RESEARCH ARTICLE   OPEN ACCESS

An Efficient Frame Embedding Using Haar Wavelet Coefficients And Orthogonal Component Analysis

Charchika Saraswat[1], Diwakar Gautam[2], Anupam Agarwal[3]

[1]Department of Electronics & Communication, Jagannath University, Jaipur, Rajasthan, India
[2]Department of Computer Science and Engineering, MNIT, Jaipur, Rajasthan, India
[3]Department of Electronics & Communication, Jagannath University, Jaipur, Rajasthan, India

Abstract
Digital media, applications, copyright defense, and multimedia security have become a vital aspect of our daily life. Digital watermarking is a technology used for the copyright security of digital applications. In this work we have dealt with a process able to mark digital pictures with a visible and semi invisible hided information, called watermark. This process may be the basis of a complete copyright protection system. Watermarking is implemented here using Haar Wavelet Coefficients and Principal Component analysis. Experimental results show high imperceptibility where there is no noticeable difference between the watermarked video frames and the original frame in case of invisible watermarking, vice-versa for semi visible implementation. The watermark is embedded in lower frequency band of Wavelet Transformed cover image. The combination of the two transform algorithm has been found to improve performance of the watermark algorithm. The robustness of the watermarking scheme is analyzed by means of two distinct performance measures viz. Peak Signal to Noise Ratio (PSNR) and Normalized Coefficient (NC).
Keywords: Digital Watermark, Principal Component Analysis, Discrete (Haar) Wavelet Transform, PSNR, NormalizedCoefficient.

I.   Introduction:

Continuous efforts are being made to devise an efficient watermarking schema, but techniques proposed so far do not seem to be robust to all possible attacks and multimedia data processing operations. Watermarking founds a sudden increase in interest, most likely due to the increase in concern over Intellectual Property Right (IPR). Watermarking techniques may be relevant in various application areas including Copyright protection, Copy protection, Temper detection, Fingerprinting etc. [1-3]. Based on their domain embedding, watermarking schemes can be classified either as Spatial Domain (the watermarking system directly alters the main data elements, like pixels in an image, to hide the watermark data) or Transformed Domain (the watermarking system alters the frequency transforms of data elements to hide the watermark data). The latter has proved to be more robust than the spatial domain watermarking [1], [4].

To transfer an image to its frequency representation, one can use several reversible conversion like Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT), or Discrete Fourier Transform (DFT)[1]. As though spatial domain based techniques cannot sustain most of the common attacks like compression, high pass or low pass based filtering, etc.[1], [4].

Since, financial implications of some of the application areas like fingerprinting and copyright protection are very high and till now no successful

algorithm seem to be available to prevent illegal copying of the multimedia content, the primary goal of this research work targeted to develop a watermarking scheme for video frames (which are stored in spatial domain as well as transformed domain) which can sustain the known attacks and various image manipulation operations.

II.   Haar Wavelet Transform:

DWT is the discrete variant of the wavelet transform. Wavelet transform represents valid alternative to the cosine transform used in standard JPEG. The DWT of images is a transform based on the tree structure with n levels that can be implemented by using an appropriate bank of filters. Essentially it is possible to follow two strategies that differ from each other basically because of the criterion used to extract strings of image samples to be elaborated by the bank of filters. Most image watermarking schemes operate either in the Discrete Cosine Transform (DCT) or the Discrete Wavelet Transform (DWT) domain. A few watermarking algorithms employ more exotic transforms such as the Fourier-Mellin Transform and the fractal transform [6].

The DWT is computed by successive low pass and high pass filtering of the discrete time-domain

signal. This is called the Mallet algorithm or Mallet-tree decomposition. Its significance is in the manner it connects the continuous-time muti-resolution to discrete-time filter.

Let a signal be denoted by *x[n]*, where *n* is an integer sequence. G_0 and H_0 represents the low pass filter and high pass filter transfer functions respectively. At each level, high-pass filters detail information, *d[n]*, is associated with low-pass filter, while scaling function produces coarse approximate, *a[n]*. Thus the time-frequency plane is resolved. The filtering and decimation process is continued until the desired level is reached. Depending on the maximum number of levels the length signal. DWT of the original signal is then obtained by concatenating all the coefficients, *a[n]* and *d[n]*, starting from the last level of decomposition.

2.1 Haar kernel function:

The family of *N* Haar functions $h_k(t)$ are defined on the interval $0 \le t \le 1$. The shape of the Haar function of an index *k*, is determined by two parameters: *p* and *q*, where

$$k = 2^p + q - 1$$

and *k* is in a range of $k = 0, 1, 2, 3 .... N-1$.

