Scalability evaluation of blind spread-spectrum image watermarking

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Overview

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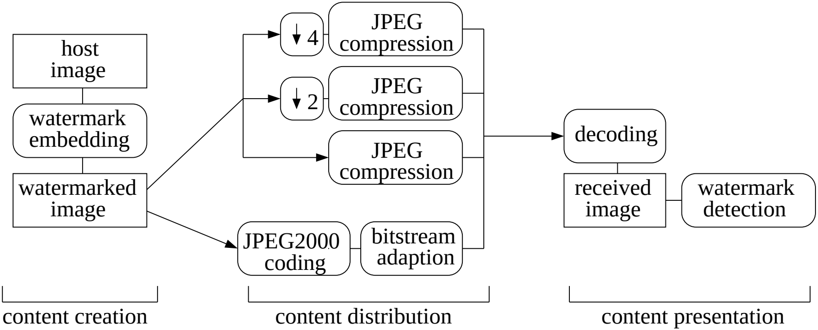
Introduction

- Watermarking embeds an imperceptible yet detectable signal in multimedia content
- Current multimedia standards (i.e. JPEG2000, H.264/SVC) support scalable coding
- The scalable bitstream can be adapted to match the presentation capabilities of a device
- This work:
  - Propose two 'scalable' watermarking schemes
  - Investigate the impact of adaption on blind spread-spectrum watermarking

Scalable JPEG2000 and JPEG Coding

- JPEG2000 supports quality and resolution scalability
  - Build one bitstream, extracted desired quality / resolution
- JPEG has limited support (Annex F, G, J), rarely implemented
  - Simulation: Construct separate bitstreams for all quality / resolution levels

Application Scenario



Scalable Watermarking?

- Scalable watermarking algorithm is intended for use with scalable content.
- Two properties [Piper et al., 2005]:
  - Watermark is detectable in any portion of the scaled content of acceptable quality.
  - Increased portions of the scaled content provide reduced error in watermark detection.

Related Work

- [Piper et al., 2005] evaluate the robustness of coefficient selection methods of non-blind schemes with regards to scalable coding
  - Their appoach maximizes watermark energy in low-frequency components via HVS modelling
  - Host interference can be completely canceled (non-blind)
- Other works are non-blind [Seo and Park, 2005] or only consider progressive decoding (no combined / resolution scalability) [Tefas and Pitas, 2001, Chen and Chen, 2000]

Generalized Gaussian Image Model

- DCT- and DWT transform coefficients can be modeled as i.i.d. samples from Generalized Gaussian distributions (GGD) [Birney and Fischer, 1995]

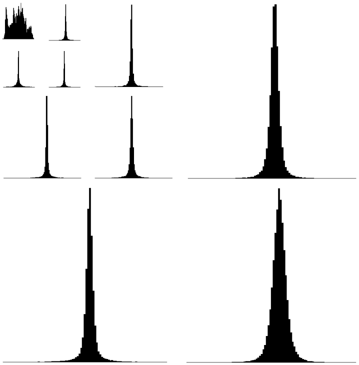
$$p(\mathbf{x}) = A\exp(-|\beta\mathbf{x}|^c), \quad -\infty < x < \infty$$

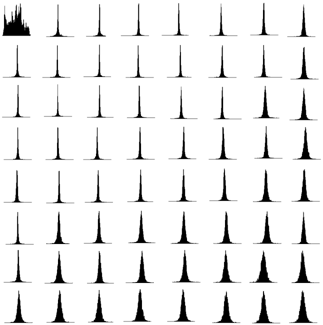
$$\beta = \frac{1}{\sigma_x}\sqrt{\frac{\Gamma(3/c)}{\Gamma(1/c)}} \text{ and } A = \frac{\beta c}{2\Gamma(1/c)}$$

- Estimate distribution parameters c (shape) and β (scale) for each DWT subband and 8×8-block DCT frequency band

Watermarking Channels

- Assume K independent watermarking channels aligned with the DWT subbands or 8×8-block DCT frequency bands
- Embed independent additive spread-spectrum watermark in each channel: $y[k] = x[k] + \alpha w[k]$
- Choose strength α such that document-to-watermark ratio (DWR) is constant across all channels





Two Watermarking Schemes

- DCT Watermarking scheme
  - 8×8-block DCT
  - Form 18 channels by concatenating coefficients from low- and mid-frequency bands
- DWT Watermarking scheme
  - Have 6 DWT subband channels for 2-level DWT transform
  - Decompose LL subband with 8×8-block DCT and construct 18 frequency channels

Watermark Detection

- Hypothesis testing problem [Hernández et al., 2000]

$$H_0: \; y[k] = x[k] \qquad \text{no/other watermark}$$
$$H_1: \; y[k] = x[k] + \alpha w[k] \qquad \text{watermarked}$$

- Formulate likelihood-ratio test conditioned on GGD

$$L(\mathbf{y}) = \sum_{k=1}^{N} \beta^c (|y[k]|^c - |y[k] - \alpha w[k]|^c)$$

- PDFs of $L(\mathbf{y})$ under hypothesis H_1 and H_0 approximately Gaussian with

$$\sigma^2_{L(\mathbf{y})|H_1} = \sigma^2_{L(\mathbf{y})|H_0} = \tfrac{1}{4} \textstyle\sum_{k=1}^{N} \beta^{2c} (|y[k] + \alpha|^c - |y[k] - \alpha|^c)^2 \text{ and}$$

$$\mu_{L(\mathbf{y})|H_1} = -\sum_{k=1}^{N} \beta^c (|y[k]|^c + \frac{1}{2} \sum_{k=1}^{N} \beta^c (|y[k] + \alpha|^c + |y[k] - \alpha|^c)$$

