of Computer and Information Technology*, vol. 2, pp. 1679–1681 (2011)
3. Zunera Jalil, Anwar M. Mirza and Maria Sabir.: Content based Zero-Watermarking Algorithm for Authentication of Text Documents. *International Journal of Computer and Information Technology*, ISSN 1947-5500, vol. 7, no. 2 (2010)
4. Mohammad Ali Nematollahi, S.A.R. Al-Haddad, Faraneh Zarafshan.: Blind digital speech watermarking based on Eigen-value quantization in DWT. *Journal of King University-Computer and Information Science*, vol. 27, 58–67 (2015)
5. Gaurav Bhatnagar, Balasubramanian Raman.: Wavelet packet transform-based robust video watermarking technique. *Indian Academy of science*, vol. 37, pp. 371–388 (2012)
6. Nidaa A. Abbas.: Image watermark detection techniques using quadrees. *Applied Computing and Informatics*, vol. 11, 102–115 (2015)
7. D.Vaishnavi, T.S. Subashini.: Robust and Invisible Image Watermarking in RGB Color space using SVD. *International Conference on Information and Communication Technologies (ICICT)*, pp. 1770–1777 (2014)
8. Srdjan Stankovic, Igor Djurovic, Ioannis Pitas.: Watermarking in the Space/Spatial Frequency Domain using Two-Dimensional Radon-Wigner Distribution. *IEEE transactions on Image Processing*, vol. 10, no. 4 (2001)
9. Rafael Gonzalez, Richard Woods.: *Digital Image processing*. Prentice Hall, Third edition (2008)
10. N. Nikolaidis, I. Pitas.: Robust image watermarking in spatial domain. *Signal processing*. vol. 66, pp. 385–403 (1998)
11. Bhupendra Ram.: Digital Image Watermarking Technique Using Discrete Wavelet Transform And Discrete Cosine transform. *International Journal of Advancements in Research and Technology*, ISSN 2278-7763, vol. 2, Issue 4 (2013)
12. Navnath S. Narwade, Narendra P. Deshmane, Pankaj Elchatwar, Pooja L.Pande.: Robust Watermarking for Geometric attack using DFT. *International Journal of Emerging Trends and Technology in Computer Science*, vol. 2, Issue 2 (2013)
13. O. Jane, E. Elbasi, H. G. ilk.: Hybrid Non-Blind Watermarking Based on DWT and SVD. *Journal of Applied research and Technology*, vol. 12, pp. 750–761 (2014)
14. Rahim Ansari, Murtyunjaya M, Devanalamath, K Manikantan, S Ramachandran.: Robust Digital Image Watermarking Algorithm in DWT-DFT-SVD Domain for Color Image. *International Conference on Communication, Information and Computing Technology* (2012)

15. B Siva Kumar, S Nagaraj.: Discrete and Stationary Wavelet Decomposition for IMAGE Resolution Enhancement. International Journal of Engineering Trends and Technology (IJETT), vol. 4, Issue 7 (2013)
16. Gaurav Bhatnagar, Q. M. Jonathan Wu, Balasubramanian Raman.: Biometric Template Security based on Watermarking. Procedia Computer Science, vol. 2, pp. 227–235 (2010)
17. Matlab, <http://www.mathworks.com>

Proceedings of the International Conference on Signal,
Networks, Computing, and Systems

ICSNCS 2016, Volume 1

Lobiyal, D.K.; Mohapatra, D.P.; Nagar, A.K.; Sahoo, M.N.
(Eds.)

2017, XVI, 352 p. 159 illus., Hardcover

ISBN: 978-81-322-3590-3