



Digital Watermarking Based on Redundant Discrete Wavelet Transform and Singular Value Decomposition

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ABSTRACT:- This paper presents a new hybrid watermarking scheme for image copyright protection, which is based on Redundant Discrete Wavelet Transform (RDWT) and Singular Value Decomposition (SVD). Its embedding algorithm hides the watermark image in the LL, LH, HL, HH sub-bands of the host image obtained after the RDWT operation by modifying the singular value on SVD version of the host image. The principal components of the watermark image are embedded in the host image to avoid the false positive problem of SVD. To find the suitable scaling factor Particle Swarm Optimizer (PSO) can be used.

Keywords: - Principal Components, PSO, RDWT, SVD, Watermarking

I. INTRODUCTION

With the help of internet communication can be established between different persons easily. Due to the high speed of internet a person can transfer multimedia data like image, audio, video etc very easily. But the transferred data is more vulnerable as an attacker can easily modify it. This brings a serious problem into the consideration, i.e. the ownership problem. So to solve this problem digital watermarking technique was proposed [1]. Digital watermarking is referred as a technique where we embed a signal normally known as watermark in the original data to protect it from the attackers and the watermark can be detected whenever required. The watermark may be a text, an image, a number etc.

There are some basic requirements which a watermarking technique has to satisfy, i.e.

- a) Undeletable:-An embedded watermark should be resistant against general image processing and tampering.
- b) Perceptually invisible:-This means there should not be much difference between the original image and the watermarked image so that human eye can detect it.
- c) Unambiguous:-The extracted watermark should be clear enough to determine the ownership problem.
- d) Non-inevitability:-This means the same watermark cannot be created from different set of host and watermark.

Based on the domain in which the watermark is inserted these techniques are classified into two categories, i.e. spatial domain and transformed domain. Spatial domain method is a direct method where we embed the data directly into the original data. This method is less complex and has less computation cost but more fragile to different attacks. On the other hand in transformed domain watermarking schemes, we embed the watermark into the coefficients of the transformed data. This technique provides more robustness than the previous one. Some of the examples of transformed domain watermarking scheme are like Discrete Cosine Transform (DCT) [2], Discrete Wavelet Transform (DWT) [3], Singular Value Decomposition (SVD) [4, 5, 6, 7, 8], Redundant Discrete Wavelet Transform (RDWT) [9] etc.

Among all the transformed domain schemes SVD is widely used as the singular values show good stability to different attacks. But implementing only SVD is very costly. As a result hybrid watermarking schemes were proposed where two or more watermarking schemes are implemented simultaneously. The SVD based watermarking techniques [3, 4, 5, 6, 7] shows good robust to different image processing attacks but most of these techniques [4, 5, 6] have a major drawback, i.e. the false positive problem. In all these techniques only the singular value of the watermark image was embedded. To avoid this problem Jain et al. [7] proposed the concept of principal component. According to this algorithm the left singular vectors (U) and the right singular vectors (V) also contain significant information. The principal component of the watermark can be calculated by multiplying the left singular vectors and the singular vectors obtained after doing SVD on watermark image. But in this algorithm the scaling factor value was not optimized. To overcome this problem R.S. Run et al. [8] used a metaheuristic algorithm to find the optimized scaling factor value. Lagzian et al. [9] proposed a hybrid watermarking scheme where he implement the RDWT and SVD together. The proposed scheme is based on R.S. Run et al. [8] and Lgzian et al. [9]. Here the host image is decomposed by using RDWT and the principal component of the watermark image is inserted into sub-bands of the host image. Particle Swarm Optimizer is used to find the scaling factor value to maintain a balance between robustness and imperceptibility of the watermark image. Rest of the paper is organized as follows. In section 2 and 3 RDWT and SVD is described respectively. In the section 4 the proposed algorithm is illustrated and in section 5 analysis of the proposed scheme is present. Finally the conclusion is discussed in section 6.

II. RDWT

DWT is one of the most commonly used watermarking techniques because of its excellent spatiolocalization property. But it has a major drawback, i.e. shift variant occurs due to the down sampling of its bands which leads to a major change in wavelet coefficient even for a minor change in input image. As a result there is an inaccurate extraction of host image and watermark image occurred. To overcome this problem, RDWT technique has proposed.

