Non-blind color GIS image watermarking algorithm based on lifting wavelet using MSVD

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Abstract--- A non-blind color GIS image watermarking algorithm based on the concept of LWT using MSVD technique has been proposed. The maximum valued coefficients of LWT in a block of size $2 \times 2$ have been used to embed color watermark. It has been observed that the perceptual quality of the watermarked image is comparatively better. The performance of the algorithm has been tested on crowd sourced GIS images taken through mobile based e-governance applications and the experimental results have been compared with some existing methods. The obtained results show that this algorithm has performed better than existing algorithms and is also robust against geometrical image processing attacks.

Keywords---GIS image; watermarking algorithm; multi-resolution singular value decomposition; Lifting Wavelet Transform; e-governance;

I. Introduction

The rapid growth of technology, GPS enabled digital cameras are gaining popularity which leads to exponential growth of geo-tagged digital images or videos. These cameras automatically add metadata (i.e. geographic information) to digital images or videos [1]. These metadata can be conveniently used to locate images on map. However, authentication and tamper detection are the major challenges in the area of image processing.

In recent years, information and communication technology (ICT) has been introduced to facilitate the communication between the government and citizens called digital governance or e-governance. The purpose of e-governance is the application of ICT and other related technology for enhancing the efficiency and effectiveness of service delivery for the citizen. In many mobile based e-governance applications GIS images are being captured from work-sites and are being kept on public domain so the purpose of social audit of schemes progress can be performed. Keeping these images over the internet may cause piracy, illegal copying and unauthorized usages which is a potential revenue loss for the government [2].

In order to protect digital images from illegal copying, tampering and unauthorized usages digital watermarking can be a better solution and can be used to establish the ownership and authenticity of digital images. Digital watermarking can be considered as a dominant technique to solve these problems. There are many techniques available in literature which advocates digital watermarking for the purpose of authenticity and ownerships [3] [4] [5] [6] [7] [8] [9]. The digital images captured by government agencies are generally geo-tagged and color. Watermarking in color images has two advantages over gray-scale image — first greater amount of data be hidden and second it has higher fidelity [10]. The work proposed in usages spatial domain color image watermarking to embed watermark by quantizing indices of the color host image in uniform color space.

In literature there are several research available based on SVD which has adequately utilized the stable property of the singular value matrix. In these techniques the singular values of the original watermark are required for extracting the embedded singular value and the U and V orthogonal matrices of the original watermark were used for recovering the watermark. Singh et. al. [14] proposed NSCT based image watermarking using MSVD which provides better reconstruction of watermarked image and robust against geometrical attacks. In this paper, a non-blind robust watermarking algorithm based on lifting wavelet Transform (LWT) using multi-resolution singular value decomposition (MSVD) has been proposed with aim to make a watermarking system robust against intentional geometrical attacks. Moreover, secrete key based on pseudo-random permutation has been used to make the system more secure. While using MSVD decomposition for color watermark images makes the system more robust.
The rest of the paper is organized as follows. In section II DCT, MSVD and LWT have been discussed. Section III addresses watermark embedding and extraction algorithm. The experimental results are conferred in section IV and the conclusion is drawn in section V.

II. Preliminaries

A. Discrete Cosine Transform: The discrete cosine transform (DCT) [15] is widely accepted transform in signal and image processing. It has wide application such as image & signal processing, pattern recognition, image compression and image steganography [16] [17]. In general, it is used to transform digital images from spatial domain to frequency domain. DCT divides an image into three frequencies (i.e. low, middle and high). The mathematical definition of two-dimensional DCT is shown in equation 1.

\[ F(u) = \left( \frac{2}{N} \right)^{\frac{3}{2}} \sum_{n=0}^{N-1} \Lambda(i) \cdot \cos \left[ \frac{\pi u}{2N} (2i + 1) \right] f(i) \]  

(1)

B. Multi-Resolution singular value decomposition (MSVD): Multiresolution singular value decomposition (MSVD) is a substitute and much alike to Discrete wavelet transforms (i.e. DWT). In Discrete wavelet transform, the input signals are filtered out as low and high pass finite impulse and outputs decimated factor of two, to achieve first level of decomposition. The similar approach is also used in MSVD. Traditional wavelet transform contains local and directional information and have basis function which is absent in MSVD [18]. However, the computation time of MSVD is comparatively lower than traditional wavelet transforms. MSVD can be obtained as follows:

Let \( K \) be a matrix of size \( M \times N \), we can obtain SVD as

\[ K = USV^T \]  

(2)

where matrices \( U \) and \( V \) are orthogonal matrices with size \( M \times M \) and \( N \times N \) respectively. \( S \) is a diagonal matrix.

MSVD can be obtained by first reshaping a matrix \( K \) to \( K_1 \) of size \( 4 \times MN/4 \) is calculated as:

\[ [U, S] = \text{SVD}(K_1) \]  

(3)

where matrix \( U \) is of size \( 4 \times 4 \) and matrix \( S \) is of size \( 4 \times MN/4 \).

