Robust Lossless Image Watermarking in Integer Wavelet Domain using SVD

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Abstract

A robust and secure technique is required to protect multimedia data as it can be easily produced as illegal copies. Digital watermarking is used for Intellectual Property Rights protection and authentication. In this paper, a lossless watermarking scheme based on Integer wavelet transform (IWT) and singular value decomposition (SVD) is implemented. The watermark image is embedded on the elements of singular values of the low-low (LL) Sub band of original image. The Integer Wavelet Transform is implemented based on lifting scheme which is computationally efficient than Discrete Wavelet Transform. The watermark image is extracted which is highly correlated with the original watermark image. The proposed algorithm is robust and authenticated under different attacks.

Keywords : IWT, Lifting Scheme, SVD

I. INTRODUCTION

Digital watermarking is a technique for inserting data (the watermark image) into an image, which can be extracted later for identification and authentication purposes. Digital watermarking technology is a method of protecting copyrights in digital images. It is realized by embedding data into an host image that is invisible to the human visual system. An effective watermarking scheme should satisfy the following basic requirements.

Imperceptibility: The difference between the original image and the watermarked image should be unknown to the human observer.

Trustworthiness: A watermarking scheme should guarantee that it is impossible to generate counterfeit watermarks and should provide trustworthy evidence to protect the rightful ownership.

Robustness: Watermarks should be robust to common signal processing and intentional attacks. The watermarks should still be extracted from the attacked watermarked image.

A. Motivation

Liu et al, proposed the scheme which performs two times of SVD transformation during embedding phase and hides the watermark in the S component of the SVD-domain image. This method performs well on transparency and robustness. It needs highly computational complexity due to two times of SVD during the watermark-embedding phase [6]. Chang et al, proposed an image watermarking scheme based on SVD. Non-fixed orthogonal bases and one-way non-symmetrical decomposition are employed in SVD. These properties provide the advantages of various sizes of transformation and more security. The robust performance of SVD-based methods is not always better than that of frequency based methods for most of attacks. SVD-based methods involve several attacks such as median, average, Gaussian filtering and noising [2]. Chin Chin Lai et al, proposed hybrid watermarking scheme based on Discrete Wavelet Transform and Singular Value Decomposition. The watermark is embedded on the elements of singular values of host image. This approach is able to withstand a variety of image processing attacks [4]. Li- bao et al, proposed watermarking based on DWT. DWT (Discrete Wavelet Transform) has been successfully used for encoding of still images. However, the filter coefficients of DWT often have floating point coefficients. When the input images consist of sequences of integers, the outputs no longer consist of integers. Lot of multiplications of floating point coefficients also increase the computational complexity [5].

II. THEORY

A. Integer Wavelet Transform

Integer Wavelet Transform is used for lossless compression. The transform coefficients are represented by finite precision numbers, and this allows for truly lossless coding.

Integer Wavelet Transform is much faster than the Discrete Wavelet Transform because the floating point wavelet transform demands for longer data length than the integer wavelet transform. Reversibility is another benefit of Integer Transform. That is, the image can be reconstructed without any loss because all the coefficients are integers and can be stored without rounding off errors. IWT is implemented using the lifting scheme (LS). Its main advantage with respect to filter bank structure lies in its better computational efficiency and in fact it enables a new method for filter design.

B. Lifting Scheme

The lifting scheme is a simple method for designing customized Biorthogonal wavelets and offers several advantages:

1)Allows a faster implementation of the wavelet transform, 2) Saves storage by providing an in- place calculation of the wavelet Transform, 3) Simplifies determining the inverse wavelet transform, 4) Provides a natural way to introduce and think about wavelets.

The Forward wavelet transform of lifting scheme divides the data set into an even half and odd half. The Predict step calculates the wavelet function in the wavelet transform. This is a high Pass filter. The update step calculates the scaling function, which results in a smoother version of the data. This operation consists of three steps.

