I.J. Information Technology and Computer Science, **2012, 3, 1-7**
Published Online April 2012 in MECS (http://www.mecs-press.org/)
DOI: 10.5815/ijitcs.2012.03.01

Strongly Robust and Highly Secured DWT-SVD Based Color Image Watermarking: Embedding Data in All Y, U, V Color Spaces

Baisa L. Gunjal
Amrutvahini College of Engineering, Sangamner, A'nagar, MS, India
Email: hello_baisa@yahoo.com

Suresh N. Mali
Principal, Singhgad College of Technology and Science, Narhe, Pune, India
Email: snmali@rediffmail.com

Abstract- **In this paper 'DWT-SVD' based Color Image Watermarking technique in YUV color space using Arnold Transform is proposed. The RGB color image is converted into YUV color space. Image is decomposed by 3 level DWT and then SVD is applied. The security is increased with watermark scrambling using Arnold Transform. The watermark is embedded in all Y,U and V color spaces in HL3 region. The decomposition is done with 'Haar' which is simple, symmetric and orthogonal wavelet and the direct weighting factor is used in watermark embedding and extraction process is used. PSNR and Normalized Correlations (NC) values are tested for 10 different values of flexing factor. We got maximum PSNR up to 52.3337 for Y channel and average value of NC equal to 0.99 indicating best recovery of watermark. The proposed scheme is non blind and strongly robust to different attacks like compression, scaling, rotation, cropping and Noise addition which is tested with standard database image of size 512x512 and watermark of size 64X64.**

***Index Terms*-DWT-SVD, Arnold Transform, YUV color space, PSNR, NC**

1. Introduction

In recent years, sharing of multimedia data including images, audios and videos in computer communications and internet has increased. Hence creations, copy, distribution and transmission of multimedia data have become common needs. Obviously, it leads to unauthorized duplication problem. Digital Image Watermarking provides copyright protection to digital images by hiding important information in original image to declare ownership. Perceptual transparency and robustness, capacity and blind watermarking are main features those determine quality of watermarking scheme [6]. Perceptual transparency means perceived quality of image should not be destroyed by presence of watermark. Robustness indicates resistance to different attacks like compression, scaling, rotation, cropping, noise attacks, sharpening, contrast adjustment etc. Perceptual transparency and robustness are two contrast measures. Hence, researchers strive for strongly robust with better perceptual transparency in watermarking schemes. The watermarking can be achieved either in spatial domain or in frequency domain. In spatial domain, watermark is embedded by directly modifying pixel values of cover image. These algorithms are simple in implementation. But problems with such algorithms are: Low watermark information hiding capacity, Less PSNR, Less Correlation between original and extracted watermark and less security, hence anybody can detect such algorithms. The Frequency domain the watermark is inserted into transformed coefficients of image giving more information hiding capacity and more robustness against watermarking attacks because information can be spread out to entire image [1]. In this paper digital color image watermarking in frequency domain is implemented using Discrete Wavelet Transform and Singular Value Decomposition and Arnold scrambling of watermark in YUV color space giving strongly robustness high security. The rest of the paper is organized as follows: Section 2 focuses on survey, section 3 describes basic foundations used for the algorithm, section 4 focuses on proposed methodology and section 5 presents experimental results. The conclusion is drawn in section 6.

2. Survey

Though Fourier transform short time Fourier transform and continuous wavelet transform are available in transform domain, but all of them are having their own limitations. Discrete Wavelet Transform provides multi resolution for given image and can efficiently implemented using digital filter, it has become attraction of researchers in image processing area. Here, review of literature survey is done on different transform in transform domain and existing color image watermarking techniques with based on 'Discrete Wavelet Transform. Following are some existing methods for in color image watermarking:' In [10], Integer Wavelet Transform with Bit Plane complexity Segmentation is used with more data hiding capacity. This method used RGB color space for watermark embedding. In [2] DWT based watermarking algorithm of color images is proposed. The RGB color space is converted into YIQ color space and watermark is embedded in Y and Q components. This method gives correlation up to 0.91 in JPEG Compression attack. In [3], Watermarking Algorithm Based on Wavelet and Cosine Transform for Color Image is proposed. A binary image as watermark is embedded into green or blue component of color image. In [1], Color Image Watermarking algorithm based on DWT-SVD is proposed in green component of color image. The scrambling watermark is embedded into green component of color image based on DWT-SVD. The scheme is robust and giving PSNR up to 42, 82. In [5], Pyramid Wavelet Watermarking Technique for Digital Color Images is proposed. This algorithm gives better security and better correlation in Noise and compression attacks.