The 1D DWT and 1D RDWT with their inverse transforms are illustrated in figure 1, where $f[n]$ and $f'[n]$ represents the 1D input signal and reconstructed signal respectively. $h[-k]$ and $g[-k]$ are the lowpass and highpass analysis filters. The corresponding lowpass and highpass synthesis filters are $h[k]$ and $g[k]$. c_j and d_j are the low-band and high-band output coefficients at level j . The analysis and synthesis for DWT and RDWT is given by,

a) DWT analysis:-

$$\begin{aligned} c_j[k] &= (c_{j+1}[k] * h_j[-k]) \downarrow 2 \\ d_j[k] &= (c_{j+1}[k] * g_j[-k]) \downarrow 2 \end{aligned} \tag{1}$$

b) DWT synthesis:-

$$c_{j+1}[k] = \frac{1}{2} ((c_j[k] \uparrow 2) * h_j[k] + (d_j[k] \uparrow 2) * g_j[k]) \tag{2}$$

c) RDWT analysis:-

$$\begin{aligned} c_j[k] &= (c_{j+1}[k] * h_j[-k]) \\ d_j[k] &= (c_{j+1}[k] * g_j[-k]) \end{aligned} \tag{3}$$

d) RDWT synthesis:-

$$c_{j+1}[k] = \frac{1}{2} (c_j[k] * h_j[k] + d_j[k] * g_j[k]) \tag{4}$$

Where $*$ means convolution, $\downarrow 2$ means downsampling and $\uparrow 2$ means upsampling. In DWT, downsampling and upsampling coefficients are present at each level of iteration. Due to downsampling the size of each sub-band decreases with increase in level of decomposition. RDWT method eliminates the downsampling and upsampling coefficients as a result the redundancy is achieved. Thus RDWT based watermarking schemes are more robust than DWT based watermarking scheme.

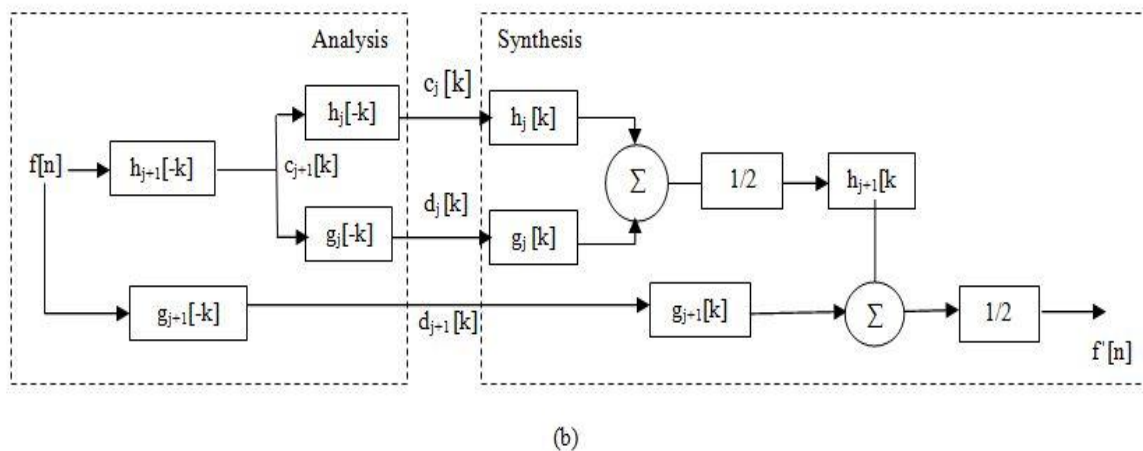
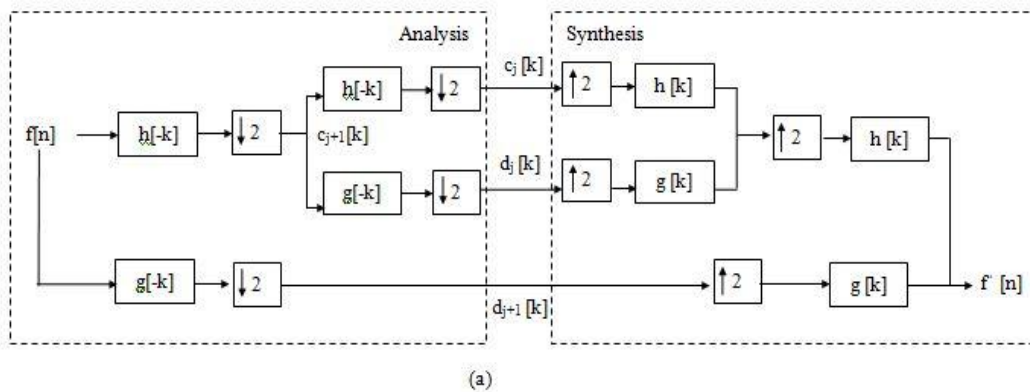