Splitting : First, pixel is split into the even position pixels $p_e(n)$ and the odd position pixels $p_o(n)$, then modifying these values using alternating prediction and updating steps.

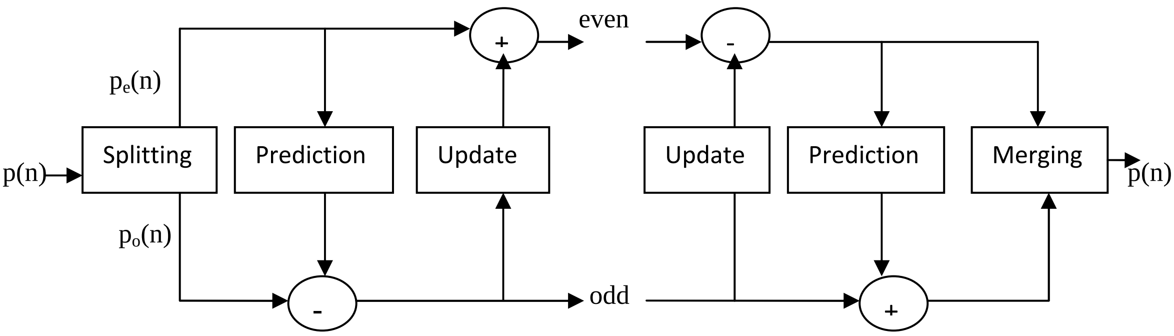
$p_e(n) = s[2n]$ and

$p_o(n) = s[2n+1]$

Prediction : Each odd pixel is predicted as a linear combination of the even pixels and subtracting it from the odd pixels.

Update : An update step consists of updating the even pixels by adding them to a predicted odd pixels.

The prediction and update step may be calculated in several steps until the forward transform is reached. Fig 2.1 represents the Forward and Inverse Wavelet Transform of Lifting Scheme.



Forward Wavelet Transform Inverse Wavelet Transform

Figure 2.1 : Lifting Scheme

C. Singular Value Decomposition

Singular value decomposition (SVD) is a general linear algebra technique for a variety of applications including solving most linear least-squares problems, computing pseudo-inverse of a matrix and multivariate analysis.

Any $m\times n$ real-valued matrix A, with $m \geq n$ can be written as the product of three matrices as specified in Equation (1)

$$A = USV^T \qquad (1)$$

If A indicates an image, it's defined as $A \in R^{m\times n}$, in which R represents the real number domain. U and V are two orthogonal matrices $U = [u_1, u_2, .., u_n] \in R^{m\times m}$ and $V = [v_1, v_2, .., v_n] \in R^{n\times n}$. S is the diagonal matrix with non negative values. The $m\times n$ matrix S is a pseudo-diagonal matrix, where its diagonal elements are $\sigma_1 \geq \sigma_2 \geq ... \geq \sigma_n \geq 0$ and it is called the singular value (SV) of A.

The main advantages of SVD in image processing applications are:(1) the image SVs (Singular Values) are stable, that means when a small disturbance is added to an image, great variance of its SVs would not occur; (2) SVs express algebraic image properties which are intrinsic and not visual.

III. PROPOSED METHOD

The watermarking scheme based on IWT and SVD is implemented. The proposed method for embedding watermark and extracting watermark are presented.

A. Watermark Embedding Algorithm

Fig.3.1 represents the watermark embedding algorithm.

