Overview

- Image adaptive data hiding
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- Image adaptive data hiding $\Rightarrow$ tuned to image statistics
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  - better fidelity
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- better fidelity
- better robustness
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- **Image adaptive data hiding** ⇒ tuned to **image statistics**
  - better **fidelity**
  - better **robustness**

- New technique suited for **JPEG2000** compressed media
Overview

- **Image adaptive data hiding** ⇒ tuned to image statistics
  - better fidelity
  - better robustness
- New technique suited for JPEG2000 compressed media
- **IDS codes** for synchronization
Embed information $M$ into a coverwork $c$ by modifying its content imperceptibly.
The Basics
Quantization Index Modulation

- Embed information $M$ into a coverwork $c$ by modifying its content imperceptibly
- Embed $m = 0$ or $1$ in a sample $x$ using Scalar QIM\(^1\)

\[
x_w = Q\left(x - \frac{m\Delta}{2}\right) + \frac{m\Delta}{2}
\]

\(^1\)Chen and Wornell
Embed information $M$ into a coverwork $c$ by modifying its content imperceptibly.

Embed $m = 0$ or $1$ in a sample $x$ using Scalar QIM$^1$

$$x_w = Q\left(x - \frac{m\Delta}{2}\right) + \frac{m\Delta}{2}$$

Choose samples (coefficients) to embed $\log_2(M)$ bits.

---

$^1$Chen and Wornell
The Basics
Perceptual Shaping

- Psychovisual studies on perceptually similar signals

\(^2\text{Distortion should remain imperceptible}\)
The Basics
Perceptual Shaping

- *Psychovisual studies* on perceptually similar signals
- *Complex* models of human visual system

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- **Psychovisual studies** on perceptually similar signals
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- First applied to **quantization** in compression schemes

\[2\text{ Distortion should remain imperceptible}\]
Psychovisual studies on perceptually similar signals
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First applied to quantization in compression schemes
How to apply to Scalar QIM?

²Distortion should remain imperceptible
The Basics
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- Psychovisual studies on perceptually similar signals
- Complex models of human visual system
- First applied to quantization in compression schemes
- How to apply to Scalar QIM?
  - Operate in transform domain

\(^2\)Distortion should remain imperceptible
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- **Complex** models of human visual system
- First applied to *quantization* in compression schemes
- How to apply to *Scalar QIM*?
  - Operate in transform domain
  - Determine maximum allowable\(^2\) distortion \(\epsilon\)

\(^2\) Distortion should remain imperceptible
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- Complex models of human visual system
- First applied to quantization in compression schemes
- How to apply to Scalar QIM?
  - Operate in transform domain
  - Determine maximum allowable\(^2\) distortion \(\epsilon\)
  - Determine quantizer stepsize \(\Delta\) to be \(\frac{\epsilon}{2}\)

\(^2\) Distortion should remain imperceptible
Watermark extractor does not need original data (key-based)
Perceptual Shaping and Data Hiding

Blind data hiding

- Watermark extractor does not need original data (key-based)
- No performance loss\(^3\)

\(^3\)Data Hiding Codes, Moulin and Koeter
Perceptual Shaping and Data Hiding

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- Perceptual Shaping \(\Rightarrow\) image dependent coefficient selection

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Watermark extractor does not need original data (key-based)
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Use mask values to select coefficients

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Perceptual Shaping and Data Hiding

Blind data hiding

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- Perceptual Shaping \(\Rightarrow\) image dependent coefficient selection
- Use mask values to select coefficients
- Compare to threshold determined by payload size

\(^3\)Data Hiding Codes, Moulin and Koeter
Lewis-Barni mask on DWT coefficients

\[ q^\theta_l(i, j) = \Theta(l, \theta) \Delta(l, i, j) \Xi(l, i, j)^{0.2} \]
Perceptual Shaping and Data Hiding
Perceptual Shaping: Lewis-Barni

- **Lewis-Barni mask** on DWT coefficients

\[
q_{l}^{\theta}(i,j) = \Theta(l,\theta)\Delta(l,i,j)\Xi(l,i,j)^{0.2}
\]

