International Journal of Advancements in Electronics and Electrical Engineering– IJAEEE
Volume 4 : Issue 2 [ISSN : 2319-7498]
Publication Date : 30 October, 2015

Comparative Performance Analysis of Video Watermarking in DCT, DCT-SVD Domains

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***Abstract*—In this paper, watermark is generated uniquely for given video combining copyright information, video signature and time stamp. This watermark is scrambled using Arnold transform method and then divided into eight sub-images. Video is divided into video sequence and audio sequence. Frames are selected using scene change method, for embedding. Each scene change frame is divided into 8 x 8 blocks and DCT is applied to check energy. High energy block is selected for embedding the watermark bit. Embedding is done using Blind DCT-SVD method. Audio stream is also divided into equal size frames and DCT-SVD method used to add watermark bit to each frame.**

Experimental results show that proposed algorithm is useful for copyright protection as well as authentication. Embedded frame is compared with original frame to check its quality. Peak Signal to Noise Ratio (PSNR) is 49.77 dB for atrium.avi and 48.35 dB for baby.mp4. Embedded video is tested for robustness against attacks such as frame swapping, frame dropping, frame averaging, filter and compression. Normalized cross correlation (NK) value is calculated by comparing original watermark and extracted watermark, which is nearly 1. The security has strengthened with scene change detection; Energy based block selection, Arnold transform and division of the watermark. Parts of watermark have been embedded in the audio data for more robustness and error correction.

***Keywords*—DCT, SVD, Video Watermarking**

I. Introduction

Video data is more complex than audio or image data. Video contains spatial as well as temporal information [1]. Video is available both in raw and compressed formats. Digital watermarking for video is a fairly new area of research which basically benefits from the results for still images [2]. Many algorithms have been proposed in the scientific literature in three major trends. The most simple and straight-forward approach is to consider a video as a succession of still images and to reuse an existing watermarking scheme for still images. Another point of view considers and exploits the additional temporal dimension in order to design new robust video watermarking algorithms [3]. The last trend basically considers a video stream as some data compressed according to a specific video compression standard and the characteristics of such a standard can be used to obtain an efficient watermarking scheme [4].

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In this paper we followed the first approach. First, we considered the video as a sequence of still images, then Discrete Cosine Transform (DCT) domain and Singular value decomposition domain were used for embedding the watermark. The remaining part of paper is organized as follows: Section-2 gives survey of work related to DCT and SVD; section-3 gives mathematical background of DCT and SVD and Arnold Transform technique was used for scrambling the watermark. In section-4 a comparison of DCT and DCT-SVD based methodology is presented. Experimentation and results are elaborated in section-5 while conclusion is drawn in section-6.

II. Previous work

Images can be represented in spatial domain and transform domain. The transform domain image is represented in terms of its frequencies however, in spatial domain it is represented by pixels. To transfer an image to its frequency representation we can use several reversible transforms like the Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT) or Discrete Fourier Transform (DFT). Each of these transforms has its own characteristics and represents the image in different ways. DCT based watermarking techniques are more robust compared to simple spatial domain watermarking techniques. DCT domain watermarking can be classified into Global DCT watermarking and Block based DCT watermarking. One of the first algorithms presented by Cox et al.[1] used global DCT approach to embed a robust watermark in the perceptually significant portion of the Human Visual System (HVS). Embedding in the perceptually significant portion of the image has its own advantages because most compression schemes remove the perceptually insignificant portion of the image. DCT based watermarking techniques are presented by Gwena.el Do.err et al.[3], Pik Wah Chan [4], Sourav Bhattacharya et. al.[5], Yujie Zhang [7] and Ersin Elbasi et al.[9]. Many researchers have already tried to combine DCT-DWT based technique as proposed by Saied Amirgholipour Kasmani et al.[12] where binary watermarked image is embedded in specific sub-bands of 3-level transformed host image. Each of DWT sub-band is selected and then DCT values are computed, then embedding is done in DCT middle frequencies. Few researchers have combined DWT and SVD to take advantage of their individual special properties. The DWT and SVD transforms are combined by Hailiang Shi et al.[13] to implement rotation, scaling and translation(RST) invariant scheme. Priyanka Singh et al.[14] used hybrid DWT-SVD based color image watermarking scheme in YUV and YIQ color spaces. The scheme tested the 512x512 size cover images to check imperceptibility and robustness in terms of Peak Signal to Noise Ratio (PSNR) and Normalized Cross Correlation (NCC) respectively. The method gives better performance in Y color space. Chih-Chin

Lai et al. [15] used DWT and SVD hybridization and proved robustness against geometric attacks. Samira Lagzian et al.[16] presented Redundant Discrete Wavelet Transform (RDWT)-SVD based method that embeds data in all low, middle and high frequency sub-bands of DWT. DWT-DFT composition is used by Xiangui Kang et al.[17] to achieve robustness against almost all affine transforms and JPEG compression attacks. Sivavenkateswara Rao V. et al.[18] combined DWT,DCT and SVD for optimization of robustness and fidelity. Say Wei et al [19] used DCT-SVD combination and Feng Liu et al [20] proposed blind method using DCT-SVD domain.

