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DWT-SVD BASED ROBUST IMAGE WATERMARKING USING ARNOLD MAP

Sushila Kamble[1], Vikas Maheshkar[2], Suneeta Agarwal[3],
and Vinay Kumar Srivastava[4]

ABSTRACT: Digital watermarking techniques have been developed to protect the copyright of multimedia objects such as text, audio, video, etc. In this paper, we propose SVD-based digital watermarking technique for robust watermarking of digital images for copyright protection. The security of the proposed scheme is increased by applying Arnold map on the watermark to be embedded. We also demonstrate the good correlation between the embedded and the extracted watermark with the help of experimental results. One of the major advantage of the proposed scheme is the robustness of the technique on wide set of attacks. Analysis and experimental results show much improved performance of the proposed method in comparison with the pure SVD-based watermarking and the technique without using Arnold map. Experimental results confirm that the proposed scheme provides good image quality of watermarked images.

Keywords: Singular value decomposition; Digital Image watermarking; Robustness; Arnold map; Copyright protection.

1. INTRODUCTION

The availability of digital data such as multimedia services on the internet leads to exponential growth of multimedia traffic (image, text, audio, video, etc.). With the ease of editing and perfect reproduction in digital domain, the protection of ownership and the prevention of unauthorized tampering of multimedia data become important concerns. Digital watermarking has been proposed as a generic technique to solve various problems associated in the area of Digital Rights Management (DRM) and multimedia security.

A fair amount of research work has been published on digital image watermarking. The watermarking techniques can be classified into following categories: spatial domain, transform domain and spread spectrum. In spatial domain techniques the watermark embedding is achieved by directly modifying the pixel values of the host image. The most commonly used method is Least Significant Bit (LSB) method. In transform domain techniques the host image is first converted into frequency domain by transformation method such as DCT, DFT, DWT, etc then, transform domain coefficients are modified by the watermark. Another technique is spread spectrum in which the basic idea is to spread the watermark energy over visually important frequency bands, so that the energy in any one band is small and undetectable, making the watermark imperceptible.

In this paper we propose the Singular Value Decomposition scheme for embedding of the watermark which is used in the most common image processing applications like Image compression, image watermarking, etc. Andrews, H.C., Patterson, C.L in his paper [1] shows that the modified image is totally indistinguishable from the original image by using only 45% of the storage space. Liu and Tan [2], has proposed the use of SVD for watermarking to insert the watermark into the SVD domain of the cover image. The proposed scheme is highly robust against image distortion. Further, attacks have appeared on the application of this scheme for proof of ownership in [3, 4].

The paper is organized as follows: Section 2 describes the different terminologies used in the paper followed by the proposed technique in section 3. Section 4 demonstrates the experimental results followed by different attacks applied on the watermarked images. The results are discussed in detail in section 5. The paper is concluded in section 6 followed by the references.

2. TERMINOLOGY

2.1. Singular Value Decomposition

SVD is an effective numerical analysis tool used to analyze matrices. The basic concept is to represent an image with size m by n as a two-dimensional m by n matrix. SVD is then applied to this matrix to obtain the U, S, and V matrices. S is a diagonal m by n matrix whose number of non-zero

[1] Computer Science & Engineering Department, MNNIT, Allahabad, India, E-mail: suhila@mnnit.ac.in,
[2] Computer Science & Engineering Department, MNNIT, Allahabad, India, E-mail: v_maheshkar@yahoo.com,
[3] Computer Science & Engineering Department, MNNIT, Allahabad, India, E-mail: suneeta@mnnit.ac.in
[4] Electronics & Communication Engineering, MNNIT, Allahabad, India, E-mail: vinay@mnnit.ac.in

elements on the diagonal determines the rank of the original matrix. The fundamental concept of the SVD-based image compression scheme is to use a smaller number of rank to approximate the original matrix. This operation can be expressed in the following equations:

Original Image: $A = USV^H$, where U is m by n, V is n by n, and $S = diag(r_1, r_2,...,r_k,0,...,0)$

Re-constructed Image: $A1 = US1V^H$, where U is m by k1, V is k1 by n, and $S1 = diag(r_1, 2,...,r_{k1})$ and $||A - A1||_2 = r_{k1+1}$

2.2. Arnold Map

The Arnold cat map is a discrete system that stretches and folds its trajectories in phase space.

Mathematically the Arnold cat map, (ACM), is represented as the following:

Let $X = \begin{bmatrix} x \\ y \end{bmatrix}$, where X is a vector, then the ACM transformation is,

$$\Gamma : \begin{bmatrix} x \\ y \end{bmatrix} \rightarrow \begin{bmatrix} 1 & p \\ q & pq+1 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} \bmod n$$

Some conditions for the map is that p and q are positive integers and $\det\left(\begin{bmatrix} 1 & p \\ q & pq+1 \end{bmatrix}\right) = 1$, which makes the map area-preserving.