3. Foundations of Proposed Method

A] YUV Color Spaces

Since Pixel values in RGB color space are highly correlated, RGB color space is converted into YUV color space. RGB color space is used for many watermarking algorithms, but RGB color space is complex in describing the color pattern and has redundant information between each component [2]. Also, embedding watermark in RGB color space is less robust than YUV color space. Hence, RGB color space is converted into YUV Color space and then Watermark is embedded. Initially color image is read and R, G, B components of original Cover Image are separated. Then they are converted into YUV color Space using following equations.

$$Y = 0.299 * R + 0.587 * G + 0.114 * B; \quad (1)$$

$$U = -0.147 * R - 0.289 * G + 0.436 * B \quad (2)$$

$$V = 0.615 * R - 0.515 * G - 0.100 * B \quad (3)$$

After embedding the watermark using DWT, YUV

color space is converted back into RGB color space using following equations.

$$R = Y + 1.140 * V \quad (4)$$

$$G = Y - 0.395 * U - 0.581 * V \quad (5)$$

$$B = Y + 2.032 * U \quad (6)$$

B] Discrete Wavelet Transform (DWT)

Discrete wavelet can be represented as

$$\psi_{j,k}(t) = a_0^{-j/2}\psi\,(a_0^{-j}t - k\,b_0) \quad (8)$$

For dyadic wavelets a_0=2 and b_0=1, Hence we have,

$$\psi_{j,k}(t) = 2^{-j/2}\psi\,(2^{-j}t - k\,) \quad j, k \in Z \quad (9)$$

DWT provides multi resolution representation of image and can efficiently implemented using digital filters. Image itself is considered as two dimensional signal. When image is passed through series of low pass and high pass filters, DWT decomposes the image into sub bands of different resolutions [4]. Decompositions can be done at different DWT levels.

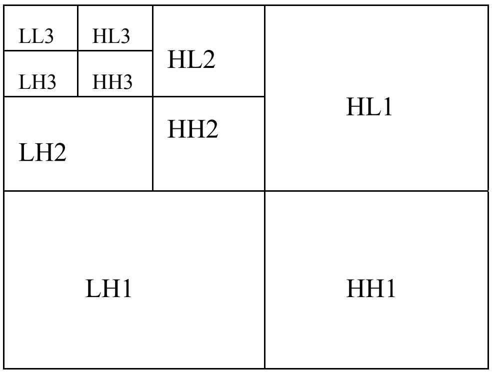


Figure 1 Three level decomposition of image giving LL3, LH3, HL3 and HH3 sub bands

Figure.1 shows three level decomposition of image giving LL3, LH3, HL3 and HH3 sub bands. LL3 called 'approximate sub band' which is low frequency sub band. HL3 called horizontal sub band, LH3 called vertical sub band and HH3 called diagonal Sub band. LH3, HL3 and HH3 are high frequency sub bands. It has been widely accepted that maximum energy of most of natural images concentrate in Low frequency area. Hence any modification low frequency sub band will cause severe and unacceptable image degradation. Hence watermark is not embedded in LL3 sub band. The good areas for watermark embedding are high frequency sub bands because human naked eyes are not sensitive to these sub bands and unable to detect, if any modification is made in high frequency sub bands of image[7][8][9]. They yield effective watermarking without being perceived by human eyes. But HH3 sub band includes edges and textures of the image. Hence HH3 is also excluded. But Human Visual System (HVS) is less sensitive in horizontal than vertical. Hence, in this paper HL3 i.e. Horizontal Sub band is selected for watermarking embedding.