III. Mathematical Preliminaries

A. *Discrete Cosine Transform*

DCT convert image into various frequency bands. Embedding watermark in low frequency band gives less perceptual distortion but simple signal processing attacks can remove the watermark. High frequency components are also affected by common image processing operations and compression attacks. Therefore the best choice for watermark insertion can be the middle frequencies.

DCT Equations:

The DCT Equation 1 computes (i,j)th entry of the DCT of an image

$$D(i,j) = \frac{1}{\sqrt{2N}} C(i)C(j) \sum_{x=0}^{N-1} \sum_{y=0}^{N-1} p(x,y) \cos\left[\frac{(2x+1)i\pi}{2N}\right] \cos\left[\frac{(2y+1)j\pi}{2N}\right] \ldots\ldots (1)$$

where, $$C(u) = \begin{cases} \frac{1}{\sqrt{2}} \text{ if } u = 0 \\ 1 \text{ if } u > 0 \end{cases}$$

The IDCT equation 2 computes (x, y)th entry of DCT Matrix

$$p(x,y) = \sum_{i=0}^{N-1} \sum_{j=0}^{N-1} C(i)C(j)D(i,j) \cos\left[\frac{(2x+1)i\pi}{2N}\right] \cos\left[\frac{(2y+1)j\pi}{2N}\right] \ldots.. (2)$$

where $$C(u) = \begin{cases} \frac{1}{\sqrt{2}} \text{ if } u = 0 \\ 1 \text{ if } u > 0 \end{cases}$$

Energy of each block Bi = $\sum_n \sum_m (\text{DC Coeff})^2$……..(3)

Maximum energy means block is more susceptible to noise.

B. *Arnold Transform*

A digital image can be considered as a two dimensional function f(x, y).

It can be represented as : Z = f(x,y) Where x, y ∈ {0,1,2,3....N-1} . Hence, N represents order of digital image. The matrix of image can be changed into a new matrix by using the Arnold transform which results in a scrambled version to offer better security. It is a mapping function which changes a point (x,y) to another point (x' , y') by using the equation (4) and (5).

x' = (x + y) mod N……………………………..…….(4)

y' = (x+2y) mod N……….…………………………...(5)

If the original image iterates n times to come to some scrambled state, the scrambled image has also needs to iterate n times using new anti-Arnold transform to come to original image. Equations (6) and (7) shows anti-Arnold transform.

x = (2x' – y') mod N ……………….…………………(6)

y = (-x' + y') mod N ………………………………...(7)

C. *Singular Value Decomposition (SVD)*

SVD is an algebraic technique for image watermarking on any digital signal. Singular values of an image have very good stability. The minor variations in singular values do not affect the perception quality of given image to a major extend. The largest of singular values shows slight changes for most common geometric attacks. SVD of an image A with size M x N is represented as (8),

$$A = U\sum V_T \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

Where, U and V are orthogonal matrices such that,

UUT =I and VVT = I

Σ is summation of diagonal entries λ1, λ2…..gives the singular vectors of A.

Thus we have,

$$A = \lambda_1 U_1 V_1^T + \lambda_2 U_2 V_2^T + \cdots \ldots\ldots\ldots + \lambda_r U_r V_r^T \ldots\ldots (9)$$

Where, r is rank A.

The columns of U and V are left and right singular vectors of A.

D. *Scene Change Detection*

For scene change detection, we used Image Differencing / Template matching method. In this method images of the same area, obtained from times t1 and t2 are subtracted pixel-wise. Mathematically, the image difference (Id) is

$$I_d(x,y) = I_1(x,y) - I_2(x,y) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

Where, I_1 and I_2 are the images obtained from t1 and t2, (x, y) are the coordinates of the pixel. The Resulting image I_d represents intensity difference of I_1 and I_2.

The change is detected by applying simple thresholding to $I_d(x,y)$ as

$$T(x,y) \begin{cases} 1 & I_d(x,y) \geq \tau \\ 0 & \text{otherwise} \end{cases} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (11)$$

Where, the threshold τ is determined empirically.