figure.1: (a)1D DWT synthesis and analysis, (b)1D RDWT synthesis and analysis

III. SVD

SVD is a mathematical tool which decomposed a matrix into 3 matrices. Let A be an image of size $M \times N$, then the SVD of A is given by $A=USV^T$, where U and V are the orthogonal matrices. S is a diagonal matrix. The columns of U

and V are known as left singular vector and right singular vector of A respectively and represents the geometrical properties of the image. The elements of S are known as singular values of A and are arranged in decreasing order. The elements of S show the brightness of the image A . The principal component can be found by multiplying U and S of the image. Most of the watermarking schemes use the concept of SVD because of two important properties, i.e. (a) Singular values do not change rapidly with the addition of small perturbation to the image. (b) Singular values represent algebraic image properties.

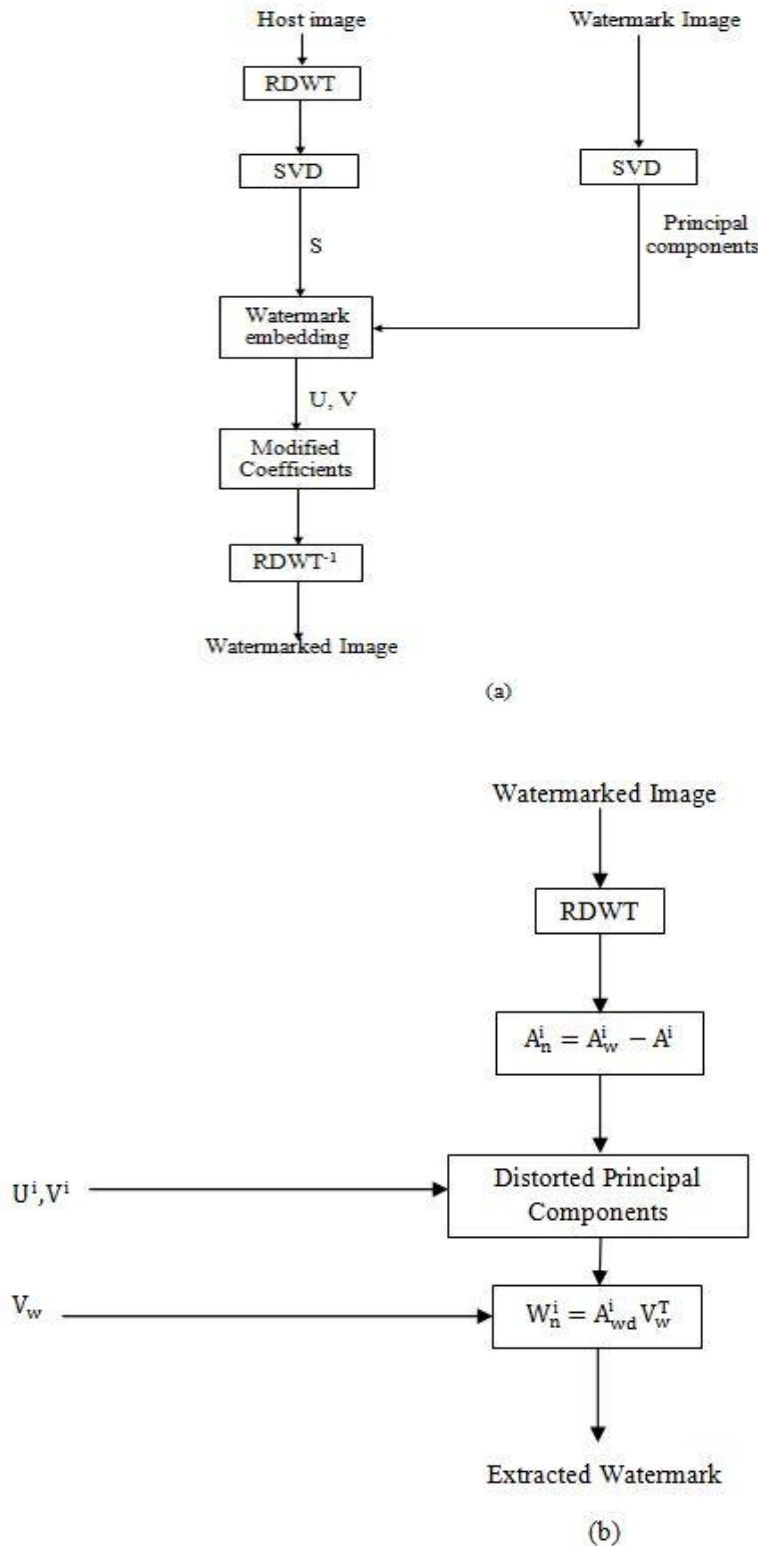


figure.2: (a) Block Diagram of watermark embedding, (b) Block Diagram of watermark extracting

IV. PROPOSED WATERMARKING SCHEME

In this paper we propose a hybrid watermarking scheme using RDWT and SVD. The block diagram of watermark embedding and extraction is shown in Fig. 2(a) and 2(b) respectively.

4.1 Steps for watermark embedding:-

- 4.1.1. Apply 1-level RDWT to decompose the host image into four sub-bands, $A = \{A^{LL}, A^{LH}, A^{HL}, A^{HH}\}$.
- 4.1.2. Apply SVD to all sub-bands, i.e. $A^i = U^i S^i V^{iT}$ Where $i=LL, LH, HL, HH$.
- 4.1.3. Perform SVD on the watermark image, $W = U_w S_w V_w^T$.
- 4.1.4. Find the principal components of the watermark image, $A_w = U_w S_w$.
- 4.1.5. Modify the singular values of all sub-bands of the host image by inserting the principal components of the watermark image, i.e. $S_w^i = S^i + \alpha \cdot A_w$ Where $i=LL, LH, HL, HH$. Here the value of α can be found by using PSO.
