Enhancing Invisibility and Robustness of DWT based Video Watermarking scheme for Copyright Protection

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Abstract

Requirements for digital watermarking are mainly application dependent. Robustness is one of the main requirements for many watermarking applications. In this paper a blind Discrete Wavelet Transform (DWT) based video watermarking algorithm for copyright protection is proposed. We have embedded a meaningful watermark invisibly into uncompressed video. The watermark is embedded in high frequency sub-band coefficients of the DWT to improve the invisibility of the marked video sequence. The watermark is first scrambled and then encoded to minimize the error probabilities during watermark detection. We have applied 2-D automorphic transform and BCH error correction coding on the binary image for scrambling and encoding the watermark respectively before the watermark embedding. We have applied key based pseudo random 3-D interleaving on the coefficients selected for watermark insertion. We have also embedded the frame number as the synchronization information instead of using the sliding correlation as proposed in [1, 5]. Experimental results have proved that the embedded data with the proposed scheme is visually transparent, robust against unintentional or malicious attacks such as frames deleting, frames inserting and frame statistical averaging. 3-D interleaving has significantly improved the robustness of the proposed scheme against temporal attacks. The watermark embedded in such way is high bit rate and thus more robust. The series of experiments conducted has revealed the effectiveness and usefulness of the proposed watermark generation and embedding strategy.

Index Terms—Discrete Wavelet Transform (DWT), Pseudo random 3-D interleaving, BCH error correction coding, Video Watermarking, Copyright protection.

1. Introduction

In recent years the digital video watermarking has gathered significant interest of research community for the protection of intellectual property and has become active area of research [1].

Because of the widespread availability and use of the World Wide Web, digital contents are vulnerable to unlimited, unrestricted and uncontrolled copying and redistribution without the loss of fidelity to the original content. This brings huge losses to digital content owners and thus is a high source of motivation for the digital video watermarking research community [2].

Encryption decryption is a powerful tool for limiting access and protection of the digital content. But after decryption the digital content is no longer safe from malicious users and hackers. Digital watermarking is one way out.

Videos generally consist of a sequence of images which when moved at particular rate gives the impression of moving pictures to naked eye and to whom human mind interprets as video sequence. Video watermarking has lot in common with image watermarking as they share some common characteristics. Some of the techniques originally proposed for image watermarking are enhanced for video watermarking [3].

In literature both meaningful and random sequence watermarks are used depending on the application requirements [4]. Some video watermarking algorithms operate in raw video sequences and some embed the watermark directly in compressed videos. In this paper we have used meaningful watermark and the embedding is done in uncompressed domain.

After the survey of current watermarking techniques it is revealed, no technique can resist all type of attacks. Generally frequency domain watermarking techniques are more robust than spatial domain watermarking techniques. In the following some spatial domain watermarking techniques and the type of attacks against which they are most resistant are described.

LSB watermarking technique is best against cropping attack, threshold-based correlation method comes up with the best results against PSNR attack, m-sequence / m-frame is good for PSNR attack and spread spectrum yields best results against add noise and PSNR attacks [5]. Frequency based watermarking techniques like DCT is best against JPEG lossy compression, DWT is best against PSNR attacks. DFT is best against row/column removal, rotation and shearing attack, and radon transform is best against rescaling.

We have chosen DWT because as it provides both spatial and frequency domain characteristics of the signal. DWT is playing important role in JPEG2000 and MPEG-4.
watermarking we are always making tradeoffs. If we want to improve the robustness we have to compromise on invisibility and vice versa.

In some of the techniques proposed in the literature the watermark is inserted serially in the frames. This type of embedding is not robust against temporal attacks like frame deleting, frame inserting and frame swapping. To overcome this problem we have applied 3-D interleaving to randomly separate and maximize the distance between the coefficients chosen for embedding. We have improved the invisibility of the watermarking scheme as proposed by H. Liu et al in [6] by embedding the watermark in high frequency coefficients. Scrambling the watermark before applying BCH coding has made watermark more robust and in turn adding in the robustness of the whole watermarking scheme. We have used key based pseudo random 3-D interleaving technique which results in the enhancement of robustness of the embedded information.

2. Watermark Embedding

In the following we have described the watermark embedding algorithm used in the paper.

2.1. Watermark Preprocessing

The watermark is a 32-by-32 binary image as shown in Fig.1 and denoted by W, such that W(i) ∈ {0,1}. There are lot of error correcting codes (ECC) currently being used in communication technology. BCH ECC is one of them. The binary watermark is first scrambled by using two dimensional automorphic transform and then encoded by BCH coding to enhance the robustness of the watermark. Scrambling has the advantage that it spreads the error bits in the whole image instead of concentrating on a particular part of the image. Equation 1 is used to scramble the image.

\[
\begin{pmatrix}
    x_{i+1} \\
    y_{i+1}
\end{pmatrix} = \begin{pmatrix}
    1 & 1 \\
    p_i & p_i + 1
\end{pmatrix} \begin{pmatrix}
    x_i \\
    y_i
\end{pmatrix} \text{ (mod M)}
\]

(1)

Where \( p_i \) acts as the cipher key. \( x_i \) and \( y_i \) are the spatial coordinates. Due to attacks we may loose some of our watermark bits. Error correction coding helps us to correct and recover up to \( N \) number of error bits depending upon the size of codeword length \( C \) and message length \( K \). The size of the codeword is a tradeoff between error correction capability and capacity. We have chosen \( K \) as 16 with the size of codeword 63 so up to 11 bits of error can be corrected.