Vladimir Arnold discovered the ACM in the 1960s, and he used the image of a cat while working on it [5].

2.3. Standard Test Images for Cover Image and Watermark Images

In the proposed scheme to validate the results and claim made we demonstrate the results with the help of standard test images. The standard test images used as cover image and watermark image are shown below.

Figure 1: Cover Images (a) Lena (b) Mandril (c) Peppers (d) Watermark

3. PROPOSED TECHNIQUE

The proposed technique is divided into two steps embedding algorithm and the extraction algorithm.

3.1. Embedding Algorithm

1. Apply the DWT to the cover image C. LL subband is selected for embedding watermark.
2. Apply SVD on the selected LL subband.
3. Apply the Arnold map to the watermark image. The encrypted watermark will increase the security of the embedding technique.
4. Modify the singular values of the transformed image with the singular values of the watermark image with alpha as the embedding strength.
5. Obtain modified cover image
6. Apply the inverse DWT to produce watermarked image.

3.2 Extraction algorithm

1. Apply DWT on the watermarked image
2. Apply SVD to this transformed image
3. Calculate the singular values from the s matrix
4. Construct the watermark using original singular vectors
5. The correlation is calculated between the original and the extracted watermark using normalized cross correlation.

4. RESULT AND DISCUSSION

The proposed technique has been implemented using MATLAB version 10 (R2010a). The watermarked images with the corresponding PSNR is shown below:

(a) Lena (b) Mandril (c) Pepper.

Figure 2: Watermarked Images with Corresponding PSNR

The robustness of the technique is analyzed by applying the different attacks on the watermarked images. The quality of the extracted watermark can be measured with the help of normalized correlation between the embedded and the extracted watermark. The following table gives the validation to our technique.

Table1
Normalized Correlation After Attacks on Watermarked Images

Attack	Attacked Watermarked Image	Decrypted watermark	Extracted Watermark
Cropping			
Image Intensity			
Speckle noise			
Gaussian noise			
Rotation			
Histogram equalization			

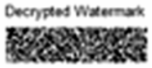
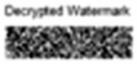
Salt& Pepper			
Gaussian filter			
Resize			
JPEG			

Table 2. Normalized Correlation After Attacks on Watermarked Images

Type of attack	Normalized correlation		
	Lena	Mandrill	Pepper
Cropping	0.9865	0.9834	0.9802
Image Intensity	0.9872	0.9872	0.9872
Speckle noise	0.9924	0.9885	0.9898
Gaussian noise	0.9985	0.9891	0.9891
Rotation	0.9872	0.9764	0.9854
Histogram equalization	0.9898	0.9879	0.9898
Salt& Pepper	0.9885	0.9860	0.9917
Gaussian filter	0.9872	0.9846	0.9878
Resize	0.9885	0.9878	0.9872
JPEG	0.9898	0.9904	0.9878

4. CONCLUSION

This paper presents a technique to embed SVD based watermark in the digital images for copyright protection. As the technique applies the watermark in the transformed domain combined with singular value decomposition the embedding has very little effect on the visual quality of the watermarked image. Simulation results demonstrate the robustness of the proposed technique to wide set of attacks. The innovation of this paper is that it applies the Arnold map to scramble the digital image watermark by using the key. It increases the security of the technique by encrypting the watermark. The discussion and experimental results validate that this algorithm has high security, robustness and visual quality of the watermarked images.

REFERENCES

[1] Andrews, H.C., Patterson, C.L. "Singular Value Decomposition (SVD) Image Coding". IEEE Transactions on Communications 24(4), 425-432 (1976).

[2] Liu, R., Tan, T., "An SVD-Based Watermarking Scheme for Protecting Rightful Ownership". IEEE Transactions on Multimedia 4(1), 121-128 (2002)

[3] Rykaczewski, R., "Comments on an SVD-Based Watermarking Scheme for Protecting Rightful Ownership". IEEE Transactions on Multimedia 9(2), 421-423 (2007).

[4] Zhang, X.P., Li, K., "Comments on an SVD-Based Watermarking Scheme for Protecting Rightful Ownership". IEEE Transactions on Multimedia 7(2), 593-594 (2005).

[5] Peterson, Gabriel, "Arnold's Cat Map" (Fall 1997). Retrieved October 22, 2008 from http://online.redwoods.cc.ca.us/instruct/darnold/maw/catmap.htm.