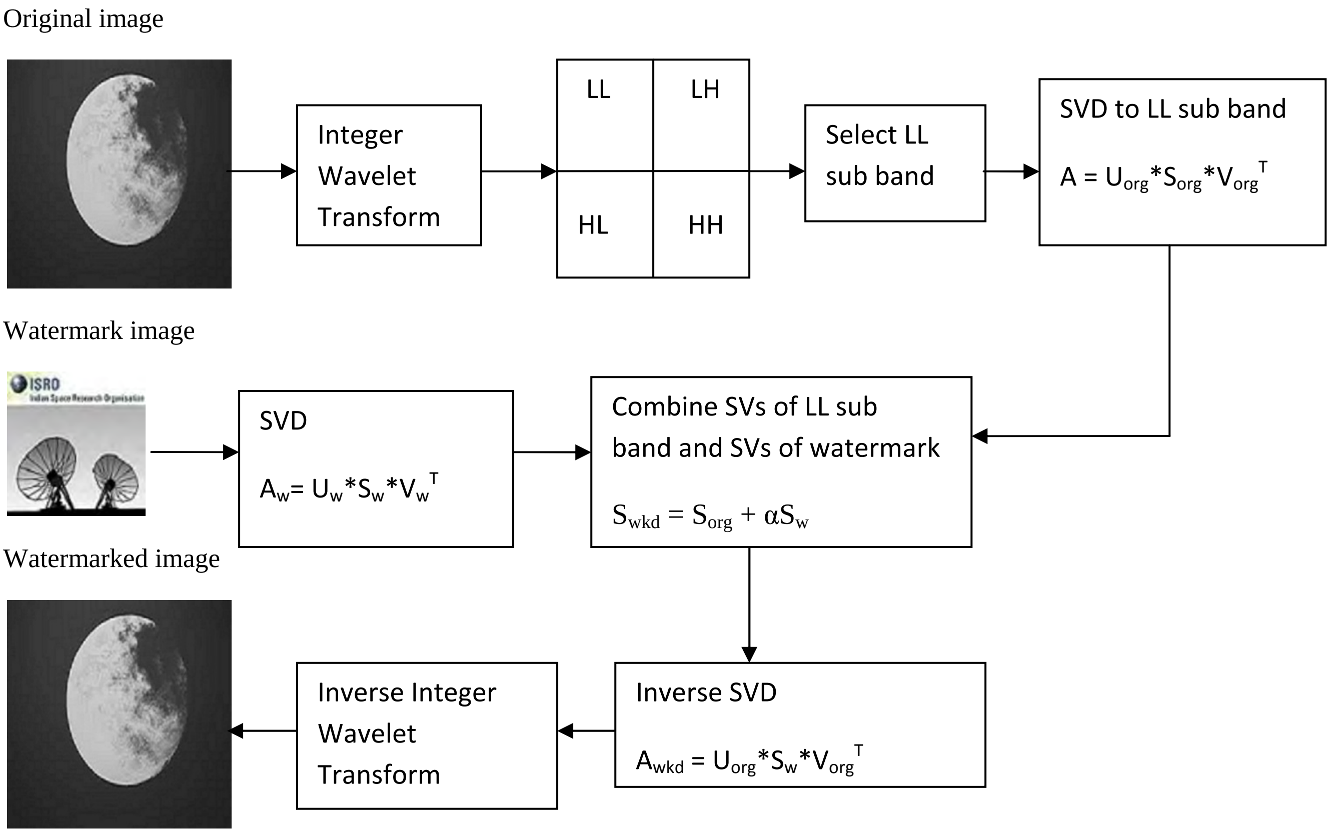


Fig 3.1 Watermark Embedding

Watermark was embedded into host image by using the following steps.

- Perform the 1-level IWT for a host image I with size L × K.
- Get the LL subband of the IWT image I.
- Apply SVD to LL_{org} subband of decomposed original image to get three components U_{org}, S_{org}, and V_{org}.
- Apply SVD to watermark image to get three components U_w, S_w, and V_w.
- Combine SVs of the watermark with the SVs of the selected LL sub-band using appropriate scaling factor α, as illustrated in Equation (2)
    - $S_{wkd} = S_{org} + \alpha S_w$ (2)
- where α is the scale factor which controls the strength of each watermark bit to be embedded.
- Perform inverse SVD to U_{org}, S_{wkd} and V_{org} to get LL_{wkd} .
- Using inverse Integer Wavelet Transform, the watermarked image will be constructed.