When $h_0(t) = \dfrac{1}{\sqrt{N}}$, the Haar function is defined as a constant when $k > 0$, the Haar function is defined as

$$h_k(t) = \frac{1}{\sqrt{N}} \begin{cases} 2^{p/2} & (q-1)/2^p \le t < (q-0.5)/2^p \\ -2^{p/2} & (q-0.5)/2^p \le t < q/2^p \\ 0 & \text{otherwise} \end{cases}$$

III. Principal Component Analysis:

Principal component analysis (PCA) is a mathematical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of uncorrelated variables called the major components. It reduces the number of principal components less than or equal to the number of the original variables. The first major component of change has the variability in the data as much the larger as possible, so hit the highest possible variance under the constraint that each (i.e. uncorrelated) components are orthogonal to preceding components. The key ingredient is combined data set normally distributed, therefore guaranteed to be independent.

PCA is sensitive to relative scaling of the original variables. PCA was invented by Karl Pearson in 1901 [9] as an analogue of the principal axes theorem in mechanics. It was later independently developed (and named) by Harold Hotelling in 1930s [10]. The method is mostly used as a tool in exploratory data analysis and for making predictive models. PCA can be achieved by eigenvalue decomposition of a data covariance

(or correlation) matrix or singular value decomposition of a data matrix, usually after mean centering (and general or using *Z* scores) the data matrix for each attribute [10].

Results of a PCA are usually discussed in terms of factor score, sometimes called the component scores [11]. PCA is the simplest of the true eigenvector based multivariate analysis. Often, our actions in a way to explain the variance in the data revealing the internal structure of the data. A multivariate high dimensional dataset data space (1 axis per variable) is assumed as a set of coordinates, in some sense. PCA is closely related to factor analysis.

The main advantage of PCA is that once these patterns in the data have been identified, the data can be compressed by reducing number of dimensions, without much loss of information. Plots the data into a new coordinate system where the data with maximum covariance are plotted together and is known as the first principal component.

Similarly, there are the second and third principal component and so on. Maximum p o w e r concentration lies in the first major component.

The below algorithm represents the algorithm utilized for PCA:

3.1 Algorithm for PCA:

Let a data set be represented by matrix Q with p rows and m columns where p represents the number of data while m represents the number of dimensions to represent a particular data.

Step 1: Compute the mean μ_i and standard deviation σ_i of each row D_i where *i* varies from 1 to p.

Step 3: Compute Z_i, according to the following equation

$$Z_i = (D_i - \mu_i)/\sigma_i \tag{1}$$

Here Z_i represents a centered, scaled version of D_i, of the same size as that of D_i.

Step 4: Principal Component Analysis on Z_i (size p x m) to obtain the principal component coefficient matrix $coeff_i$ (size m x m).

Step 5: Calculate vector *Score(i)* as

$$Score(i) = Z_i \times coeff_i \tag{2}$$

where *Score(i)* represents the principal component scores of the ith sub-block.

IV. Proposed Method:

In this work we propose an invisible and semi visible watermarking (according to dynamic range of hiding parameter, *alpha*) using the methodology depicted by the following steps:-

4.1 Steps:
4.1.1) Embedding the Watermark in cover image:

Step 1: Convert each frame from RGB to YUV colour format.

Step 2: Apply 2-level Haar transform to the Luminance (Y) component and obtain 4 sub-bands LL, LH, HL and HH of sizes *N/4* x *N/4*.

Step 3: Divide the LL sub-bands into *k* non-overlapping sub-blocks each of dimension *n* x *n* of the same size as that of message.

Step 4: Embedding of watermark is established with strength α into each sub-block firstly by obtaining the principal component scores by PCA Algorithm (3.1). The embedding is carried out using equation below.

$$score(i) = Score(i) + \alpha W \qquad (3)$$

Where, *score(i)* represents the principal component matrix of the ith sub-block.

Step 5: Apply inverse PCA on the modified PCA components of sub-blocks of the LL sub-bands to obtain the modified wavelet coefficients.

Step 6: Apply 2-level inverse DWT to obtain the watermarked luminance component of frame. Then convert video frame back into its RGB components.

4.1.2) Watermark Extraction from Watermarked Frame:

The below steps should be carried out parallel on original and watermarked images to obtain *Score(i)* and *score(i)*.

Step 1: Convert each frame from RGB to YUV colour format.

Step 2: Choose the luminance (Y) component of the frame and apply 2-level Haar transform to obtain 4 sub-bands LL, LH, HL and HH of sizes *N/4* x *N/4*.

