

Adaptive DWT and SVD domain digital image watermarking for fingerprint security

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Abstract— In the proposed system, an adaptive DWT-SVD domain digital watermarking technique for fingerprint security is developed. Fingerprints are unique biometric data mainly used for personal identification and authentication purpose. So they have to be protected by any accidental or intentional attacks. Here we have been proposed a watermarking scheme where the minutiae points are extracted from fingerprint images and an equivalent binary watermark is generated which is itself embedded into original host fingerprint. In addition to improve the robustness of watermark an Arnold transform is performed on it before embedding is done. Different experiments are performed to test the effectiveness and robustness of proposed algorithm and the experimental results shows that the scheme is effective and robust against various image processing attacks. Results shows higher PSNR and NC values under general image processing.

Index Terms— Arnold transform, Digital Watermarking, DWT, Fingerprint minutiae, Normalized coefficient, Peak signal to noise ratio, SVD.

I. Introduction

With the development of network and multimedia technologies, multimedia copyright protection and content authentication have become serious problems that need to be solved urgently. Multimedia and network security issues are classically handled through cryptography, however, cryptography ensures confidentiality, authenticity, and integrity only when a message is transmitted through a public channel such as an open network. It does not protect against unauthorized copying after the message has been successfully transmitted. Digital watermarking is an effective way to protect copyright of multimedia data even after its transmission. Among the various biometrics, fingerprints are more famous in the authentication area, as they are unique to each person and are widely used in identification and verification of personal individuality. However, they are susceptible to accidental and intentional attacks, when transmitted over network. Thus, a defensive scheme is needed which will preserve fidelity and prevent modifications. Digital watermarking technology provides strong solution for it. DWT and SVD are two most popular tools used in watermarking algorithm. With the increasing use of SVD, the digital watermarking technology in transform domain has been greatly developed.

Digital watermarking is the process of embedding or hiding digital information called watermark into a multimedia product such as an image, audio or video. Digital watermarks should be imperceptible, difficult to remove, i.e., robust to common attacks, and of large capacity. Existing watermarking schemes can be divided into two categories: spatial domain schemes and transform domain schemes. Spatial domain schemes embed data by directly modifying pixel values of the host image, while transform domain schemes embed data by modifying transform domain coefficients. The major advantage of transform domain methods is their superior robustness to common image distortions.

The typical Transformation-Domain Methods are mostly based on the domain of Discrete Fourier Transform (DFT), Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT), etc. Wavelet transform is superior to time-frequency transform for its inner predominance. For example, wavelet has the character of multi-resolution, which can avoid the rectangle brought by DCT. As DWT decomposes images into four bands, DWT-based watermarking schemes can embed data in all frequencies. This result in robustness to a wide range of attacks for embedding in low and high frequency bands are complementary. Recently, some researchers began to make use of spatial domain technique Singular Value Decomposition (SVD) to embed a Watermark. SVD is a compression technique that can be used in a wide range of applications where data may be organized in a matrix representation. SVD is suitable for watermarking applications since some largest singular values are sufficient to embed instead of using all singular values. The theoretical background of SVD technique in image processing applications to be noticed is:

1. The SVs (Singular Values) of an image has very good stability, which means that when a small value is added to an image, this does not affect the quality with great variation.
2. SVD is able to efficiently represent the intrinsic algebraic properties of an image, where singular values correspond to the brightness of the image and singular vectors reflect geometry characteristics of the image.
3. An image matrix has many small singular values compared with the first singular value. Even ignoring these small singular values in the reconstruction of the image does not affect the quality of the reconstructed image.

For any watermarking algorithm the watermark has to satisfy several requirements as follows-

1. Perceptual transparency: In a wide variety of watermarking applications, the watermark should not affect the quality of the host media and be imperceptible to human eyes.
2. A payload of watermark: Depending on the applications, the payload of the watermark should be enough to retrieve the embedded watermark.
3. Robustness: For the authentication purpose a fragile watermark is used for authenticity of the host media. However, if a watermark is used for Internet applications such as transmitting data through a noisy channel or compressing data so as to reduce bit-rate for network transference, the watermark must survive under those situations.
4. Non-blind versus blind: A non-blind scheme can use the original media and the secret key during the watermark detection. However, a blind scheme can only use the secret key. In particular, a semi-blind scheme requires both the secret key and the watermark sequences.

