A generic image watermarking system

- Requirements
  - Invisibility
  - Robustness
  - No ambiguity

- Distortions
  - Image processing
  - Compression
  - 

- Extraction
Advantages of this scheme

• Advantages:
  – Semantically meaningful watermark pattern
  – Good perceptual invisibility
  – Acceptable robustness
  – Various user-selected options
  – Reasonable complexity/execution time
• Watermarks are randomly permuted to spread their spatial relationship, and then embedded in the DCT domain of the host image, with consideration of invisibility/robustness
Block Diagrams of the Original Algorithm

Original Image → FDCT → Embedding (Polarity Reversing) → IDCT → Watermarked Image

Watermark Image → Pseudo-random Permutation → Block-based Mapping → Watermarked Image

Digital Watermark $W$ → Pseudo-Random Permutation → Block-Based Permutation → Watermarked Image $\hat{x}$

PSNR = 38.45 dB
Block Diagrams of the Original Algorithm

- Original Image
- Suspected Image
- FDCT
- Extract the Permutated Data (XOR)
- Reverse Block-based Permutation
- Reverse Pseudo-random Permutation
- Extracted Watermark
Block DCT/IDCT

- **Advantages**
  - Fast
  - Suitable for robustness against JPEG compression

- **Disadvantages**
  - Block effect
  - Effect of picture cropping
Semantic Meaningful Watermarks

- Watermarks can be verified with naked eyes by understanding the semantics of the extracted watermark patterns

The seal of CML (in Chinese characters)
• A $n$-bit Linear Feedback Shift Register (LFSR) is used to generate the maximal length $(2^n-1)$ sequence

The 14-bit Shift Register that permutes 1-16384
Block-based Mapping

- Watermark blocks with more signal pixels are embedded into image blocks with higher variances
  - to achieve better perceptual invisibility.
Embedding (1/2)

- Choices of embedding positions within each block:
  - Low-frequency
    - Bad invisibility
  - High-frequency
    - Bad robustness
  => Middle-frequency
- Fix positions in each block
• Polarity: the inequality relations between the scaled DC value and the selected AC coefficients

\[
P(i, j) = \begin{cases} 
1, & \text{if } \left| \frac{AC(i, j)}{Q(i, j)} \right| \ast Q(i, j) > \left( \frac{|DC|}{ScaleFactor \ast Q(0,0)} \right) \ast Q(0,0) \\
0, & \text{otherwise}
\end{cases}
\]

• Effects of the JPEG quantization table are also considered
Polarity Reversing

- Polarity: the inequality relationship between DC & corresponding AC values within each DCT block.

<table>
<thead>
<tr>
<th>Watermark Bits: 0 1 0 1 0 0 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polarity: 1 1 0 0 1 0 1</td>
</tr>
<tr>
<td>Reversed Polarity: 1 0 0 1 1 0 0</td>
</tr>
</tbody>
</table>

Embedding

Extraction

XOR
• **Exclusive-or (XOR)** operations are performed on the two polarity patterns to obtain the permuted binary data.