The Choice of Filter Banks for Wavelet-based Robust Digital Watermarking

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Overview

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Watermarking in the Wavelet Domain: Different Filters

The choice of filter for Watermarking:

- Known to be important from compression applications
- Expected to influence watermarking performance
- Possible optimization for robustness or image quality
- Yet little is said in the literature on the filter choice

→ This paper aims to rank filters by WM requirements
Marking Process:
- Decompose image ... up to depth $n$
- Choose subbands
- Modify coefficients ... in secret places
- Finally apply the inverse transform for marked image
Factors influencing a DWT-based scheme’s performance:

- Choice of Filter
- Subband depth of marking
- Decomposition Scheme for embedding

Factors shared with non-DWT schemes:

- Embedding technique
- Embedding intensity
- Image properties (e.g. variation of texture)
The Filters tested are:

<table>
<thead>
<tr>
<th>Orthogonal Filters:</th>
<th>Biorthogonal Filters:</th>
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<tbody>
<tr>
<td>Name</td>
<td>Length</td>
</tr>
<tr>
<td>Haar</td>
<td>2</td>
</tr>
<tr>
<td>Daub4</td>
<td>4</td>
</tr>
<tr>
<td>Daub6</td>
<td>6</td>
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<tr>
<td>Daub8</td>
<td>8</td>
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</table>
Experimental Setup (cont.)

The Watermarking Technique for Testing:

- Mark the chosen subbands’ maximum DWT coefficients using non-blind multiplicative embedding:
  \[ x'_i = x_i (1 + \alpha m_i) \]
- A Pyramid decomposition is used
- Subbands for marking: 1, 1-2, 1-3 or 1-4
- Marking intensity: 20%-80%
- The watermark can be any file; here: binary image
- Use the embedding coordinates for reading the mark
Experimental Setup (cont.)

Watermark Embedding → Image Quality Scoring (MSE) → Compression Attack (JPG or DWT) → Watermark Detection → Detection Scoring (MSE and $L^q$d)

Cover Image

Watermark (binary image) → Detected Watermark
Our watermark is an image — how can we measure detection quality automatically?

- Humans can still identify a heavily distorted logo
- Can we mimic this in software?

The $L^{qd}$ quality measurement:

- Is a modification of the $L^q$ pseudo-norm for image querying [Jacobs et.al. 1995]
- Exploits the DWT-domain’s multiresolutional properties
The $L^q_d$ Quality Measurement (cont.)

$L^q_d$ Philosophy:

- Mark Recognition depends on only few coefficients
- Use rough details: Coarse subbands
- Insignificant coefficients can be discarded
The $L^{qd}$ Algorithm:

- Fully decompose both images (Haar, Pyramid)
- Set $n\%$ top coefficients to 1 or -1, and all others to 0
- For each image’s nonzero coefficients:
  - If the other image’s corresponding coefficient differs, add a value from a weight table
  - Weights are experimentally determined [Jacobs]
- The $L^{qd}$ is the two sums’ normalized minimum
- The lower the $L^{qd}$ value the better the match
Testing parameters:

- Watermark intensity
- Attack compression ratio
- Kind of attack (JPG or DWT)
- The image characteristics
- Chosen subband depth for marking

Rankings depend most on image, subband depth and kind of attack.
Image Degradation:

- Marking only subband 1: little degradation
- Increasing the subband depth: visible artifacts

Reasons: Choice of significant coefficients for marking and 1:4 relationship from coarser to finer subbands.

However: Much better robustness at subband depths > 1
The Degradation Rankings:

Degradation against subbands measured in MSE

- Antonini, Brislawn, Villa1
- Haar, Daub4, Daub6, Daub8
- Odegard, Villa2
- Villa3
- Villa4
- Villa5
- Villa6

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The Detection Rankings (JPG attack):

Detection (JPG attack) against subbands measured in $L^{qd}$

Subbands: Haar, Daub4, Daub6, Daub8, Antonini, Brislawn, Villa1, Villa2, Villa3, Villa4, Villa5, Villa6, Odegard

Rank 1 2 3 4 average
The Detection Rankings (DWT attack):

Detection (DWT attack) against subbands measured in $L^{qd}$
Conclusions

- Quality and robustness against attacks are contradicting requirements
- In both cases, performance of filters depends on the subband depth (2 is a reasonable compromise)
- Adapting the marking intensity leads to a better tradeoff
- Other influences are beyond the marker’s control
- *Villa3* has good overall properties (followed by the group around *Antonini* and *Villa6*)
Further Work

This work has been extended to use the SCS (Scalar Costa Scheme, introduced by Eggers in 2000) instead of the Multiplicative embedding.

This work is part of an ongoing project on Wavelet-based Second Generation Watermarking.

For more details, including a more detailed version of the paper, please see my web pages on the project:

http://herbert.the-little-red-haired-girl.org/en/research/