B. Watermark Extraction

Fig. 3.2 represents the watermark extraction algorithm.

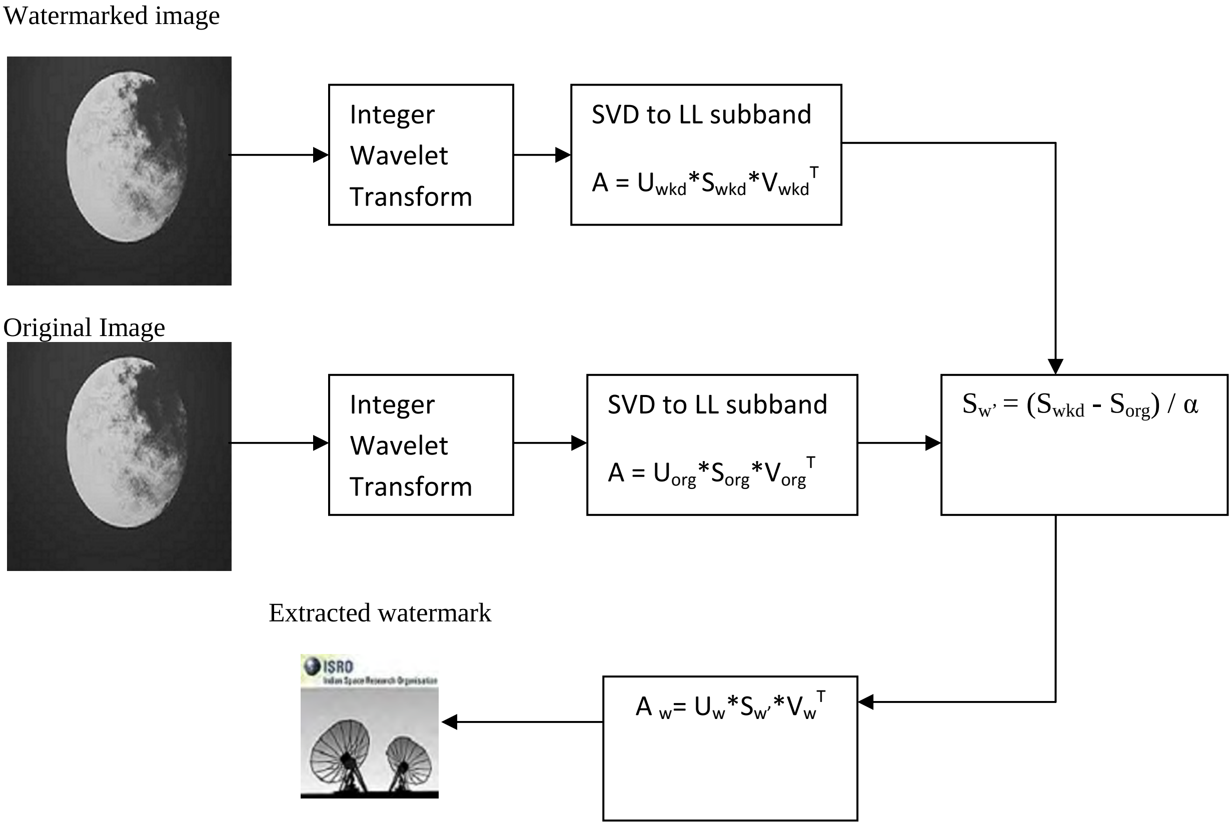


Fig 3.2Watermark Extraction

Embedded Watermark was extracted from the watermarked image by using the following steps.