The matrix \( T \) is calculated as:

\[ T = U^T K_1 \]  

(4)

where, matrix \( T \) of size \( 4 \times MN/4 \).

Each row of the matrix \( T \) can be reshaped to obtain four different matrices of size \( M / 2 \times M / 2 \). The resultant reshaped matrices can be called as \( LL, LH, HL \) and \( HH \) sub-bands. The pictorial representation of MSVD is shown in figure. MSVD resist against geometrical image processing attacks (i.e. reshaping, resizing, cropping, and rotation).

C. Lifting Wavelet Transform (LWT): The lifting wavelet transform scheme, proposed by Sweldens [19], overcomes the shortcoming of tradition discrete wavelet transform. This scheme simplifies the problem of reversibility by directly evaluating into integer domain. The performance of this scheme is better than DWT (in terms of time and space) therefore it is being widely used in image processing (i.e. image compression [20], watermarking [21] [22]). The signal decomposition in LWT is achieved through following three steps:

• Split - In the split step the given signal \( S(n) \) is being divided into non overlapping odd \( S_o(n) \) and even \( S_e(n) \) samples as:

\[ S_o(n) = S(2n) \], \( S_e(n) = S(2n+1) \]  

(5)

• Predict - The samples obtained in previous step can be used to predict each other if they are correlated by abstracting the difference value represented by \( G(n) \) as:


G(n) = S_0(n) − P[S_e(n)],
(6)

where P(S_e(n)) is the predict operator and G(n) is high-frequency component that is used to define error between original sample and predicted value.

- Update - The even samples S_e(n) are updated using update operator U(n) to reconstruct the abstract difference G(n), which is represented by low-frequency component L(n) which is the coarse approximation of the original signal S(n) as follows:

\[ L(n) = S_e(n) + U(G(n)) \]  
(7)

III. Proposed Digital Image Watermarking Technique

A. Watermark Embedding Algorithm: This section describes our proposed watermark embedding technique. In the watermark embedding process, initially the original host image (I) of size \( M \times N \) can be decomposed into three different basic color components (i.e. Red, Green and Blue). Discrete Cosine Transform is applied on each color component separately. Afterwards, two level LWT transform is applied on each of the color components to obtain average, vertical, horizontal and diagonal details of the host image (also called sub-bands). The coefficients of all the sub-bands are grouped into block of size \( 2 \times 2 \). These blocks are randomly shuffled using secret key. In order to employ security measures, pseudo-random permutation has been used. In each block, the indices of maximum valued coefficients are identified. The color component of watermark image (W) is also separated and Multi-Resolution singular value decomposition then can be applied on each of the color planes, which can result in LL, LH, HL, and HH sub-bands. The coefficients of these sub-bands are quantized into the maximum value obtained in each block. This process is applied for each color planes and sub-bands. The block diagram for embedding watermark is shown in figure 1. The process shown in figure 1 is only for single color plane. The same process is applied on different color planes. The steps to embed watermark is as follows:

**Input:** Color host and watermark image.

**Output:** Watermarked Image.

1. Let I be the host image and W be the watermark image.
2. Transform I using DCT.
3. Perform two-level LWT, to obtain average (A), vertical (V), horizontal (H) and diagonal (D) details of the host image.
4. Group coefficients into non-overlapping blocks (B_i) of size \( 2 \times 2 \) for each A, H, V, and D.
5. Randomly shuffle all blocks using secret key (k_1).
6. Find index of maximum value for each block.
7. Apply Multi-Resolution singular value decomposition, to obtain LL, LH, HL, and HH sub-bands.
8. Quantize coefficients of sub-bands with corresponding sub-bands of I to get A, H, V, and D.
9. Reshuffling all blocks using secret key(k_1).
10. Perform inverse LWT.
11. Perform inverse DCT.
12. Watermarked image I is obtained.
Figure 1: Block diagram of watermark embedding process

B. Watermark Extraction Algorithm: The watermark extraction process is very similar to that of embedding process. The block diagram of watermark extraction is shown in figure 2. At first, the host image and the watermarked images are decomposed into three basic color components and DCT transform is applied. Afterwards, two-level LWT transform is applied on each color components to obtain average, vertical, horizontal and diagonal details of the host image, on both images. Then, the coefficients of all the sub-bands are grouped into block of size \(2 \times 2\). These blocks are randomly shuffled using secret key. In each block, the indices of maximum valued coefficients are identified. The coefficients of host image are subtracted from watermarked image to get LL, LH, HL, and HH sub-bands of the watermark and then inverse MSVD is applied to get watermark image. The figure 2 depicts the extraction process only for single color plane. The steps to extract watermark is as follows:

