A Digital WATERMARKING Algorithm with High Efficiency Based on
DWT and LSB

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Abstract. In order to improve the performance of digital watermarking system, a novel watermarking
algorithm for blind watermarking based on the least significant bits and support vector machine.
Firstly, digital watermarking was pretreated by binaryzation. Subsequently, the watermark signal is
embedded into least significant bit of the low frequency coefficients by the Discrete Wavelet
Transformation. Finally, the trained support vector machine is used to extract the attacking vetors.
Simulation results show that the watermarking algorithm has good invisibility and robustness
to general attacks and geometrical distortions.

Introduction

The improvement of new information technology necessitates the development of the multimedia
data, such as images, music, e-books and video. At the same time, digital copyright disputes are
gradually increasing. Therefore, copyright protection is becoming important. It is a technology that to
embed some information into digital carrier, and not affected the value of the host carrier. Digital
watermarking is an effective method of digital copyright protection and an important branch of
information hiding technology. It is the first time that Kunder proposed the watermarking technology
based on the Discrete Wavelet Transform. Firstly, the host image is transformed by wavelet
transform; secondly, the watermark of the special stator is embedded in the corresponding image
subband; thirdly, the embedded image is obtained by taking inverse wavelet transform [1]. LSB is the
main way of spatial method for image hiding. The principle of it is to make the image like what it not
be hided with another image and to replace the least important bits of pixels in the image of the host
image for hiding. As an arithmetic which can hide bulk information, LSB is still widely used in many
field for it’s easily understand and operation [2]. Basing on these questions we raise a method base on
DWT and LSB. For LSB, in order to promote, the efficiency of embedding, changing the last bit of the
low frequency coefficients by the Discrete Wavelet Transformation, and it doesn’t influence the
quality of itself. To dispose of hidden information which basing on digital watermarking technology
has big problem. The times we scrambling is very important, too few the effect is not ideal and too
many is much complex. There we put forward a new way to solve these problem. The algorithms,
dealing with frames spatial representation, often realize LSB or PVD methods [3] in regard to raster
representation of separate frames. A major shortcoming of such algorithms is weak sustainability of
hidden data to further container compression. In [4], Zheng proposed a digital watermarking method
based on SVD, which the optimization objective is the blind watermarking method. It is used the
characteristics of matrix sparsity to avoid large computation that eigenvalues and eigenvectors in the
singular value decomposition, but SVD is insensitive to geometrical deformation, so the method is
worse to resist geometrical distortions. Some other ways of steganographic data hiding into video,
providing enhanced robustness of hidden data, but dependent on used coding algorithms (MPEG-4),
are steganographic concealment directly into the compressed data flow at the level of spectral
coefficients, as well as embedding data using information of movement vectors [5]. In the paper, a
novel combination of DWT-LSB and SVM method is proposed to resist the geometrical distortion. At
first, the host image is applied into the method of multi-scale wavelet transform. Since the least significant bit in the host image is not important, the intensity of embedding in the least significant bit is less than others. Then the least significant bit in the

Watermark Embedding Based on DWT-LSB

The basic principle of the digital watermarking embedding algorithm based on DWT-LSB which is developed the spatial domain into the Discrete Wavelet domain. The watermark is embedded into the least significant bit in the low frequency coefficient matrix. Then the Wavelet domain is converted into the spatial domain to complete the embedding of the watermark. The specific embedding procedure is as follows [1]:

Step1: The M by M gray scale host image is divided into 8×8 subblocks, and each subblock is transformed by Discrete Wavelet Transform;

Step2: The N by N binary watermark \( w(i, j) \) is stored in the order of every two subblocks as one bit, which is embedded in the least significant bit of the low frequency coefficient of \( \lambda_1 \) and the new one is recorded as \( \lambda'_1 \);

Step3: The process that the watermark is embedded into the low frequency coefficients is as follows:

\[
T = \lambda_1 \mod \alpha
\]

\[
\lambda'_1 = \begin{cases} 
\lambda_1 - T + 3\alpha / 4 & \text{The binary value of the watermark pixel is } 1 \text{ and } T \geq \alpha / 4 \\
\lambda_1 - T - \alpha / 4 & \text{The binary value of the watermark pixel is } 1 \text{ and others}
\end{cases}
\]

\[
\lambda'_2 = \begin{cases} 
\lambda_1 - T + 5\alpha / 4 & \text{The binary value of the watermark pixel is } 1 \text{ and } T \geq 3\alpha / 4 \\
\lambda_1 - T + \alpha / 4 & \text{The binary value of the watermark pixel is } 1 \text{ and others}
\end{cases}
\]

Step4: The embedded image is transformed into IDWT and sequentially stored back, then it is reconstructed the watermarked image \( I' \).

Watermark Extraction Based on DWT-LSB

The digital watermarking extraction algorithm based on DWT-LSB is described as follows [1]:

Step1. After the watermarked image is transformed with 8×8 subblocks. If the watermarked image is not attacked, is true, or else, the image \( w(i, j) \) can be extracted by the least significant bit in the low frequency coefficient of the revised watermarked image.