- 4.1.6. Compute the new modified coefficient for each sub-band, i.e. $A^{i_{new}} = U^i S_w^i V^{iT}$ Where $i=LL, LH, HL, HH$.
- 4.1.7. Perform inverse RDWT using 4 sets of modified coefficients to obtain the watermarked image, A_w .

4.2 Steps for watermark extraction:-

- 4.2.1. Apply RDWT to the attacked image to decompose it into 4 sub-bands, $A_w = \{A_w^{LL}, A_w^{LH}, A_w^{HL}, A_w^{HH}\}$.
- 4.2.2. Subtract the attacked watermarked image coefficients for each sub-band with the original sub-band coefficients, $A_n^i = A_w^i - A^i$ Where $i=LL, LH, HL, HH$.
- 4.2.3. Compute the distorted principal component for each sub-band, $A_{wd}^i = (U^{iT} A_n^i V^i) / \alpha$ Where $i=LL, LH, HL, HH$. Here the division will be done on element-by-element wise.
- 4.2.4. Obtain the watermark for each sub-band, $W_n^i = A_{wd}^i V_w^T$ Where $i=LL, LH, HL, HH$.

V. ANALYSIS

In this paper we have proposed a new RDWT-SVD based watermarking scheme where the principal components of the watermark image are embedded into the host image so that the false positive problem can be avoided. To find the suitable scaling factor value PSO is used. As a result robustness and transparency can be achieved. Peak Signal to Noise Ratio (PSNR) can be evaluated to find the quality of the watermarked image and to find the robustness Normalized Cross-Correlation (NC) can be calculated.

VI. CONCLUSION

In this paper RDWT is proposed to overcome the drawback of DWT based watermarking scheme. The redundancy in the RDWT provides the robustness to the watermarked image. As the embedding of watermark image occurs in all sub-bands, more information can be transferred and principal components help to avoid the false positive problem. Thus the proposed scheme can satisfy the capacity, robustness and imperceptibility.

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