Robust & Blind Video Watermarking Algorithm Using SVD Transform

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***Abstract*— With the advance of editing software and the popularity of the internet, illegal operations in digital media, have become easy, fast and difficult to prevent. Therefore, the protection of the intellectual property rights of digital media has become an urgent matter. In order to provide intellectual property rights, Digital watermarking schemes are most commonly used. Digital watermarking is an essential tool in digital media for copyright protection and authentication.**

Video watermarking is relatively a new technology that has been proposed to solve the problem of illegal manipulation and distribution of digital video. It is the process of embedding copyright information in video bit streams. Video Water marking in particular is quite expensive and complex. Video watermarking introduces more issues compared to the Image watermarking. In video watermarking, watermark can be embedded in spatial domain and transform domain. There are various transforms like DCT, DFT, DWT and SVD etc.

In this paper A blind Video watermarking algorithm is implemented based on Singular Value Decomposition (SVD). The algorithm robustness is tested against attacks such as JPEG compression, median filtering, lowpass filtering, gaussian noise, salt and pepper noise, gamma correction and resizing. The performance of the algorithm is evaluated using parameters like mean square error (MSE), peak signal to noise ratio (PSNR), bit error rate (BER), embedding time and retrieving time.

Keywords—VideoWatermarking,Singular Value Decomposition,Robustness,Peak Signal to Noise Ratio,Mean Square Error,Bit Error Rate

I. INTRODUCTION

The rapid expansion of the internet in the recent years has rapidly increased the availability of digital data such as audio, images and videos to the public. As we have witnessed in the past few months, the problems of protecting multimedia information becomes more and more important and a lot of copyright owners are concerned about protecting any illegal duplication of their data or work. Some serious work has to be done to maintain the availability of multimedia information and at the same time protecting the intellectual property of creators, distributors or simple owners of such data. This is an interesting challenge and is probably the reason why so much attention has been drawn toward the development of digital images protection schemes. Of the many approaches available to protect visual data, digital watermarking of images, is to embed information data within the image with an insensible form for human visual system (HVS) but in a way that protects from attacks such as to a human eye but still allows its positive identification in comparison with the owner's key if necessary.

Digital watermarking provides protection of intellectual property in the digital world. Just as plagiarism runs rampant in the physical world, unauthorized copying of data whether it be audio, visual, or video exists in the digital world. Digital watermarking attempts to copyright the digital data that is freely available on the World Wide Web to protect the owner's rights. As opposed to traditional, printed watermarks, digital watermarks are transparent signatures. They are integrated within digital files as noise, or random information that already exists in the file, thus, the detection and removal of the watermark becomes more difficult. Typically, watermarks are dispersed throughout the entire digital file such that the manipulation of one portion of the file does not alter the underlying watermark.

II. FEATURES OF WATERMARKING SCHEME

Digital watermarking techniques are useful for embedding metadata in multimedia content. There are alternate mechanisms like using the header of a digital file to store meta- information. However, for inserting visible marks in images & video and for adding information about audio at the beginning or end of the audio clip etc. the digital watermarking technique is appealing, since it provides following main features and does not require out-of-band data as in other mechanisms.

- **Imperceptibility**: The embedded watermarks are imperceptible both perceptually as well as spastically and do not alter the aesthetics of the multimedia content that is watermarked. The watermarks do not create visible artifacts in still images, alter the bit rate of video or introduce audible frequencies in audio signals.
- **Robustness**: Depending on the application, the digital watermarking technique can support different levels of robustness against changes made to the watermarked content. If digital watermarking is used for ownership identification, then the watermark has to be robust against any modifications.

The watermarks should not get degraded or destroyed as a result of unintentional or malicious signal and geometric distortions like analog-to-digital conversion, digital-to-analog conversion, cropping, resampling, rotation, dithering, quantization, scaling and compression of the content. On the other hand, if digital watermarking is used for content authentication, the watermarks should be fragile, i.e. the watermarks should get destroyed whenever the content is modified so that any modification to content can be detected.

- **Inseparability**: After the digital content is embedded with watermark, separating the content from the watermark to retrieve the original content is not possible.
- **Security**: The digital watermarking techniques prevent unauthorized users from detecting and modifying the watermark embedded in cover signal. Watermark keys ensure that only authorized users are able to detect/modify the watermark.

III. SINGULAR VALUE DECOMPOSITION(SVD)TRANSFORM

Computer technology these days is most focused on storage space and speed. One way to help cure this problem is Singular Value Decomposition. We have put together this easy to read explanation of how to use Singular Value Decomposition to reduce the space required for storing images.