IV. Proposed System

After the text edit has been completed, the paper is ready for the template. Duplicate the template file by using the Save As command, and use the naming convention prescribed by your conference for the name of your paper. In this newly created file, highlight all of the contents and import your prepared text file. You are now ready to style your paper; use the scroll down window on the left of the MS Word Formatting toolbar.

The proposed method is implemented in DCT-SVD as well as in DCT domain. The DCT-SVD domain methodology is presented in A here, while DCT based methodology is explained in B.

A. *DCT-SVD Domain Methodology*

The DCT-SVD based embedding algorithm is presented in table 1 and watermark extraction algorithm is shown in table 2

TABLE 1: DCT-SVD BASED WATERMARK EMBEDDING

	Input – Video Sequence (V), Watermark Image (W) Output – Embedded Video Sequence (EV), PSNR
	Steps
1	Read Video sequence (V) and convert it into frames F1…Fn
2	Apply scene change algorithm to get scene changed frames (Fs1…..Fsm)
3	Divide each scene changed frame into 8 X 8 blocks and apply DCT and check energy of each block (Bi)
4	If energy of Block Bi is More than threshold t1, select this block for embedding
5	Select Watermark image (W) of size 256 X 256, Divide by 16 to get, 64 X 64 sub-images (Wm1….Wm16).
6	Select each one of the sub-images Wmi and apply Arnold transform to scramble it.
7	Apply SVD on selected block for embedding [u s v] = svd(Bi)

8	Watermark is embedded into S(1,1) as follows
	Z = mod(S(1,1), Q)
	if (W(i) == 1)
	if(Z<=Q/4)
	S(1,1) = S(1,1)-Z-Q/4
	else
	S(1,1) = S(1,1)-Z+3*Q/4
	end
	else
	if(Z>=3*Q/4)
	S(1,1) = S(1,1)-Z+5*Q/4
	else
	S(1,1) = S(1,1)-Z+Q/4
	end
	end

9	Apply Singular value decomposition to obtain embedded block Bem = u * sm * vt
10	Apply inverse DCT on embedded block to obtain embedded frame Fem
11	Merge all frames to obtain watermark embedded video EV
12	Compare original frame(Fsi) and embedded frame(Femi) to check perceptual quality and calculate PSNR

TABLE 2: DCT-SVD BASED WATERMARK EXTRACTION

	Input – Watermarked Video Sequence (EV), Output – Extracted Watermark Image (EW), NC
	Steps
1	Read Video watermarked sequence (EV) and convert it into frames F1…Fn
2	Apply scene change algorithm to get scene changed frames (Fs1…..Fsm)
3	Divide each scene changed frame into 8 X 8 blocks and apply DCT and check energy of each block (Bi)
4	If energy of Block Bi is More than threshold t1, select this block for extraction
5	Apply SVD on selected block for embedding [u s v] = svd(Bi)

6	Watermark is extracted from S(1,1) as follows
	Z = mod(S(1,1), Q)
	if (Z > Q/2)
	EW = 1
	else
	EW = 0
	End

7	Apply Arnold transform to unscramble it.
8	Combine all sub-images of extracted watermark to form a complete watermark image
9	Compare original and extracted watermark using Normalized Correlation (NC)

B. *DCT Domain Methodology*

To implement DCT domain watermark embedding algorithm, SVD steps are skipped from table 1, watermark is embedded into DC Coefficient at DC(1,2) position and to implement DCT domain watermark extraction algorithm SVD related steps are skipped from table 2 and watermark is extracted from DC(1,2) position. The rest of the algorithmic steps will be applied in same sequence as given in table 1 and table 2.

V. Experimental Results

The proposed work is implemented using Java Net beans IDE version 7.3 and Matlab [version 8.0.0.7837(R2012b)]. The experimentation is carried out on personal computer with Intel(R), Core(TM) i3-2310M, processors rated at 2.10 GHz, main memory of 4 GB and 32 bit Microsoft Windows 7 operating system. The varieties of tests are carried out to evaluate perceptual quality and robustness for videos of different frame sizes and grey scale watermark of 256x256 sizes. The following table 3 shows database used for experimentation. Fig.1. shows sample output of DCT-SVD based method with original frame, original watermark cameraman, scrambled watermark, watermarked frame, extracted watermark and recovered watermark cameraman

To evaluate performance and test robustness with respect to various attacks, VideoPad Video Editor V 3.81 is used. Extracted watermark is compared with original watermark using Normalized Correlation (NC)