Step 3: Divide the LL sub-band into n × n non-overlapping sub-blocks.

Step 4: Pass each block of chosen LL band to PCA Algorithm (3.1).

Step 5: From the LL sub-band, the watermark gray values are extracted from the principal components of each sub-block by using below equation:

$$W(i) = (score(i) - Score(i)) / \alpha \qquad (4)$$

where *W(i)* is the watermark extracted from the ith sub block.

4.2 Verification of the Result:

The MSE (Mean Square Error) and NC (Normalized Coefficients) values are calculated for the watermarking procedure. And the criterion of good watermarking technique is lower should be the MSE value and higher should be the NC value. MSE represent the similarity index of original image in comparison to watermarked image while MSE represent the index that shows the deterioration or damage of extracted watermark when compared to original watermark which was used for hiding in the previous stage. Resemblance of watermarked image or attacked frame to cover (original image). Better is resemblance, better is watermarking scheme.

4.2.1 PSNR: *The Peak-Signal-To-Noise Ratio (PSNR)* is used to evaluate deviation of the watermarked and the attacked watermarked frames from the original frame and is defined as:

$$PSNR = 10\ Log_{10}\ (255^2\ /\ MSE),\ \text{measured in}$$
dB (decibels) units.

Where, *MSE* (mean squared error) between original and distorted frames (size *m x n*) is defined. MSE is sum of squared difference between original and watermarked frame.

4.2.2 The Normalized Coefficient (NC): It gives a measure of the robustness of watermarking. NC can be ranged between 0 to1:

$$NC = \sum \frac{W(i) * W'(i)}{\sqrt{W^2(i) * W'^2(i)*}}$$

W and W' represent the original and extracted watermark respectively.

V. Experimental Results:

The proposed algorithm is implemented on a Core-i5 processor, running on a Windows7 platform (64bit). The experiment was performed for a given set of cover images and watermark images. The 'baboon.tif', 'lena.tif', 'pirate.tif', and 'cameraman.tif' etc. images are considered for experimental work.

The watermark images are taken as gray values images, while the cover information is rendered as colored ones as depicted by Fig.(1& 2) .
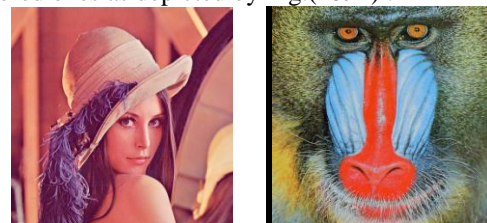

Fig.1 Cover Image Set

Fig. 2 Watermark Images set

The cover image at its initial phase are transformed to cylindrical color space (YUV). The luminance component is further applied for its DWT transform, from which the LL (approximation band) is extracted.

The principal coefficient are evaluated for non-overlapping distinct block set of LL band. The

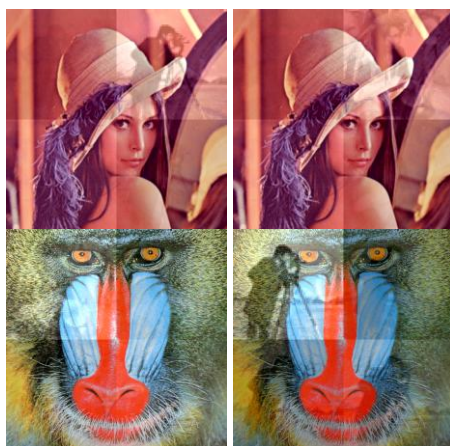embedding is carried out by Algo.4.1.1 as represented by Fig.(3):-


Fig. 3 Watermarked Images

The embedded watermark or message image can be extracted by using Algo. 4.1.2 applied parallel on watermarked and cover images respectively. The extraction process is carried out on Fig.(3) results and extracted watermark is represented by Fig.(4).

The performance of the proposed watermarking algorithm is evaluated using prominent performance measurement methods of PSNR and NC coefficients.
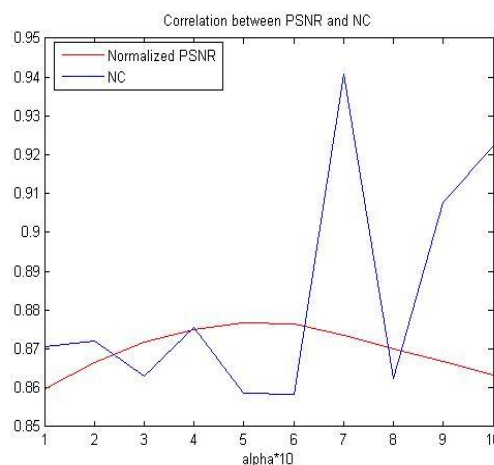