Step2. The image \( w(i, j) \) is obtained from the least significant bit by the following formula.

\[
T = \lambda'_1 \mod \alpha
\]

\[
W(i, j) = \begin{cases} 
1 & T \geq \alpha / 2 \\
0 & \text{others}
\end{cases}
\]

SVM

The standard SVM constructed by Vapnik is solved using quadratic programming which is computation expensive, and is also difficult to be implemented adaptively [6]. SVM has been
SVM has successfully applied to numerous classification and pattern recognition problems such as text categorization, image recognition, and bioinformatics. SVM-based classifier is built to minimize the structural misclassification risk, whereas conventional classification techniques often apply minimization of the empirical risk. Therefore, SVM is claimed to lead enhanced generalization properties. Further, application of SVM results in the global solution for a classification problem.

SVM based classification is attractive, because its efficiency does not directly depend on the dimension of classified entities. This property is very useful in fault diagnostics, because the number of fault classification features does not have to be drastically limited. The watermarked images which are attacked geometric distortion would be corrected, and SVM is used for the geometric correction, as a supervision learning model.

Let \( p_i = (p_{i1}, p_{i2}, \ldots, p_{im})^T (i = 1, 2, \ldots, M) \) be a sample of \( p \in \mathbb{R}^n \) and belong to Class I or Class II. For linearly separable data, it is possible to determine a hyperplane that separates the data leaving one class on one side of the hyperplane, the other on the other side. This plane can be described by the equation [7]:

\[
f(x) = w^T x + b = \sum_{j=1}^{n} w_j x_j + b = 0
\]

where \( w \in \mathbb{R}^n \) is a weight vector and \( b \) is a scalar. The vector \( w \) and the scalar \( b \) determine the position of the separating hyperplane.

**Simulation**

In the simulations, three host images and one watermark are tested. Three host images with sizes \( 512 \times 512 \) are shown from Fig. 1 a–c, referred to as “Couple”, “Man”, “Peppers”, respectively and one watermark image with size \( 32 \times 32 \) is shown in Fig. 2. Three watermarked images are shown from Fig. 1 d–f.

![Figure 1. a–c The host images of Couple, Man, Peppers, d–f The watermarked images of Couple, Man, Peppers.](image)

**Shuai Yin**

Figure 2. The watermark image.
Peak signal-to-noise ratio (PSNR) between original host image and watermarked image is measured by Eq. (2).

$$PSNR = 10 \times \log_{10} \frac{mn \times \max(I_{ij}^2)}{\sum_{i=1}^{m} \sum_{j=1}^{n} [I_{ij} - I_{ij}^*]^2}$$  \hspace{1cm} (2)

Where $I_{ij}$ and $I_{ij}^*$ refer to the host image and watermarked image; $m$ and $n$ refer to the width and length of host image, respectively. The peak signal-to-noise ratio of the above three watermarked images that are also used in references [3] and [4] is shown in table I:

Table 1. The peak signal-to-noise ratio of the watermarked images (PSNR).

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<tr>
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<tbody>
<tr>
<td>Couple</td>
<td>37.2391</td>
<td>36.8652</td>
<td>37.1721</td>
</tr>
<tr>
<td>Man</td>
<td>38.7693</td>
<td>38.1547</td>
<td>38.3208</td>
</tr>
<tr>
<td>Peppers</td>
<td>39.0873</td>
<td>38.6983</td>
<td>37.6945</td>
</tr>
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Normalized correlation (NC) between original watermark and extracted watermark is computed by Eq. (3).

$$NC = \frac{\sum_{i=1}^{m} \sum_{j=1}^{n} W_{ij} \times W_{ij}^*}{\sqrt{\sum_{i=1}^{m} \sum_{j=1}^{n} W_{ij}^2} \sqrt{\sum_{i=1}^{m} \sum_{j=1}^{n} W_{ij}^{*2}}}$$  \hspace{1cm} (3)

Where $W_{ij}$ is the original watermark and $W_{ij}^*$ is the extracted watermark; $m$ and $n$ denote the equal width and length of watermark, respectively. After the geometric attack on the embedded image of “Couple”, the algorithm in this paper is used to extract the watermark and calculate the normalized correlation, as shown in table II:

Table 2. The watermark detection results for geometric distortions (NC).

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<tr>
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<tr>
<td>Rotation 45°</td>
<td>0.86676</td>
<td>0.71865</td>
<td>0.79231</td>
</tr>
<tr>
<td>Translation (H 20, V 20)</td>
<td>0.88653</td>
<td>0.72025</td>
<td>0.76256</td>
</tr>
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</table>

From the table 1, PSNR of the algorithm in our paper is close to 40dB, which the watermark is hidden better. In table 2, the proposed algorithm based on DWT-LSB and SVM has higher quality and better performance than paper [3] and [4] in the watermarking extracting and the NC is better. In
Whether under geometric attack or not, it is the high quality of the extracted watermark and the NC value is close to 1. In the absence of strict requirements to the capacity of the hiding algorithm, the accuracy of the recovery can be significantly increased by repeated duplication of an embedded message, and through the use of codes of detection and correction of errors.

**Conclusion**

After Discrete Wavelet transformation, the use of LSB algorithm have a great impact on the quality of carrier the image and promote the efficiency of embedding and save the space. Experiments show that our algorithm is improved the robustness and high efficiency embedding and anti-clipping digital watermark algorithms based on the LSB, watermark separation and image interpolation has obvious anti-clipping effect.

**Acknowledgement**

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**References**