II. Related work

Early work of digital watermarking is done in spatial domain [6]. Recent developments are mostly focused on frequency domain and wavelet domain watermarking techniques [1-4]. R.Chouhan, A. Mishra, P. Khanna proposed DWT based Digital Watermarking in [3], uses a wavelet-based blind watermarking scheme has been proposed as a means to provide protection against false matching of a possibly tampered fingerprint by embedding a binary name label of the fingerprint owner in the fingerprint itself. Khalil Zebbiche, Lahouari Ghouti, Fouad Khelifi [4], introduce an application of wavelet based watermarking method to hide the fingerprint minutiae data in fingerprint images. The application provides a high security to both hidden data (i.e. fingerprint minutiae) that have to be transmitted and the host image (i.e. fingerprint). The original unmarked fingerprint image is not required to extract the minutiae data. The method is essentially introduced to increase the security of fingerprint minutiae transmission and can also used to protect the original fingerprint image. Weimin Yang, Xiaoning Zhao [7], introduce a new watermarking algorithm is based on Singular Value Decomposition (SVD) and discrete wavelet transform (DWT). The algorithm uses a gray image as a watermark, increasing embedded information capacity. The algorithm can satisfy the transparency and robustness of the watermarking system very well. Here 3-level wavelet transformation is performed on original image and intend to embed watermark in LL_3 also the Arnold transform for watermark image is done before embedding process.

III. Fingerprint minutiae

Fingerprints are the patterns formed on the epidermis of the fingertip. It is believed with strong evidences that each fingerprint is unique. Each person has his own fingerprints with the permanent uniqueness. So fingerprints have being used for identification and forensic investigation for a long time. A fingerprint is composed of many ridges and furrows.

However, shown by intensive research on fingerprint recognition, fingerprints are not distinguished by their ridges and furrows, but by Minutia, which are some abnormal points on the ridges [9]. Among the variety of minutiae types reported in literatures, two are mostly significant and in heavy usage: one is called termination, which is the immediate ending of a ridge; the other is called bifurcation, which is the point on the ridge from which two branches derive.

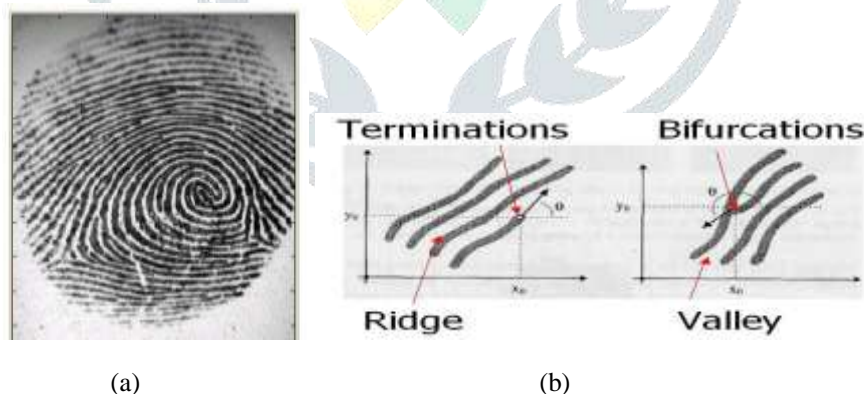


Fig.1-(a) Typical fingerprint image (b) Minutiae. (Valley is also referred as Furrow, Termination is also called Ending and Bifurcation is also called Branch)

IV. DWT, SVD And Arnold transform

A. Discrete Wavelet Transform

In DWT transformation the image is divided into four multiresolution sub-bands LL, LH, HL and HH using DWT. Fine-scale DWT coefficients are represented by LH, HL, HH sub-bands and coarse-scale DWT coefficients are represented by LL sub-bands. LL sub-band is further decomposed into four multiresolution sub-bands to obtain next coarser wavelet coefficients [12-14]. This process is repeated several times determined by application for which it is used. For k level DWT, there are $(3^k) + 1$ sub-bands available. Wavelet transform is a time-frequency domain combined analysis method. It has multi-resolution analysis features. After wavelet decomposition, many signal processing, such as compression and filter are likely to change the high

frequency wavelet coefficients. If the watermark sequence is embedded into this part, its information may be lost in the processing in sequence, which will reduce the robustness of the watermark [3]. In order to ensure the watermark has a better imperceptibility and robustness, the approximation sub-image LL_3 coefficients are chosen to embed watermark. The three level 2-D DWT decomposition of an image is shown in figure as below-

