Digital watermarking techniques for JPEG2000 scalable image coding

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Contents

- Introduction
- Digital watermarking: properties and applications
- Discrete wavelet transform and its applications
- Scalable image coding and its application in multimedia signal processing
- Research techniques for image watermarking for JPEG2000 content adaptation
- Recent developments and open questions in this field
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Introduction

- A digital watermark is the copyright or author identification information which is embedded directly in the digital media in such a way that it is imperceptible, robust and secure.

Audio watermarking

Image watermarking

Video watermarking
Digital watermarking: properties and applications
Watermarked image

Difference image

Extracted watermark
Example
Example
Example

Watermark in homogeneous region

Watermark in textured region
Digital watermarking: properties

- Imperceptibility
  
  ➢ Measurement metrics: RMSE, PSNR, SSIM etc.
Digital watermarking: properties

- Imperceptibility
  - Measurement metrics: RMSE, PSNR, SSIM etc.

- Robustness
  - Measurement metric: Hamming distance, Correlation etc.
Digital watermarking: properties

- Imperceptibility
  - Measurement metrics: RMSE, PSNR, SSIM etc.

- Robustness
  - Measurement metric: Hamming distance, Correlation etc.

- Fragility

- Tamper-resistance

- Data payload
Applications

- Copyright protection.
- Owner identification.
- Content authentication.
- Broadcast monitoring.
- Transaction tracking.
- Media digital rights management (DRM) in content supply chain.
- Tamper proofing.
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- **Discrete wavelet transform and its applications**
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Discrete Wavelet Transform (DWT) and applications
DWT

2D wavelet decomposition
# DWT

## 2 level decomposition

<table>
<thead>
<tr>
<th>LL2</th>
<th>HL2</th>
<th>HL1</th>
</tr>
</thead>
<tbody>
<tr>
<td>LH2</td>
<td>HH2</td>
<td></td>
</tr>
</tbody>
</table>

| LH1 | HH1 |  

![DWT Diagram](image_url)
DWT Applications

• Compression
  • JPEG-2000 image compression
  • MC-EZBC video compression
• De-noising
• Edge-detection
• Image retrieval
• Gait analysis
• Digital communication and many others
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Scalable image coding
JPEG2000 image coding using DWT

Original (979 KB)

JPEG2000 (1.83 KB)

JPEG (6.21 KB)
JPEG2000 image coding
JPEG2000 image coding

Bit plane N

Bit plane N-1

Bit plane N-2

Bit plane 0

Most significant

Least significant

LL2

HL2

HH2

LH2

HH1

HH2

LH1

HL1

LL2
JPEG2000 image coding
Resolution scalability
Resolution scalability
Resolution scalability
Quality scalability
Quality scalability
Quality scalability
Example

Reconstructed images compressed at 0.125 bpp by means of (a) JPEG and (b) JPEG2000
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Robust watermarking techniques for scalable coding

E: Encoding engine and distribution server
X: Hybrid communication channel
D: End-user display devices
Watermarking techniques

Embedding:

\[ \xi() \]

Original Image \( (I) \)

Watermark \( (W) \)

Watermarked Image \( (I') \)

Extraction:

\[ \omega() \]

Test Image \( (I') \)

Extracted watermark \( (W') \)

Authentication

Watermark detection decision

Original Image \( (I) \)

Original watermark \( (W) \)
Watermarking techniques

Embedding Domain

Pixel Domain

Transform Domain

Fourier

DCT

Wavelet

Non-Blind

Blind
Watermarking techniques

Host Image $\rightarrow$ DWT $\rightarrow$ Coefficient selection and watermark embedding $\rightarrow$ IDWT $\rightarrow$ Watermarked Image

Watermark $\rightarrow$ Comparison of original and extracted watermark $\rightarrow$ Watermark Extraction (Blind / Non-blind) $\rightarrow$ DWT

Test image $\rightarrow$ Attack including content adaptation
Watermarking techniques

Embedding

\[ C'_{m,n} = C_{m,n} + \alpha C_{m,n} w_{m,n}, \]

Extract

\[ W_{\text{ext}} = \frac{C' - C}{\alpha C}, \]

where \( C'_{m,n} \) = modified coefficient,
\( C_{m,n} \) = wavelet coefficient to be modified,
\( w_{m,n} \) = watermark information,
\( \alpha \) = watermark strength parameter,
\( w_{\text{ext}} \) = extracted watermark.
Wavelet based image compression (Bit-plane discarding):

\[ C_q = \left[ \frac{C}{Q} \right], \]

\[ \hat{C} = Q.C_q + \left( \frac{Q - 1}{2} \right), \]

where \( C_q \) = quantised coefficient, \( C \) = original coefficient, \( Q \) = quantisation parameter,

\( C^\wedge \) = decoded coefficient
\( Q = 2^N \)

\( k \in \{ \pm 1, \pm 2, \pm 3 \ldots \} \)

\( C_k \) = Center point value

\[ C_{(k-1)} = (k-1).2^N + \frac{2^N - 1}{2} \]

\[ C_k = k.2^N + \frac{2^N - 1}{2} \]
Algorithm 1:


Embed 1: C & C' in different cluster:

\[
\frac{k \cdot 2^N}{1 + \alpha w_1} \leq C \leq k \cdot 2^N.
\]

\(w_1 = \text{value to embed '1'}.\)
Robustness Analysis:

Embed 1: C & C’ in same cluster:

\[ k \cdot 2^N \leq C \leq \frac{C_k}{1 + \alpha T}. \]

T = Threshold for watermark detection.
Robustness Analysis:

Embed 1: combined:

\[
\frac{k.2^N}{1+\alpha w_1} \leq C \leq \frac{C_k}{1+\alpha T}.
\]
Robustness Analysis:

Embed 0: C & C’ in different cluster:

\[ \frac{k \cdot 2^N}{1 + \alpha w_0} \leq C \leq k \cdot 2^N. \]

\( w_0 \) = value to embed ‘0’. 

