Watermarking Experiments Based On Wavelet Transforms

Chaur-Chin Chen
Department of Computer Science
National Tsing Hua University
Hsinchu, Taiwan 300
Tel: +886 3 573-1078
Fax: +886 3 572-3694
E-mail: cchen@cs.nthu.edu.tw

A Proposed Watermarking Scheme

A general watermarking scheme includes

(a) a watermark acquisition: Sampling $N(0,1)$ with a private seed.
(b) a watermark embedding: insert the watermark into wavelet coefficients.
(c) a watermark extraction and verification
Criteria for a Watermark to Meet

- **Transparency:** The watermark should be perceptually invisible or its presence should not be confused with the image being protected.

- **Robustness:** The watermark should still be detected after the image has undergone linear or nonlinear operations (attacks) such as median filtering, cropping, scaling, compression, and enhancement.

- **Capacity:** The watermarking strategy must be of allowing multiple watermarks to be embedded into an image with each image still being independently verifiable.
Watermark Embedding

Let \(\{X(i,j)\}\) be a gray level image of size \(N_1 \times N_2\), and let \(c_0 = 1/\sqrt{2}, c_1 = 1/\sqrt{2}\), define

\[
H = \begin{bmatrix}
c_0 & c_1 \\
c_0 & -c_1 \\
c_0 & c_1 \\
c_0 & -c_1 \\
\vdots & \ddots & \ddots & \ddots & \ddots \\
c_0 & c_1 \\
c_0 & -c_1 \\
c_0 & c_1 \\
c_0 & -c_1
\end{bmatrix}
\]

Then Haar wavelet transform [?] of \(X\) can be written as

\[
Y = P \bigotimes_4 H \bigotimes_3 X \bigotimes_1 H^t \bigotimes_2 Q
\]  \hspace{1cm} (1)

where \(\bigotimes_j\) is an ordered matrix multiplication, and \(P, Q\) are the products of row and column permutation matrices, respectively, for the purpose of downsampling for a coarser wavelet transform.
where \( Y_1 = HL_3 = H_{HL3}(X) \) and \( Y_2 = LH_3 = H_{LH3}(X) \) are images consisting of wavelet coefficients of high-low and low-high bands at level 3 whose sizes are both \( M_1 \times M_2 \), where \( M_1 = N_1/8 \) and \( M_2 = N_2/8 \), respectively. Let \( W \) be a watermark of size \( M_1 \times M_2 \) which is acquired by sampling \( N(0,1) \), a Gaussian distribution with zero mean and unit variance. Our embedding scheme is done pointwise by

\[
Y_1 \leftarrow Y_1 * (1 + \alpha W) \tag{2}
\]
\[
Y_2 \leftarrow Y_2 * (1 - \alpha W) \tag{3}
\]

where \( \alpha \in (0,0.3] \).
Watermarking Extraction and Detection

Let \( \{X(i,j)\} \) be the original image of \( N_1 \times N_2 \), and let \( \{W(i,j)\} \) be an authorized watermark, a matrix of \( M_1 \times M_2 \). Suppose that \( \{Y(i,j)\} \) is an observed image of \( N_1 \times N_2 \), then the extracted watermark \( W^* \) can be computed by the following formulas:

\[
Z = H_{HL3}(X) \quad \text{or} \quad Z' = H_{LH3}(X) \quad (4)
\]
\[
T = H_{HL3}(Y) \quad \text{or} \quad T' = H_{LH3}(Y) \quad (5)
\]
\[
W^*(i,j) = \frac{1}{\alpha} \left( \frac{T(i,j)}{Z(i,j)} - 1 \right) \quad \text{or} \quad W^*(i,j) = \frac{-1}{\alpha} \left( \frac{T'(i,j)}{Z'(i,j)} - 1 \right) \quad (6)
\]

\[
\text{Sim}(W^*, W) = \left( \frac{W^*, W}{\sqrt{(W^*, W)}} \right) \quad (7)
\]

According to a theorem of Probability Theory, \( \{W(i,j)\} \) can be treated as a random sample of size \( K = M_1 \times M_2 \) from \( N(0,1) \), and \( \{W^*(i,j)\} \) is a set of \( K \) numbers, thus, \( \text{Sim}(W^*, W) \sim N(0,1) \). Therefore, the two-sided confidence interval of \( \text{Sim}(W^*, W) \) is \([-1.96, 1.96] \), which helps determine the significance of the \( \text{Sim}(W^*, W) \) index or the existence of an extracted watermark.

Experimental Results

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Haar</td>
<td>41.29</td>
<td>30.46</td>
<td>33.96</td>
<td>45.95</td>
<td>33.34</td>
<td>32.60</td>
<td>30.51</td>
<td>36.01</td>
</tr>
<tr>
<td>PSNR</td>
<td>41.95</td>
<td>2.66</td>
<td>3.33</td>
<td>23.17</td>
<td>3.40</td>
<td>3.41</td>
<td>2.91</td>
<td>3.12</td>
</tr>
</tbody>
</table>

Table 1: PSNR and Sim of Watermarked Lenna, lena0, Under Attacks.
Figure 2: (a) Lenna, (b) lena0: A Watermarked Image.
Figure 3: 99 Sim values of random watermarks vs. a true one.

Figure 4: Scaling

Figure 5: Smoothing
Figure 9: Wavelet Compression