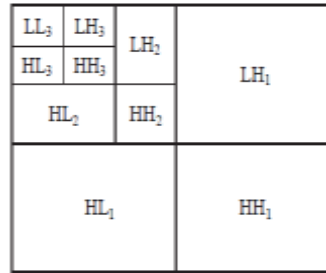


Fig.2-Three level wavelet decomposition

B. Singular Value Decomposition

SVD is one of the effective tool to analysis the matrices. While using the SVD transformation a matrix is decomposed into three matrices U, S, V. U and V are the unitary matrices and S is a diagonal matrix .If a $m \times n$ image is represented as a real matrix A , it can be decomposed as: $A = USV^T$. It is called a singular value decomposition of A . Where U is a $m \times m$ unitary matrix, S is a $m \times n$ matrix with nonnegative numbers on the diagonal and zeros on the off diagonal, and V^T denotes the conjugate transpose of V, an $n \times n$ unitary matrix. The nonnegative components of S represent the luminance value of the image [7].Changing them slightly does not affect the image quality and they also don't change much after attacks, watermarking algorithms make use of these two properties.

$$I = U \cdot S \cdot V^T = \sum_{k=1}^N u_k \cdot s_k \cdot v_k^T$$

With $U = [u_1, u_2, u_3, \dots]$ and $V = [v_1, v_2, v_3, \dots]$

C. Arnold Transform

To confirm the security and improve the robustness of the proposed watermarking scheme, the watermark should be pre-processed before embedded into the original image. Arnold Transform is commonly known as cat face transforms and is only suitable for $N \times N$ images digital images. Arnold transform can be expressed as-

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} 1 & 1 \\ 1 & 2 \end{bmatrix} \times \begin{bmatrix} x \\ y \end{bmatrix} \text{ Mod } N$$

Where (x, y) is the location coordinates of the original image pixels, and (x', y') is the location coordinates of image pixels that after transform[9].Arnold Transform is periodic in nature. The decryption of image depends on transformation periods. Period changes in accordance with size of image. Iteration number is used as the encryption key. When Arnold Transformation is applied, the image can do iteration, iteration number is used as a secret key for extracting the secret image.

V. Proposed Watermarking scheme

The proposed watermarking scheme is divided into two parts-

- A. Watermark Embedding
- B. Watermark Extraction

A. Watermark embedding scheme

The steps of minutiae watermark embedding as are follows:

Step 1: The fingerprint image is decomposed into its 3-level two-dimensional DWT coefficients. Out of the all sub-bands, only LL_3 approximation sub-band is selected.

Step 2: Fingerprint Pre-processing

A real fingerprint might have discontinuities that might lead to erroneous minutiae. Therefore, minutiae extraction is preceded by fingerprint pre-processing. This step involves normalization, ridge orientation and frequency estimation. The filtered output is then binarized and thinned to one-pixel width.

Step 3: Minutiae Extraction

Minutiae points such as end points and bifurcation points are identified by calculating Crossing number (CN). The Crossing Number method extracts the ridge endings and bifurcations from the skeleton image by examining the local neighborhoods of

each ridge pixel using a 3×3 window. The CN value is then computed, which is defined as half the sum of the differences between pairs of adjacent pixels in the eight neighborhoods.

$$CN=0.5 \sum_{i=1}^8 | P_i - P_{i+1} |, P_1 = P_9$$

If crossing Number is 1, 2 and 3 or greater than 3 then minutiae points are classified as Termination, Normal ridge and Bifurcation respectively.

The minutiae thus extracted have the following information: x and y coordinates and the type of minutiae (ending or bifurcation). All these information is converted to binary form by 8-bit representation and a binary watermark is generated by concatenating the eight individual bit planes.

Step 4: Perform Arnold transform for watermark image W.

Step 5: We obtain the watermarked image coefficients matrix A_w through the following three steps:

1. $A = USV^T$
2. $S + W = U_w S_w V_w^T$
3. $A_w = U S_w V^T$

Step 6: Apply reverse wavelet transform for original image, and then changing the double-precision real number to unsigned 8-bit integer.

B. Watermark extraction scheme

We can extract the watermark by the reverse calculation of watermark embedding:

Step 1: Perform a 3-level wavelet transform using haar wavelet for watermarked image, and obtain low-frequency wavelet coefficient LL_3 (denotes as A^*).

Step 2: Apply SVD to the A^* , $A^* = U * S_1 * V^{T*}$, and obtain U^*, S_1^*, V^{T*} .