**Input:** Host and Watermarked Image.

**Output:** Extracted Watermark.

1. Let I be the host image to be watermarked and I' is the watermarked image.
2. Perform DCT transform on I and I'.
3. Perform two-level LWT transform on both images I and I' to obtain A, A, H, H, V, V, D, and D.
4. Group coefficients into non-overlapping blocks \(B_k\) of size \(2 \times 2\).
5. Randomly shuffle all blocks using secret key \(k_1\).
6. Find index of maximum value for each block.
7. De-quantize coefficients of sub-bands with corresponding sub-bands of I and I to get LL, LH, HL, and HH sub-bands.
8. Perform inverse MSVD.
9. Watermarked image W is obtained.
IV. Results and Discussion

This section deals with the experimental results. We have used four color GIS images (size $1600 \times 1200$) taken from various geographical locations shown in figure 3 as experimental subjects and color watermark of size $100 \times 36$ (figure 4). In figure 5, watermarked images and corresponding extracted watermark are shown without applying any attack. In table 1, PSNR value of watermarked image is shown. To test the performance of this algorithm, in terms of robustness and reliability, we have performed some fundamental geometric and non-geometric attacks such as Gaussian filter, speckle noise, salt & pepper noise, rotation, and scaling. In table 2, the results of experimental image under different attacks and extracted watermark are shown in terms of PSNR and NCC values. In table 3, PSNR and corresponding NCC values of the extracted watermark after various attacks on different images are shown.

![Block diagram of watermark extraction process](image)

Figure 2: Block diagram of watermark extraction process

![Experimental Images](image)

Figure 3: Experimental Images

![Watermark Image](image)

Figure 4: Watermark Image
Figure 5: Watermarked Image & Extracted Watermark

<table>
<thead>
<tr>
<th>Image</th>
<th>PSNR</th>
</tr>
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<tr>
<td>Nursery 1</td>
<td>60.352138</td>
</tr>
<tr>
<td>Nursery 2</td>
<td>60.352238</td>
</tr>
<tr>
<td>Nursery 3</td>
<td>60.352138</td>
</tr>
<tr>
<td>Nursery 4</td>
<td>60.352138</td>
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</table>

Table 1: PSNR values of watermarked image

<table>
<thead>
<tr>
<th>Attack</th>
<th>PSNR</th>
<th>NCC</th>
<th>Extracted Watermark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speckle</td>
<td>53.2345</td>
<td>0.7326</td>
<td></td>
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<tr>
<td>Salt &amp; Pepper</td>
<td>52.7889</td>
<td>0.7070</td>
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<tr>
<td>Poisson</td>
<td>52.0012</td>
<td>0.7145</td>
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<tr>
<td>Gaussian</td>
<td>54.1123</td>
<td>0.7812</td>
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</table>
Table 2: PSNR and NCC values of extracted watermark with different attack

<table>
<thead>
<tr>
<th>Image / Attack</th>
<th>Speckle</th>
<th>Salt &amp; Pepper</th>
<th>Poisson</th>
<th>Gaussian</th>
<th>Rotation</th>
<th>Cropping</th>
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<tbody>
<tr>
<td>Nursery 1</td>
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<td>0.8210</td>
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<td>0.8822</td>
<td>0.8212</td>
<td>0.7959</td>
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<tr>
<td>Nursery 3</td>
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<td>Nursery 4</td>
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PSNR Value

<table>
<thead>
<tr>
<th>Image / Attack</th>
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<th>Nursery 2</th>
<th>Nursery 3</th>
<th>Nursery 4</th>
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<tbody>
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<td>47.5237</td>
<td>51.2344</td>
<td>49.5689</td>
<td>53.8989</td>
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</tbody>
</table>

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The significant difference between watermarked image without & with attacks can be observed through histogram plots (figure 6) which clearly indicate that most of the information is localized towards the center, though the watermarked image is distorted. Verma et al. [23], has shown the significant difference between traditional and lifting wavelet transforms in case of watermarked image is distorted.

Moreover, we have also compared our results with different existing techniques such as [14] & [24] shown is table 4. On comparing our technique using NCC (average values) for different attacked watermarked images shows that it is more robust against scaling and Gaussian filter attacks. The result shown in table 2 is much better than techniques proposed in [14] & [24].

<table>
<thead>
<tr>
<th>Attack / NCC</th>
<th>Singh et al. [14]</th>
<th>Wang et al. [24]</th>
<th>Proposed Scheme</th>
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<td>Gaussian</td>
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<td>0.8812</td>
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<td>Rotation</td>
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<td>0.6521</td>
<td>0.8989</td>
</tr>
<tr>
<td>Salt &amp; Pepper</td>
<td>0.9832</td>
<td>-</td>
<td>0.8210</td>
</tr>
</tbody>
</table>

Table 4: Comparison of results

V. Conclusion

In this paper, a novel non-blind color image watermarking scheme based on lifting wavelet is proposed. The benefits of LWT over traditional wavelet transform are utilized to enhance the performance. The color watermark image is decomposed using MSVD and embedded into the maximum coefficient value of the host image. We have also employed security measures to shuffle blocks of host image which adds extra layer of security and robustness. The experimental results on GIS images have shown that our proposed algorithm not only achieve higher level of level of invisibility but are also robust in some intentional image processing attacks.

References


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