Fig. 4 Extracted Watermarks or Message

The following plot represent the PSNR and NC plot for two cover images. The plot shows that via this proposed methodology we have succeed to achieve the targeted value of high PSNR and NC value nearer to 1.
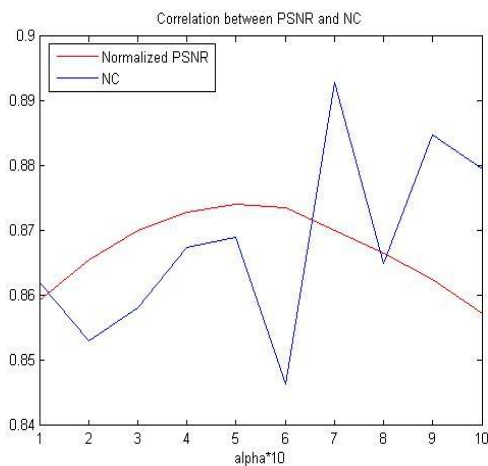
(a)

(b)
Fig. 5(a), (b) Plots for PSNR & NC

VI. Future Scope & Conclusion:
In this article we proposed an efficient watermarking algorithm for invisible and semi visible watermarking algorithm, depending on the value of alpha under the consideration. Higher value give semi visible resemblance, but if alpha continuously goes on increasing may degrade the frame quality, while for lower value of alpha the system generates invisible water mark frames.

As a future scope the concept of Cryptography and Digital Watermarking can be combined to implement more secure Digital Watermarking system. We can use the watermarking technique in the frequency domain of various applications watermark, as the image watermark. We can also implement in other spatial domain techniques and cryptography algorithms for most advanced encryption technique to encrypt the messages. As a future work the video frames can be subject to scene change analysis to embed an independent watermark in the sequence of frames formation of a scene, and repeat this process for all scenes within a video.

REFERENCES
[1]   Saraju P. Mohanty "*Digital Watermarking: A Tutorial Review*", URL: http:// www. csee. usf. edu/~ smohanty/ research /Reports /WMSurvey1999 Mohanty.pdf & http:// citeseer .ist. psu.edu / mohanty99 digital.htm.
[2]   W. Bender, D. Gruhl, N. Morimoto, and A. Lu. "*Techniques for data hiding*". *IBM Systems Journal,* Vol. 35.(3/4), 1996, pp. 313-336.
[3]   M. Arnold, M. Schmucker, and S.D. Wolthusen, "*Techniques and application of Digital Watermarking and Content Protection*", Eds.Northwood ,Artech House, 2003.

[4] I.J. Cox, J.Kilian, T.Leighton and T. Shamoon, *"Secure Spread Spectrum watermarking for Multimedia,"* IEEE Tras. on Image Processing , Vol. 6,No12, 1997, pp. 1673-1687.

[5] Potdar, Vidysagar and Han, Song and Chang, Elizabeth, "*A survey of digital image watermarking techniques*", Proceeding of *3rd IEEE-International Conference on Industrial Informatics, Frontier Technologies for the Future of Industry and Business*, pp. 709-716, Perth, WA, Aug 10, 2005.

[6] F. Bossen M. Kutter , F. Jordan, "*Digital signature of color images using amplihlde modulation,*" in Proc. of SPlE storage and retrieval for image and video databases, San lose, USA, vol. 3022-5, February 1997, pp. 518-526.

[7] Hsu C. T. and Wu, J. L. *Hidden Digital Watermarks in Images. IEEE Trans. on Image Processing*, vol. 8, no. 1, pp. 55-68. 1999.

[8] Selesnick, I.W.; Baraniuk, R.G.; Kingsbury, N.C. - 2005 - The dual-tree complex wavelet transform.

[9] Hotelling, H. (1933). *Analysis of a complex of statistical variables into principal components.* Journal of Educational Psychology, 24, 417-441, and 498-520

[10] Hotelling, H. (1936). Relations between two sets of variates. Biometrika, 27 ,321 Abdi. H., & Williams, L.J. (2010). "*Principal component analysis*" Wiley Interdisciplinary Reviews: Computational Statistics, 2: 433–459. doi:10.1002/wics.101.

[11] N. Terzija, "*Digital Image Watermarking in The Wavelet Domain*", Technical Report, Faculty of Engineering Sciences, Gerhard-Mercator-Universität Duisburg, December2002, http://www.fb9dv.uni-duisburg.de/members /ter/trep_1202.pdf