C] Singular Value Decomposition (SVD)

Singular Values of the image gives very good stability. When a small value is added, it does not result too much variation. Hence Singular Value decomposition in linear algebra is used to solve many mathematical problems. Every real matrix A can be decomposed into product of three matrices $A=U\sum V^T$, where U and V are orthogonal matrices such that, UU^T =1 and VV^T = 1 and $\sum$ is summation of diagonal entries λ_1, λ_2…..gives the singular vectors of A. These diagonal entries are called as Singular Values of A and the decomposition is called as 'Singular Value Decomposition'. Thus we have,

$$A = \lambda_1 U_1\, V_1^T + \lambda_2 U_2\, V_2^T + \cdots .. + \lambda_r U_r\, V_r^T \quad (10)$$

where r is rank of matrix A. Singular Values specifies the luminance of an image layer while corresponding pair of singular vectors specifies the geometry of the image layer. The SVD can be used as convenient tool for watermarking in DWT domain [1].

D] Arnold Transform

Arnold Transform has special property that given image comes to it's original state after specific number of iterations. These specific number of iterations termed as 'Arnold Periodicity'. Hence Arnold Transform is used as efficient technique for increasing security in watermarking schemes [6]. The Arnold Transform of image is

$$\begin{pmatrix} x_n \\ y_n \end{pmatrix} = \begin{bmatrix} 1 & 1 \\ 1 & 2 \end{bmatrix} \begin{pmatrix} x \\ y \end{pmatrix} (mod\ N) \quad (11)$$

Where, (x, y) ={0,1,.....N} are pixel coordinates from original image. (x_n,y_n) are corresponding results after Arnold Transform. The periodicity of Arnold Transform

(P), is dependent on size of given image. From equation: 11 we have,

x_n=x+y (12)

y_n=x+2*y (13)

If (mod (x_n, N) ==1 && mod (y_n, N) ==1) then P=N (14)

4. Proposed Methodology

A] Watermark Embedding Algorithm

The proposed algorithm is modification of the scheme given in [1], where watermark was embedded in green component of color image. The algorithm is modified for YUV color space for complete analysis of results in Y, U and V components and increased security by Arnold Transform.

Step 1: Read Color cover Image and convert it into YUV color space to separate Y,U and V components using equations 1,2 and 3.

Step 2: Apply 3 levels DWT to Y component to get 'Y_HL3_Component' as shown in fig: 1.

Step 3: Apply SVD to 'Y_HL3_Component' as follows:

$[\mathrm{U}, \mathrm{S}, \mathrm{V}] = \mathrm{SVD}(\mathrm{Y\_HL3\_Component})$ (15)

Step 4: Read Watermark say 'W'.

Step 5. Apply 'Arnold Transform to given watermark 'W' to give scrambled watermark say 'W1' using equations 12 and 13 and 14.

Step 5. Apply following formulae for Watermark formulation and embedding:

$\mathrm{S1} = \mathrm{S} * \mathrm{K1} * \mathrm{W1}$ (16)

Where K1 is flexing factor

Step 6: Apply SVD for above S1 component

$[\mathrm{U1}, \mathrm{SS}, \mathrm{V1}] = \mathrm{SVD}(\mathrm{S1})$ (17)

Step7: Apply inverse SVD to get 'New_HL3_Component'.

$\mathrm{New\_HL3\_Componet} = \mathrm{U} * \mathrm{SS} * '\mathrm{V}'$ (18)

Step 8: Apply Inverse DWT at Level3, Level2,Level1 step by step to get 'Y_Watermarked_Component'.

Step 9: Convert 'Y_Watermarked_Component' U and V components to get final 'Watermarked_Image' in RGB color space using equations 4, 5 and 6. Similar algorithms can be followed for watermark embedding in U and V components.

B] Watermark Extraction Algorithm

Step 1: Convert 'Watermarked_Image' from RGB color space into Y, U, V color space. Here we get 'Y_New_Component' using equations 1, 2 and 3.

Step 2: Decompose 'Y_New_Component' using 3 level DWT to get 'Y_New_HL3_Component' shown in figure :1.

Step 3: Apply SVD to 'Y_New_HL3_Component'.

$[\mathrm{UU}, \mathrm{S2}, \mathrm{VV}] = \mathrm{SVD}(\mathrm{Y\_New\_HL3\_Component}$ (19)

Step 4: Apply following final extraction formulae to get 'Extracted_Watermark'.