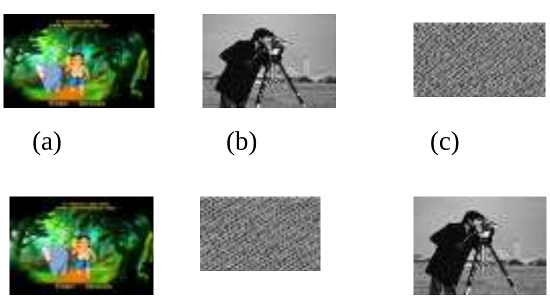
$$NC = \frac{\sum_{i=1}^{M} \sum_{j=1}^{N} (x(i,j) \times y(i,j))}{\sum_{i=1}^{M} \sum_{j=1}^{N} (x(i,j))^2} \text{......................................} (12)$$

The major attribute to measure image quality is PSNR. Higher PSNR implies better quality of watermarked image. Initially, the Mean Square Error (MSE) is found and PSNR is calculated using MSE. MSE between two input Frames (F1) and (F2) is given by equation (13),

$$MSE = \frac{1}{M * N} \sum_{i=1}^{M} \sum_{j=1}^{N} [F1(i,j) - F2(i,j)]^2 \dots\dots\dots\dots (13)$$

Where, M*N is size of images, F1 (i, j) is pixel of original frame, and F2(i, j) is pixel values of watermarked frame. Now, PSNR of two Frames F1 and F2 of size M x N is given by equation (14),

$$PSNE(dB) = 10\log_{10} \frac{255}{MSE} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (14)$$



(a) (b) (c) (d) (e) (f)

Figure 1. Sample output of DCT-SVD based method (a)Original Cover Frame (b) Original Watermark (c) Scrambled Watermark d)Watermarked Frame e) Extracted Watermark f) Recovered Watermark

Following table 3 shows results of DCT-SVD method with respect to various attacks

TABLE 3: NK VALUES AFTER SIGNAL PROCESSING AND VIDEO PROCESSING ATTACKS

Attack Type	Video Sequence (NK Values)				
	Akiyo	*Atrium*	*Baby*	*GT*	*MB*
Median Filter(3X3)	0.9950	0.9698	0.9642	0.9762	0.9655
Smoothing	0.9849	0.9548	0.9623	0.9631	0.9612
Weighted Average	0.9950	0.9648	0.9623	0.9631	0.9612
Gaussian Noise	1.0000	0.9849	0.9976	0.9896	0.9765
MPEG-4 Compression	0.9648	0.9554	0.9634	0.9534	0.9532
Frame Dropping	1.0000	0.9877	0.9865	0.9844	0.9852
Frame Swapping	1.0000	0.9898	0.9913	0.9873	0.9905

TABLE 4: PERFORMANCE OF DCT-SVD, COMPARED WITH [12] METHOD

Attack Type	DCT-SVD (NC)		DCT (NC) [12]	
	Akiyo	*GT*	*Akiyo*	*GT*
Median Filter(3X3)	0.9950	0.9762	0.8726	0.8655
Smoothing	0.9849	0.9631	0.8316	0.8612
Weighted Average	0.9950	0.9631	0.8681	0.8772
Gaussian Noise	1.0000	0.9896	0.8886	0.8765
MPEG-4 Compression	0.9648	0.9534	0.8590	0.8532
Frame Dropping	1.0000	0.9844	0.8848	0.8852
Frame Swapping	1.0000	0.9873	0.8873	0.8905

Original frame compared with embedded frame for Perceptual Quality Test

TABLE 5: PERCEPTUAL QUALITY TEST

Video Files	PSNR(dB)	
	DCT-SVD Method	*DCT Method*
Akiyo.mp4	48.59	45.96
Atrium.avi	49.67	44.89
Baby.mp4	48.35	44.56
GT.mp4	48.88	45.67
MB.mp4	49.21	44.79

From Table 4, it is clear that NC values of candidate videos Akiyo and GT are better in DCT-SVD domain than DCT domain also Table 5 shows DCT-SVD domain maintains frame quality as compared to only DCT domain.

Conclusion

We have proposed a technique for copyright protection. The achievement of imperceptibility, robustness and strong security in digital video watermarking techniques is a challenging issue. The method proposed here fulfills these requirements simultaneously. The practical demonstration shows that performance of proposed method in DCT-SVD domain is superior to DCT domain for different sizes candidate videos i.e. Akiyo, Atrium, GT, Baby, MB and 256x256 sizes grey scale watermarks. The proposed DCT-SVD based method is strongly robust against various signal processing and video processing attacks. The proposed method is also found superior than DCT based method [12] against various attacks. The security has strengthened with scene change detection, Energy based block selection, Arnold transform and splitting the watermark.

Acknowledgment

We are thankful to MKSSS's Cummins College of Engineering for Women, Padmashri Dr. D. Y. Patil College of Engineering and Technology and Sinhgad Institute of Technology and Science for encouragement and support.

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