The singular value decomposition was originally developed by differential geometers, who wished to determine whether a real bilinear form could be made equal to another by independent orthogonal transformations of the two spaces it acts on. Eugenio Beltrami and Camille Jordan discovered independently, in 1873 and 1874 respectively, that the singular values of the bilinear forms, represented as a matrix, form a complete set of invariants for bilinear forms under the orthogonal substitutions. James Joseph Sylvester also arrived at the singular value decomposition for real matrices in 1889, apparently independent of both Beltrami and Jordan. Sylvester called the singular values the canonical multipliers of the matrix A. The fourth mathematician to discover the singular value decomposition independently in Autonne in 1915, who arrived at it via the polar decomposition, the first proof of the singular value decomposition for rectangular and complex matrices seems to be by Eckart and Young in 1936; they saw it as a generalization of the principal axis transformation for Hermitian matrices.

Singular Value Decomposition (SVD) is said to be significant topic in linear algebra by many renowned mathematicians. SVD has many practical and theoretical values, other than image compression. One special features of SVD is that it can be performed on any real (m, n) matrix. It factors A into three matrices U, S, V, such that $A=USV^T$.Where U and V are orthogonal matrices and S is a diagonal matrix.

Singular Value Decomposition (SVD) is a lossless compression technique. So, it is particularly useful when the exact reconstructions of images are required. If less priority to fidelity loss, it will extend to lossy compression technique to achieve high compression ratio.

It's necessary to first introduce the conception of singular value for understanding Singular Value Decomposition [12]. The singular values of an $m \times n$ matrix are defined as follows:

$$\lambda_1 \geq \lambda_2 \geq \cdots \geq \lambda_r > \lambda_{r+1} = \cdots = \lambda_n = 0$$

Let $\sigma = \sqrt{\lambda_i} (i = 1,2 \ldots, n)$ and those are called as singular values of matrix A, and the number of nonzero singular values is consistent with the number of columns of matrix A, and the number of nonzero singular values is consistent with number of rank.

The Singular Value Decomposition can be defined as:

Let matrix A€Cr^{m+n}(r ≥ 1) its non zero singular values are σ_i(i=1,2,…r) Therefore, a new diagonal matrix $\sum_r$ can be defined as $\sum_r = diag(\sigma_1, \sigma_2, \ldots., \sigma_r)$. Matrices $U_{m\times m}$ and $V_{n\times n}$ can make transformation as follows:

$$U^H AV = \begin{bmatrix} \sum_r & 0 \\ 0 & 0 \end{bmatrix}$$

Then the singular value decomposition of matrix A can be defined as:

$A = USV^H$ where

$$S = \begin{bmatrix} \sum_r & 0 \\ 0 & 0 \end{bmatrix}$$

U is an orthogonal matrix with columns that are unit basis vectors spanning the data space, R_m. V is an $n \times n$ orthogonal matrix with columns that are basis vectors spanning the model space, R_n. S is a $m \times n$ diagonal matrix with diagonal elements called singular values. The singular values along the diagonal of S are customarily arranged in decreasing size $\sigma_1 \geq \sigma_2 \geq \cdots \geq \sigma_{n-1} \geq \sigma_n \geq 0$. The columns of U are the eigenvectors AA^T with eigen values σ_i^2, the columns of v_i of V are the eigenvectors of $A^T A$ with eigen value. The σ_i are termed the singular values of the matrix A, the and v_i are the left and right singular vectors of A, respectively.

IV. PROPOSED VIDEO MARKING ALGORITHM

This section contains the description of SVD properties, watermark embedding and retrieving process.

Basic idea

The theoretical analysis of the singular values of an image suffering geometric distortions is provided in [11]:

- The matrix and its transpose have the same non-zero singular values.
- The matrix and its row-flipped or column-flipped have the same non-zero singular values.
- The non-zero singular values of matrix are the constant ratios to its scaled matrix (which is row or column repeated several times).

Every real matrix A can be decomposed into three matrices $A = U\Sigma V^T$,

$UU^T = I$, $VV^T = I$ and $\Sigma = diag(\lambda_1, \lambda_2 \ldots)$.

where U and V are orthogonal matrices,

The $\lambda_1, \lambda_2 \cdots$ are the singular values of A which are sorted decreasingly. The columns of U are called the left singular vectors of A. The columns of V are called the right singular vectors of A. And the singular value decomposition can be formulated as:

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

where r is the rank of matrix A.

Because of above properties, SVD can be used for watermarking against geometrical distortions. The key to blind watermarking is to maintain the original order of singular values.