$\mathrm{S\_New} = \mathrm{U1} * \mathrm{S2} * '\mathrm{V1}'$ (20)

$\mathrm{Extracted\_Watermark} = (\mathrm{S\_New} - \mathrm{S})/\mathrm{K}$ (21)

Step 5: Perform 'Image Scrambling' using 'Arnold Transform' with' KEY' that we had used in embedding process to recover the Watermark using equations 12,13 and 14. Similar algorithms can be followed for extracting watermark for U and V color spaces.

5. Experimental Result

This scheme is implemented in Matlab. Results are tested, analyzed and observations are given here with readings. Here, two performance parameters are applied to measure the performance of watermarking scheme: 'Perceptual Transparency' and 'Robustness'. Perceptual transparency means perceived quality of image should not be destroyed by presence of watermark. 'Perceptual Transparency' is measured in terms of 'Peak Signal to Noise Ratio'. Bigger is PSNR, better is quality of image. Robustness is measure of immunity of watermark against attempts to remove or destroy it by image modification and manipulation like compression, filtering, rotation, scaling, collision attacks, resizing, cropping etc. Robustness is measured in terms of Normalized Correlation (NC). The correlation factor

(Normalized Correlation) measures the similarity and difference between original 'watermark and extracted watermark. It's values is ideally 1, but the value more than 0.75 is highly accepted. The formulae for these parameters are given below:PSNR for image with size M x N is given by:

$$PSNR(db) = 10log_{10}\ \frac{(Max_I)^2}{\frac{1}{M*N}\sum_{i=1}^{M}\sum_{j=1}^{N}[f(i,j)-f'(i,j)]^2} \quad (22)$$

Where, f (i, j) is pixel of original image. f '(i, j) ispixel values of watermarked image. Max_I is the maximum pixel value of image. Normalized Correlation (NC) is given by:

$$NC = \frac{\sum_{i=1}^{N} w_i\, w_i\,'}{\sqrt{\sum_{i=1}^{N} w_i}\sqrt{\sum_{i=1}^{N} w_i'}} \quad (23)$$

Where, N is number of pixels in watermark, wi is original watermark, wi' is extracted watermark. The standard color Lena image of 512X512 size and grey scale watermark of 64x^4 is used for testing. The flexing factor is varied for 10 different values. The PSNR and NC are recorded for Y, U and V spaces as given in Table 1. Table 2 and Table 3. In Figure:3, Comparative results of Flexing factor versus PSNR and factor versus NC in Y,U,V Channels are given. The maximum recorded PSNR is up to 52.3337 for Y channel and average value of NC equal to 0.99 indicating best recovery of watermark. From Figure 3, it is clear that PSNR and NC are two contrast requirements. If we try to achieve more PSNR, NC is degraded and vice versa. The proposed scheme is also robust to different attacks like compression, scaling, rotation, cropping noise etc.

a) Original Cover Image	b) Y Component of Image	b) U Component of Image	b) V Component of Image	e)Watermarked Image

Figure:2 Original Color Lena image with 5212 X 512 size, Y,U, U components and Watermarked Image.