Multi-channel Detection

- Have K channels with separate detection statistics $L(\mathbf{y}_i)$ with μ_i and σ_i
- Assuming channel independence, global detection statistic with Gaussian PDF becomes

$$L_{global}(\mathbf{y}) = \sum_{i=1}^{K} \frac{L(\mathbf{y}_i) - \mu_{L(\mathbf{y}_i)|H_0}}{\sigma_{L(\mathbf{y}_i)}}$$

- Determine global detection threshold

$$T_{global} = \sqrt{2}\,\mathrm{erfc}^{-1}(2P_{fa})$$

for false-alarm rate $P_{fa} = 10^{-6}$

Experimental Setup (1)

- Perform watermark detection on adapted bitstream for increasing quality for three resolution layers
  - B ... base resolution layer (128×128 pixel)
  - E1, E2 ... resolution enhancement layers
  - B+E1 ... 256×256 pixels, B+E1+E2 ... 512×512 pixels
- JPEG: Quality factor 10 to 90
- JPEG2000: JPEG2000 bit rate 0.1 to 2 bpp (Kakadu 6.0)
- Use 512×512 grayscale images with different characteristics

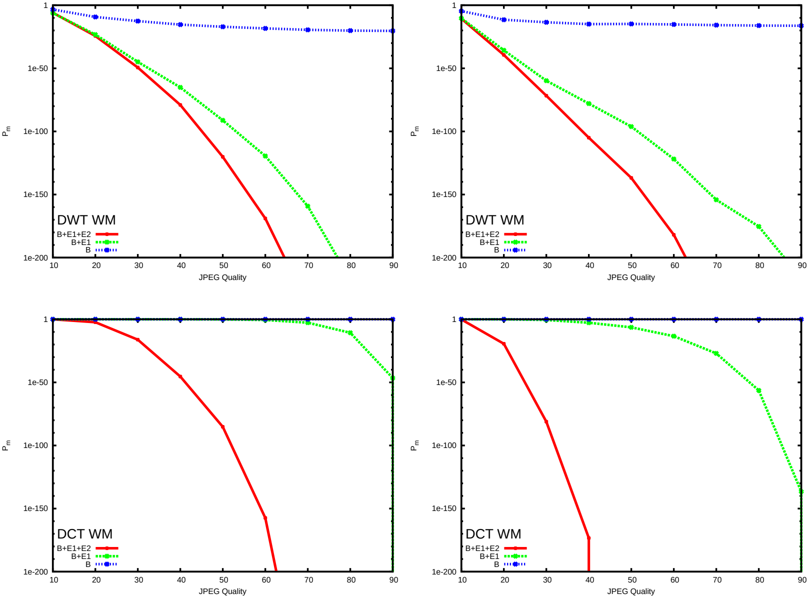
Experimental Setup (2)

- Use blind DWT and DCT watermarking scheme
- Set document-to-watermark ratio (DWR) to 20 dB

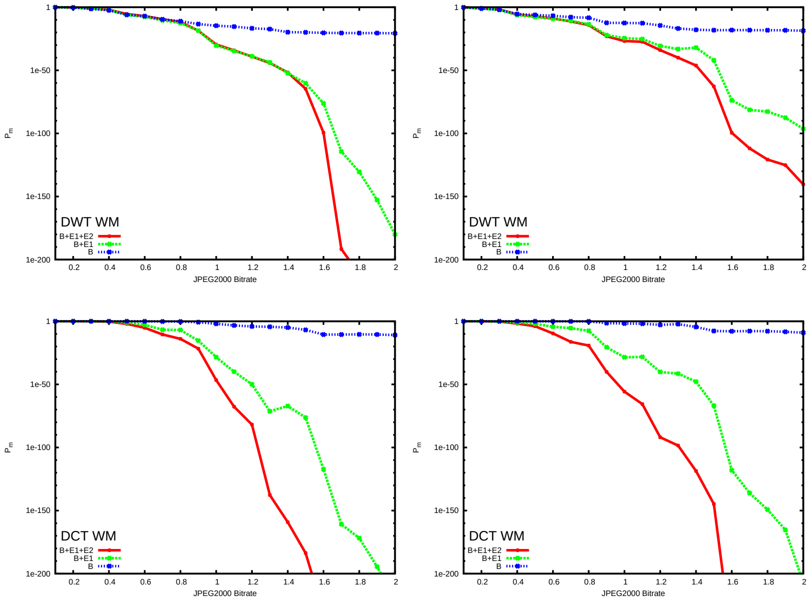
Image	Embed PSNR		JPEG Q=30		J2K 0.3 bpp	
	DWT	DCT	DWT	DCT	DWT	DCT
Barbara	39.98	40.61	29.82	29.91	28.82	28.88
Houses	36.86	35.22	28.87	27.81	23.95	23.96

- Repeat each experiment 1000 times to estimate parameters of detection statistics

Results: DWT & DCT scheme, JPEG compression



Results: DWT & DCT scheme, JPEG2000 compression



Conclusion

- Have proposed two scalable watermarking schemes, compliant with Piper's definition
  - Can use additional transmitted data to improve detection reliability
  - DCT watermarking scheme performs poorly with base layer data only
- Watermarking schemes benefit from using multiple channels
- Watermark domain does not necessarility have to match compression domain
- Source code available upon request: `http://wavelab.at/sources`

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