2.2. Pseudo Random 3-D Interleaving Based on Secret Key

Applying interleaving on a video sequence can increase the robustness of the signal and in turn decrease the probability of decoding error. If a watermark signal is attacked in such a way that a part of each frame is cropped or damaged the 3-D interleaving can still achieve zero probability of symbol decoding error. In another scenario where 3-D interleaving has yielded excellent results occurs when a malicious attacker removes watermark signal completely from a group of frames like bursts of errors in communication 3-D interleaving can still reduce error probabilities of detection[7]. In our scheme we have improved the robustness of 3-D interleaving by making the whole 3-D interleaving process dependent on a secret key.

2.3. Watermark Insertion

By applying 3-level DWT on the video frames we get ten sub-bands. The top band is the approximation (LL3/CA3) band and contains low frequency coefficients. The rest nine sub-bands \{LHi, HLi, HHi / CHi, CVi, CDi, i=1:3\} consist of detail coefficients and have high frequency. CH, CV, CD high pass sub-bands compose of edge components of horizontal vertical and diagonal directions respectively. We have selected CD3 sub-band for embedding the watermark, as we achieved highest PSNR by embedding in this sub-band.

Watermarking embedding methodologies have great influence on the robustness of embedded watermark. Cox et al. [8] proposed to embed watermark in low frequency coefficients to improve the robustness of the watermark signal. In literature survey it became evident that some authors have embedded watermark in middle frequency components of DCT (Discrete Cosine Transform) [9]. Huang et al. [10] proposed to insert watermark in the DC components rather than embedding in AC coefficients to achieve better robustness.

We have selected the most insignificant components of the original image for watermark embedding to ensure invisibility. After 3-level DWT we have selected 1024 central high frequency coefficients per frame and then combined the coefficients of 32 frames to make a 3-D coefficients block. Then we have applied pseudo random 3-D interleaving on the selected 32768 central high frequency coefficients to make the embedded watermark robust against burst of errors. Then the watermark signal is added in these interleaved coefficients.
We have chosen four least significant bits for watermark oblivious watermarking scheme for watermark extraction in this paper. The watermark extraction process is inverse of the watermark embedding procedure.

The 3-level DWT is applied to the watermarked video frames. Then the synchronization information is checked. We placed empty frames in place for lost frames. After that we applied pseudo random 3-D interleaving on the selected central 32768 coefficients and extracted the embedded watermark from four least significant bits. Later on BCH decoding is applied to correct the error bits and then the original watermark is extracted by applying automorphic transform. The automorphic transform is periodic i.e. same image as original can be obtained by repeatedly applying 2-D automorphic transform. The watermark extraction process is shown in Fig. 3.

4. Experimental Results

We have tested the proposed algorithm on various video sequences. We have embedded the watermark in 32 frames. The video we selected for watermarking has the frame rate of 29, spatial resolution of 240 x 352. Our technique results in better PSNR than the scheme proposed in [6].
Table 1.

PSNR for different frames with the proposed scheme

<table>
<thead>
<tr>
<th>Frame #</th>
<th>PSNR</th>
<th>Frame #</th>
<th>PSNR</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>54.6588</td>
<td>16</td>
<td>50.8711</td>
</tr>
<tr>
<td>4</td>
<td>51.2470</td>
<td>18</td>
<td>51.5633</td>
</tr>
<tr>
<td>6</td>
<td>54.6457</td>
<td>20</td>
<td>51.8744</td>
</tr>
<tr>
<td>8</td>
<td>55.5305</td>
<td>22</td>
<td>54.6441</td>
</tr>
<tr>
<td>10</td>
<td>51.7447</td>
<td>24</td>
<td>51.9417</td>
</tr>
<tr>
<td>12</td>
<td>53.6664</td>
<td>26</td>
<td>53.3418</td>
</tr>
<tr>
<td>14</td>
<td>53.5187</td>
<td>28</td>
<td>51.5987</td>
</tr>
</tbody>
</table>

Table 2 shows the PSNR of different frames as proposed by H. Liu et al in [6]. This clearly shows the improvement achieved by our scheme.

Table 2.

PSNR for different frames with the scheme proposed by H. Liu et al in [6]

<table>
<thead>
<tr>
<th>Frame #</th>
<th>PSNR</th>
<th>Frame #</th>
<th>PSNR</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>39.4801</td>
<td>16</td>
<td>37.7761</td>
</tr>
<tr>
<td>4</td>
<td>37.6792</td>
<td>18</td>
<td>37.8804</td>
</tr>
<tr>
<td>6</td>
<td>38.5363</td>
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</tr>
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<td>10</td>
<td>38.4047</td>
<td>24</td>
<td>39.5494</td>
</tr>
<tr>
<td>12</td>
<td>37.6643</td>
<td>26</td>
<td>38.3756</td>
</tr>
</tbody>
</table>

5. Conclusion

In this paper a blind video watermarking technique is proposed. We have improved the invisibility of the scheme proposed in [6] by embedding high bit meaningful watermark in the high frequency sub-band coefficients. The proposed scheme is robust against temporal attacks like frame dropping, frame addition and frame replacement. The introduction of key based 3-D interleaving has further enhanced the robustness of the scheme. Scrambling the original watermark image increases the robustness. BCH coding has reduced the bit error rate and thus enhanced the robustness of the watermark against temporal attacks. We have embedded the synchronization information using aspects of HVS which further enhances the robustness of the proposed scheme. The embedded watermark is also invisible and robust against malicious attacks.

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7. References