Table 1: Output Results for embedding watermark in HL3 region of Y color space

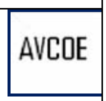
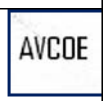
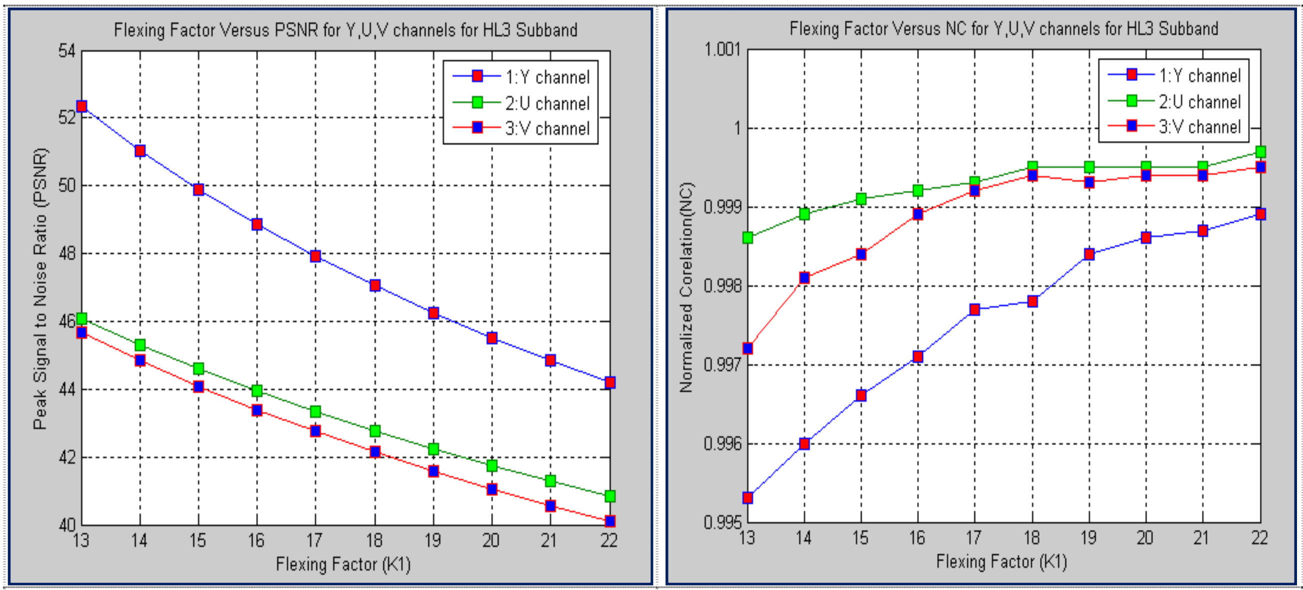
Flexing Factor	K1=13	K1=14	K1=15	K1=16	K1=17	K1=18	K1=19	K1=20	K1=21	K1=22
PSNR	52.3337	51.0430	49.8893	48.8500	47.9068	47.0449	46.2525	45.5200	44.8396	44.2048
Original Watermark										
Extracted Watermark										
NC	0.9953	0.9960	0.9966	0.9971	0.9977	0.9978	0.9984	0.9986	0.9987	0.9989

Table 2: Output Results for embedding watermark in HL3 region of U color space

Flexing Factor	K1=13	K1=14	K1=15	K1=16	K1=17	K1=18	K1=19	K1=20	K1=21	K1=22
PSNR	46.0759	45.3006	44.5911	43.9461	43.3467	42.7688	42.2489	41.7465	41.3000	40.8557
Original Watermark	AVCOE	AVCOE	AVCOE	AVCOE	AVCOE	AVCOE	AVCOE	AVCOE	AVCOE	AVCOE
Extracted Watermark	AVCOE	AVCOE	AVCOE	AVCOE	AVCOE	AVCOE	AVCOE	AVCOE	AVCOE	AVCOE
NC	0.9986	0.9989	0.9991	0.9992	0.9993	0.9995	0.9995	0.9995	0.9995	0.9997

Table 3: Output Results for embedding watermark in HL3 region of V color space

Flexing Factor	K1=13	K1=14	K1=15	K1=16	K1=17	K1=18	K1=19	K1=20	K1=21	K1=22
PSNR	45.6565	44.8344	44.0823	43.3892	42.7466	42.1475	41.5863	41.0592	40.5624	40.0922
Original Watermark	AVCOE	AVCOE	AVCOE	AVCOE	AVCOE	AVCOE	AVCOE	AVCOE	AVCOE	AVCOE
Extracted Watermark	AVCOE	AVCOE	AVCOE	AVCOE	AVCOE	AVCOE	AVCOE	AVCOE	AVCOE	AVCOE
NC	0.9972	0.9981	0.9984	0.9989	0.9992	0.9994	0.9993	0.9994	0.9994	0.9995



A) Comparative results of Flexing factor versus PSNR in Y,U,V Channels

B) Comparative results of Flexing factor versus NC in Y,U,V Channels

Figure 3 Comparative results of Flexing factor versus PSNR and Flexing factor versus NC

6. Conclusion

The experimental results have demonstrated that our 'DWT-SVD' based Color Image Watermarking technique in YUV color space using Arnold Transform is very effective. The algorithm is strongly secured including many security levels in watermark embedding and robust to different attacks. We got maximum PSNR up to 52.3337 for Y channel and average value of NC equal to 0.99 indicating best recovery of watermark. The proposed scheme is non blind and strongly robust to different attacks like compression, scaling, rotation, cropping and Noise addition. As per ISO's norms, the still Image Compression standard JPEG2000 has replaced Discrete Cosine Transform by Discrete Wavelet Transform. Hence most of researchers are focusing on DWT which is implemented here. The Watermarking' methodology presented here can be extended for videos' for authentication and copyright protection.