- Perform the 1-level IWT on a watermarked image I^w with size L × K.
- Get the LL subband of the IWT image I^w.
- Apply SVD to LL_{wkd} subband of decomposed watermarked image to get three components U_{wkd}, S_{wkd}, and V_{wkd}.
- Apply SVD to original image to get three components U_{org}, S_{org}, and V_{org}.
- Subtract the SVs of the watermarked image with the SVs of the selected LL sub-band of original image and divide the resukt using the same scaling factor α, as illustrated in Equation (3)
  - $S_{w'} = (S_{wkd} - S_{org}) / \alpha$ (3)
- Perform the multiplication of U_w, $S_{w'}$ and V_w to get the watermark image.
- Output the extracted Watermark Image.

IV. EXPERIMENTAL RESULTS

This section represents the experimental results for the lossless image watermarking scheme. The watermarking scheme was developed in JAVA with NetBeans environment. SVD of this scheme was developed using Java Matrix (JAMA) package. Singularvaluedecomposition class of JAMA package is used to get three matrices from single input matrix.

Fig 4.1 shows the host image, watermark image and watermarked images. The images used in experiments are of size 512 × 512 for host image and of size 256 × 256 for the watermark image.

A. Host Image and Watermark Image

a) Host Image (PSNR = 37 dB) b) Watermark Image c) Watermarked Image

4.1 Host image, watermark image and Watermarked image

Normalized correlation (NC) is used to evaluate the similarity between the original watermark W and the extracted watermark W' which is retrieved from an attacked watermarked image.

$$NC(w,w') = \frac{\sum_{i=1}^{L}\sum_{j=1}^{K} w_{ij} \oplus w'_{ij}}{L \times K}$$

where L and K represents the length and width of the watermark image. High NC value represents more resemblance between w and w'.

Peak signal-to-noise ratio (PSNR) is employed to evaluate the difference between I and Iw.

$$PSNR(I, I^{w}) = 10 \times \log_{10} \frac{255^2}{MSE\ (I, I^{w})}$$

$$\text{M}SE\ (I, I^{w}) = \frac{1}{L \times k} \sum_{i=1}^{L}\sum_{j=1}^{K} \left| I_{ij} - I_{ij}^{w} \right|^2$$

where I and Iw denote the host image and the watermarked image. I_{ij} and I^{w}_{ij} stands for the original pixel value and its corresponding watermarked pixel value. The higher PSNR value for I and Iw represents few differences between original image and watermarked image.

B. Attacks on Watermarked Image

In this section, we examine the robustness of the proposed method. Table 1 shows the attacked watermarked images and extracted watermark images along with PSNR and NC.

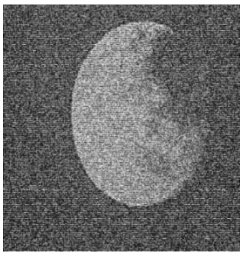
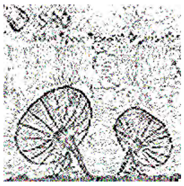
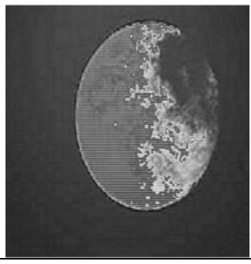
Attacks	Attacked Watermarked image	Extracted Watermark image	PSNR (dB)	NC
Salt and Pepper			16.67	0.26
Uniform Noise			7.67	0.46
Contrast			17.31	0.98

Table 1: Attacked Watermarked image and Extracted watermark image

V. CONCLUSION AND FUTURE WORK

A non-blind watermarking scheme based on IWT and SVD was implemented. Modifying Singular Values of the host image in IWT domain provides high robustness against the common attacks. High PSNR of watermarked image is another benefit of the algorithm as the result of IWT implementation. Making trade off between PSNR of the watermarked image and correlation between extracted watermark and the original data lead to selecting the best value of the scaling factor. The proposed algorithm takes the advantages of the Wavelet Transform and SVD methods. The extracted watermarks are more robust against all mentioned attacks. IWT is useful for medical imaging and remote sensing applications because it produces lossless image. In future, this watermarking scheme can be extended to blind watermarking.

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