Watermark embedding

Before the watermark embedding, the original binary sequence must be modulated as a sequence consisting of "1" (modulated from "1") and "-1" (modulated from "0"). In order to keep the order of singular values and robustness to some attacks such as MPEG-2, the watermark embedding process is follows:

a) Apply SVD to the whole cover frames A: $A = U\Sigma V^T$. *The* $\lambda_1, \lambda_2 \ldots$ are singular values of the cover frames.

b) Modify the singular values of the cover frames according to the robustness and visibility:

$$\lambda_i' = 0.5((\lambda_{i-1} + \lambda_{i+1}) + \alpha.w_i.(\lambda_{i-1} - \lambda_{i+1})$$

Because the largest singular values are more important to the image quality, and the smallest singular values are more sensitive to the noise, we choose the middle singular values to embed the watermarks.

c) Get the watermarked video frame $A' = U\Sigma' V^T$,$\Sigma' = diag(\lambda_1', \lambda_2', \ldots \lambda_r')$ where r is the rank of A'.

Watermark extraction

The watermark extracting process is as follows:

a). Apply SVD to whole watermarked frame A': $A' = U\Sigma' V^T$, and the $\lambda_1', \lambda_2', \ldots$ are the singular values of image.

b). Extract the watermarks from the singular values:

$$\begin{cases} w_i = 0; & if\ \lambda_i' > 0.5(\lambda_{i-1}' + \lambda_{i+1}') \\ w_i = 1; & if\ \lambda_i' < 0.5(\lambda_{i-1}' + \lambda_{i+1}') \end{cases}$$

V. EXPERIMENTAL RESULTS AND PERFORMANCE EVALUATION

In this paper, the performance evaluation is based on different parameters; some of these are imperceptibility, robustness against common signal processing operations. Each of these metrics is described in the following sections.

Imperceptibility

An important way of evaluating watermarking algorithms is to compare the amount of distortion introduced into a host image by a watermarking algorithm. In order to measure the quality of the image at the output of the decoder, mean square error (MSE) and peak to signal to noise ratio (PSNR) ratio measurement which measures the maximum signal to noise ratio found on an image has been used as an objective measure for the distortions introduced by the watermarking system are often used.

Mean Square Error (MSE)

The Mean squared error or MSE of an estimator is one of the way to quantify the amount by which an estimator differs from the true value of the quantity being estimated. As a loss function, MSE is called squared error loss. MSE measures the average of the square of the 'error'. The error is the amount by which the estimator differs from the quantity to be estimated. A lower value for MSE means lesser error.

$$MSE = \frac{1}{MN}\sum_{x=1}^{M}\sum_{y=1}^{N}[I(x,y) - I'(x,y)]^2$$

I(x, y) is the Original image

I' (x, y) Approximation version (Extracted image)
M and N are the dimensions of the images.

Peak Signal to Noise Ratio (PSNR)

The PSNR (Peak signal ratio) presents the distortion caused by the watermarking which depends on the MSE. This factor evaluates the imperceptibility of the digital watermarking. In fact, a great distortion of the media indicates the presence of a watermarking. Because many signals have a very wide dynamic range, SNR or PSNR is usually expressed in terms of the logarithmic decibel scale .

The SNR or PSNR is most commonly used as a measure of quality of watermarked image. There is an inverse relation between the MSE and SNR or PSNR values. Logically, a higher value of SNR or PSNR is a good because it means that the ratio of signal to noise is higher. Here, the signal is the original image and the noise is the error in reconstruction. So, find a watermarking scheme having a lower MSE and a high SNR or PSNR.

$$SNR = 10\log_{10}\left\{\frac{\sum_{x=1}^{M}\sum_{y=1}^{N} I(x,y)^2}{\sum_{x=1}^{M}\sum_{y=1}^{N}[I(x,y) - I'(x,y)]^2}\right\}$$

$$PSNR = 20\log_{10}\left(\frac{255}{\sqrt{MSE}}\right)$$

I(x, y) is the Original image

$I'(x, y)$ Approximation version (Watermarked image)

Bit Error Rate (BER)

BER is the ratio of number of erroneous bits in the extracted watermark (compared to the original watermark) to the total number of bits of the watermark image.

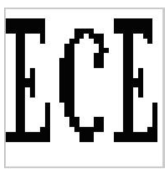
Simulation Scenario

The algorithm is implemented using MATLAB 7.2 version .The watermark used is binary logo(ECE) . In our experiments, binary logo is 1024 bits in length. The cover videos used for embedding watermark ECE are "Mobile" &"Akiyo" videos. The video sequences conform to PAL standard with the resolution of 176×144 for "Mobile" and "Akiyo. There are 256 frames in "Mobile" and "Akiyo" video sequence .Watermarks are embedded in luminance channel of video frames. The watermark intensity is 0.48 and 4 bits is embedded in each frame at the 3^{rd}, 5^{th}, 7^{th} and 9^{th} coefficients.

The algorithm was tested by using attacks such as Gaussian Noise, Salt and Pepper Noise, JPEG compression, Gamma Correction, Resizing, median filtering and lowpass filtering. The parameters used for evaluating the performance of technique are mean square error (MSE), peak signal to noise ratio (PSNR), bit error rate (BER), embedding time and retrieving time. Figure 1.1 to Figure 1.12 shows the simulation results. Table.1 shows the performance against typical attacks. According to the simulation results , our algorithm possesses good visible quality of the watermarked video and is robust to attacks.