Acknowledgement

This research work is funded by Board of Colleges and University Development (BCUD), University of Pune, Maharashtra, India. Thanks to BCUD, Pune for providing 'Research Grant' for research project "Robust Digital Image Watermarking using Discrete Wavelet Transform" for period 2010-2012. File: Ref. No.- BCUD/OSD/390 dated 25/10/2010. We are also thankful to Amrutvahini College of Engineering, Sangamner, A'nagar and Singhgad College of Technology and Science, Narhe, Pune, MS, India for their support during this research work.

References

[1] Cheng-qun Yin, Li Li, An-qiang Lv and Li Qu, " Color Image Watermarking Algorithm Based on DWT-SVD", Proceeding of the IEEE International Conference on Automation and Logistiocs August 18-21, 2007, Jinan, China, PP: 2607-2611

[2] Guangmin Sun, Yao Yu, " DWT Based Watermarking Algorithm of Color Images", Second IEEE Conference on Industrial Electronics and Application",2007, PP 1823-1826.

[3] Wei-Min Yang, Zheng Jin, " A Watermarking Algorithm Based on Wavelet and Cosine Transform for Color Image", First International Workshop on Education Technology and Computer Science", 2009, PP 899,903.

[4] Hong-Mei Yang, Yong-Quang Liang, Xiao-Dong Wang, Shu-Juan Ji, "A DWT-Based Evaluation Method of Imperceptibility of watermark in Watermarked Color Image", Proceeding of the 2007 International Conference on Wavelet Analysis and Pattern Recognition, Beijing, China, 2-4 Nov, 2007

[5] Awad Kh. Al-smari and Farhan A. Al-Enizi, "A Pyramid-Based Technique for Digital Color Images Copyright Protection", International Conference on Computing, Engineering and Information, 2009, pp 44-47

[6] B.L.Gunjal, R.R.Manthalkar, "Discrete Wavelet Transform Based Strongly Robust Watermarking Scheme for Information Hiding in Digital Images", Third International Conference- Emerging Trends in Engineering and Technology,19-21 Nov 2010 , Goa, India, ISBN 978-0-7695-4246-1, http://doi.ieeecomputersociety.org/10.1109/ICETET.2010.12.

[7] S. Joo, Y. Suh, J. Shin, H. Kikuchi, and S. J. Cho., "A new robust watermark embedding into wavelet DC components," ETRI Journal, 24, 2002, pp. 401-404.

[8] Voloshynovskiy. S. S. Pereira and T. Pun. 2001. "Attacks on Digital watermarks: classification, Estimation-Based attacks and Benchmarks", Comm, Magazine. 39(8):118-126.

[9] Abu-Errub, A., Al-Haj, A.,"Optimized DWT-based image watermarking", First International Conference on Applications of Digital Information and Web Technologies, IEEE,2008, 4-6.

[10] K. Ramani, E Prasad, S Varadarajan, "*Stenography using BPCS to the integer wavelet transform*", IJCSNS international journal of Computer science and network security, vol-7, No: 7 July 2007.

Baisa L. Gunjal completed her B.E. Computer from University of Pune and M.Tech in I.T. in Bharati Vidyapeeth, Pune , Maharashtra, india. She is having 13 Years teaching experience in Computer Engineering. She is having 18 international and national journals. and conferences publications. Presently she is working on "Watermarking research project" funded by BCUD, University of Pune. Her areas of interest includes Image Processing, Advanced databases and Computer Networking.

Dr. Suresh N. Mali has completed his PhD from Bharati Vidyapeeth Pune and presently he is working as Principal, Singhgad College of Technology and Science, Narhe, Pune, India. He is author of 3 books and having more than 18 international and national publications. Now, he is working as Member of expert Committee of AICTE, New Delhi to visit at various newly opened institutes on behalf of for western region, working as BOS member for Computer Engineering at University of Pune, MS, India. He has worked as a Member of Local Inquiry Committee to visit at various institutes on behalf of University of Pune. His areas of interest mainly include Image Processing.