\( (k-1) \cdot 2^N \)  \( k \cdot 2^N \)  \( (k+1) \cdot 2^N \) 

\( C_{(k-1)} \)  \( C_k \)  \( C' \)
Robustness Analysis:

Embed 0: C & C’ in different cluster:

\[ \frac{C_{(k-1)}}{1 + \alpha T} \leq C \leq \frac{k \cdot 2^N}{1 + \alpha w_0}. \]
Robustness Analysis:

Embed 1 or 0 for correct watermark extraction:

\[
\frac{k.2^N}{1 + \alpha w_1} \leq C \leq \frac{k.2^N}{1 + \alpha w_0}.
\]
Simulation results:

- **Watermark detection of 1 at Q=2^7 (alpha = 0.5)**

  Map of original coefficient values (C) to retain the watermark information.

- **Watermark detection of 0 at Q=2^7 (alpha = 0.5)**

- **Watermark detection of 1 or 0 at Q=2^7 (alpha = 0.5)**

Map of original coefficient values (C) to retain the watermark information.
Simulation results:

Effect of bit-plane based coefficient selection procedure against JPEG2000 quality scaling considering 64:1 compression ratio. Quantisation steps: $Q = 2^0$ to $Q = 2^9$. 

Simulation results:
Wavelet based image compression (Bit-plane discarding):

\[ C_q = \left[ \frac{C}{Q} \right], \]

\[ \hat{C} = Q.C_q + \left( \frac{Q-1}{2} \right), \]

where \( C_q = \) quantised coefficient, 
\( C = \) original coefficient, 
\( Q = \) quantisation parameter, 
\( \hat{C} = \) decoded coefficient 
\( Q = 2^N \)

\( k \in \pm 1, \pm 2, \pm 3... \)
\( C_k = \) Center point value

\[ C_{(k-1)} = (k-1).2^N + \frac{2^N-1}{2} \]
\[ C_k = k.2^N + \frac{2^N-1}{2} \]
Algorithm 2:


\[ \lambda = 2^M \]
**Embedding algorithm**

Tree for C: \( b(C) = (n \% 2)011 = 1011 \)

\[
b_i = \left\lfloor \frac{|C|}{\lambda/2^i} \right\rfloor \% 2, \; i \in 0,1,2,3,..., \quad C = 142 \quad \lambda = 2^5 = 32
\]

\[
b(C) = 01000 \quad d = 6
\]
# Tree based watermarking rule

<table>
<thead>
<tr>
<th>Symbols</th>
<th>Binary Tree</th>
<th>Watermark association</th>
</tr>
</thead>
<tbody>
<tr>
<td>Embedded Zero (EZ)</td>
<td>000xxxx</td>
<td>0</td>
</tr>
<tr>
<td>Embedded Zero (EZ)</td>
<td>001xxxx</td>
<td>0</td>
</tr>
<tr>
<td>Cumulative Zero (CZ)</td>
<td>010xxxx</td>
<td>0</td>
</tr>
<tr>
<td>Weak One (WO)</td>
<td>011xxxx</td>
<td>1</td>
</tr>
<tr>
<td>Weak Zero (WZ)</td>
<td>100xxxx</td>
<td>0</td>
</tr>
<tr>
<td>Cumulative One (CO)</td>
<td>101xxxx</td>
<td>1</td>
</tr>
<tr>
<td>Embedded One (EO)</td>
<td>110xxxx</td>
<td>1</td>
</tr>
<tr>
<td>Embedded One (EO)</td>
<td>111xxxx</td>
<td>1</td>
</tr>
</tbody>
</table>
# Experimental Results

$$\Phi = \frac{\sum_{m=0}^{X-1} \sum_{n=0}^{Y-1} (I(m, n) - I'(m, n))^2}{L}$$

<table>
<thead>
<tr>
<th>Image</th>
<th>Existing Algorithm</th>
<th>Proposed Algorithm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(\phi)</td>
<td>PSNR</td>
</tr>
<tr>
<td>Boat (704x576)</td>
<td>86.40</td>
<td>53.74</td>
</tr>
<tr>
<td>Barbara (704x576)</td>
<td>80.64</td>
<td>55.12</td>
</tr>
<tr>
<td>Blackboard (704x576)</td>
<td>69.12</td>
<td>56.45</td>
</tr>
<tr>
<td>Light House (768x512)</td>
<td>84.48</td>
<td>55.36</td>
</tr>
</tbody>
</table>
Experimental Results

Robustness against JPEG2000: Blackboard

Robustness against bit plane discarding: Blackboard
Experimental Results

Robustness against JPEG2000: Light House

Robustness against bit plane discarding: Light House
Experimental Results

Robustness against JPEG2000: Blackboard

Robustness against JPEG2000: Light House
Experimental Results

Robustness against JPEG2000: Blackboard

Robustness against JPEG2000: Light House

Proposed algorithm
Existing algorithm
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Demo

- Watermarking demo.
Open questions in this field and comments

• Watermarking a growing research area for digital copyright protection and other applications.
• Scalable coded contents are being used for various applications including mobiles.
• Watermarking for scalable coded contents are challenging and needs more research.
• Video watermarking is a promising research area to explore.
Pointers

• WEBCAM Framework developed by The University of Sheffield.
  • http://svc.group.shef.ac.uk/webcam.html
Pointers

Books:
- Digital Watermarking by Cox, Miller, Bloom & Miller
- Information Hiding Techniques for Steganography and Digital Watermarking by Petitcolas and Katzenbeisser

Papers:
Questions and Answers:
Thank You All

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