SIMULATION RESULTS

Fig 1.1. a) Original mobile video frame (176x144) and its Luminance Channel



b) Embedded binary watermark-ECE(32x32)

Fig 1.2. a) Watermarked mobile video frame and its Luminance Channel with average MSE = 7.7454, average PSNR = 40.0230 db and Embedding time = 22.2493 Sec

b) Retrieved watermark with BER = 0 and Retrieving time = 20.5208 sec

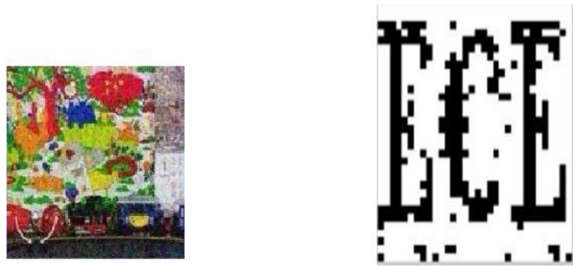


Fig 1.3 Gaussian noise (mean = 0, variance = 0.01) added watermarked mobile video frame and Retrieved watermark with BER = 0.060547

Fig 1.4 Salt and pepper noise (density = 0.2) added watermarked mobile video frame and Retrieved watermark with BER = 0.14063

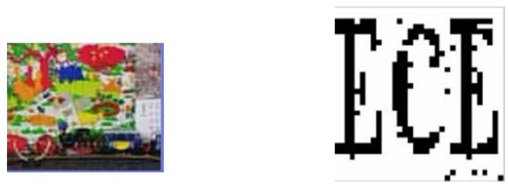


Fig 1.5 JPEG Compressed watermarked mobile video frame and Retrieved watermark with BER=0.029297

Fig 1.6 Gamma corrected (γ=1.2) watermarked mobile video frame and Retrieved watermark with BER=0.0078125

Fig 1.7 Resized (144x144) watermarked mobile video frame and Retrieved watermark with BER=0.017578

Fig 1.8. Median filtered watermarked mobile video frame and Retrieved watermark with BER=0.052734

Fig 1.9. Low pass filtered watermarked mobile video frame and Retrieved watermark with BER=0.06543

Fig 1.10. a) Original Akiyo video frame (176x144) and its Luminance Channel

b) Embedded binary watermark-ECE(32x32)

Fig 1.11. a) Watermarked akiyo video frame and its Luminance Channel with average MSE=14.4441, average PSNR=36.9378 dB and Embedding time = 22.2464 sec

b) Retrieved watermark with BER=0.011719 and Retrieving time = 20.7144 sec

Fig 1.12. Low pass filtered watermarked Akiyo video frame and Retrieved watermark with BER=0.085938

SL NO	ATTACK	MOBILE VIDEO (BER)	AKIO VIDEO (BER)
1	GAUSSIAN NOISE (Mean=0,Variance=0.01)	0.060547	0.03125
2	SALT AND PEPPER NOISE (Density=0.2)	0.14063	0.089844
3	JPEG COMPRESSION	0.029297	0.075195
4	GAMMA CORRECTION (γ=1.2)	0.0078125	0.078125
5	RESIZING (144X144)	0.017578	0.064453
6	MEDIAN FILTERING	0.052734	0.077148
7	LOWPASS FILTERING	0.06543	0.085938

Table 1. Performance against typical attacks on MOBILE and AKIYO videos

CONCLUSION & FUTURE WORK

From the simulation results, it is observed that the SVD based blind video watermarking algorithm is robust to most of the attacks like Gaussian noise, Salt and Pepper noise, JPEG compression, Gamma correction, resizing, median filtering and lowpass filtering with maximum bit error rate(BER) of 0.14063 for binary logo(ECE). And also it is observed that watermarked video possess good visible quality with average MSE of 7.7454 & average PSNR of 40.0230 dB for mobile video, average MSE of 14.4441 & average PSNR of 36.9378 dB for Akiyo video. Embedding time for watermark ECE into mobile video is 22.2493sec & its retrieving time is 20.5208sec. Embedding time for watermark ECE into akiyo video is 22.2464sec & its retrieving time is 20.7144sec.. Moreover, the watermarks can be detected without the original video or any other information of the original singular values, which is not possible in other techniques such as “A SVD-Based Watermarking Scheme for Protecting Rightful Ownership” and “A Geometric Distortion Resilient Image Watermarking algorithm Based on SVD”.

Poor retrieval against attacks like cropping and rotation is the limitation of this algorithm.

The algorithm can be improved to gain better performance against other attacks like cropping, rotation etc.

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