Step 3: Associating with U_w, V_w and S_1^* , obtain D^* according $D^* = U_w S_1^* V^T$, in the end we can obtain the watermark which is embedded according to $W^* = (D^* - S)$.

Step 4: Changing the double-precision real number to unsigned 8-bit integer for watermark image, and perform inverse Arnold transform for watermark image.

VI. Result

The cover image is 256×256 grayscale host fingerprint image and watermark image is 32×32 binary image equivalent to minutiae of fingerprint image. The extraction of watermark is tested under various attacks, noising attacks (salt and pepper, Gaussian noise), de-noising attacks (median filter), geometric attacks (rotation, cropping) and image processing attack (blurring). The normalized coefficient is used to measure the similarities of extracted watermarks. Fig. (3) shows the original host fingerprint, original watermark, watermarked fingerprint and extracted watermark images. The calculated PSNR between host fingerprint and watermarked fingerprint image is 99 and MSE=0. The correlation coefficient between embedded and extracted watermark without performing any attack is 0.9888.

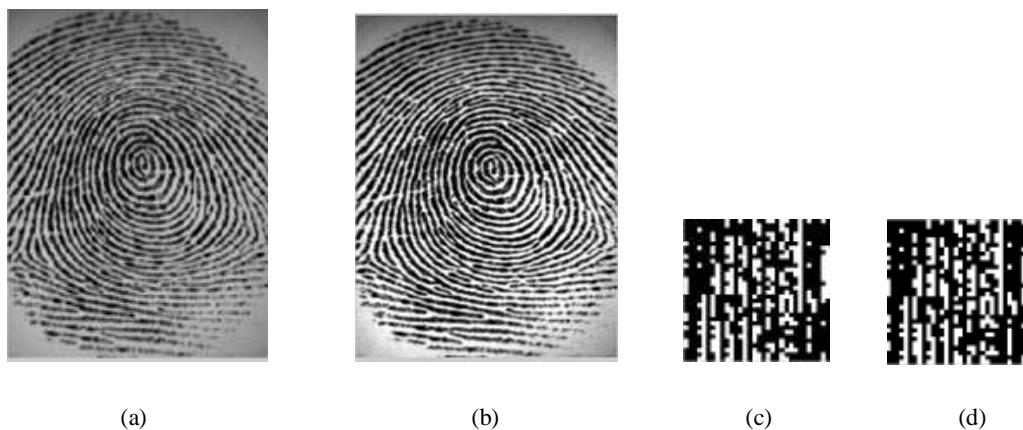


Fig.3-(a) Original host fingerprint (b) Watermarked fingerprint with PSNR=99 and MSE=0 (c) original watermark (d) Recovered watermark

Table-1 shows the various attacked watermarked fingerprint images and extracted binary watermarks from each of them.

TABLE 1








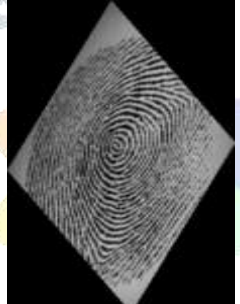


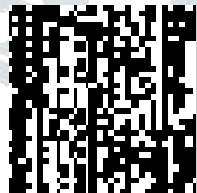

 Gaussian noise	 Salt and pepper	 Median filter attack
 Extracted watermark	 Extracted watermark	 Extracted watermark
 Blurring	 Rotation	 Cropping
 Extracted watermark	 Extracted watermark	 Extracted watermark

Table-2 shows verification accuracy of extracted watermark when watermarked fingerprint is attacked.

TABLE 2

Sr. no.	1	2	3	4	5	6	7
Attack	No attack	Gaussian noise	Salt and pepper	Median filtering	Blurring	Rotation	Cropping
NC	0.9888	0.9485	0.9409	0.9533	0.9506	0.8559	0.9415

VII. Conclusion

Earlier many watermarking mechanisms for fingerprint security have been proposed, but due the trade-off between identification efficiency and security of stored template, practical application have not benefited up to desired level. The earlier proposed DFT and DCT based watermarking technique has drawbacks in terms of correlation coefficient and robustness. These disadvantages of earlier techniques are overcome in DWT-SVD based watermarking algorithm. So here we designed a watermarking algorithm to improve the recognition performance as well as the security of fingerprint based biometric system which will provide adequate security to fingerprint data without degrading visual quality.

Future work

The proposed watermarking algorithm can be significantly using for other biometric data such as face template in combination with fingerprints and preserve the integrity of both.

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