- \(\Theta\) depends on resolution level and orientation
Lewis-Barni mask on DWT coefficients

\[ q^\theta_l(i, j) = \Theta(l, \theta)\Delta(l, i, j)\Xi(l, i, j)^{0.2} \]

- \(\Theta\) depends on resolution level and orientation
- \(\Delta\) measures local brightness
Perceptual Shaping and Data Hiding

Perceptual Shaping: Lewis-Barni

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- Accurate representation of HVS.
Lewis-Barni mask on DWT coefficients

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Perceptual Shaping and Data Hiding

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- + Accurate representation of HVS.
- + DWT Based
- - High Complexity.
Solanki mask on DCT coefficients of 8 by 8 blocks

\[ E_{\text{block}} = \sum_{i,j=0}^{7} ||C(i,j)||^2 - ||C(0,0)||^2 \]
Solanki mask on DCT coefficients of 8 by 8 blocks

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+ Low Complexity
Solanki mask on DCT coefficients of 8 by 8 blocks

\[ E_{\text{block}} = \sum_{i,j=0}^{7} \|C(i,j)\|^2 - \|C(0,0)\|^2 \]

- Low Complexity
- DCT based
Solanki mask on DCT coefficients of 8 by 8 blocks

\[ E_{\text{block}} = \sum_{i,j=0}^{7} ||C(i,j)||^2 - ||C(0,0)||^2 \]

- Low Complexity
- DCT based
- Block based
Perceptual Shaping and Data Hiding

Perceptual Shaping: Tree Based

- **Tree based mask** on DWT coefficients

\[
E_{\text{tree}}(l, \theta, i, j) = \sum_{k=1+a}^{l-1} \sum_{x,y=0}^{2^{l-k}-1} ||l_k^\theta(i+x, j+y)||^2,
\]

(1)
Perceptual Shaping and Data Hiding
Perceptual Shaping: Tree Based

▶ Tree based mask on DWT coefficients

\[
E_{\text{tree}}(l, \theta, i, j) = \sum_{k=1+a}^{l-1} \sum_{x, y=0}^{2^l-1} ||l_k^\theta(i + x, j + y)||^2 , \quad (1)
\]

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Perceptual Shaping and Data Hiding

Perceptual Shaping: Tree Based

- **Tree based mask on DWT coefficients**

\[
E_{\text{tree}}(l, \theta, i, j) = \sum_{k=1+a}^{l-1} 2^{l-k-1} \sum_{x, y=0}^{2^{l-k}-1} ||I_{\theta}^k(i + x, j + y)||^2 ,
\]  

(1)

- + Low Complexity
- + DWT based
Perceptual Shaping and Data Hiding

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- **Tree based mask** on DWT coefficients

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- + Low Complexity
- + DWT based
- + Good visual performance
Perceptual Shaping and Data Hiding

Perceptual Shaping: the masks

(a) Lewis-Barni
(b) Solanki
(c) Tree Based
Synchronization issues modeled by IDS channel
- Synchronization issues modeled by IDS channel
- Conventional ECC expect a substitution-only channel
Synchronization issues modeled by IDS channel
Conventional ECC expect a substitution-only channel
We use an improved Davey-MacKay construction:
- Synchronization issues modeled by IDS channel
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- We use an improved Davey-MacKay construction:
  - outer non-binary error-correcting code
Synchronization issues modeled by IDS channel

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- outer non-binary error-correcting code
- sparse code
Synchronization issues modeled by IDS channel
- Conventional ECC expect a substitution-only channel
- We use an improved Davey-MacKay construction:
  - outer non-binary error-correcting code
  - sparse code
  - pseudo-random binary marker sequence
Overview of the complete system

- Payload: 300 bits
- Modified coefficients: 3000 (rate 1/10 IDS code)
Results

IDS performance

- High error rate, especially for Tree-based
- Still within capabilities of ECC
Results
Decoding performance

- Robustness as good as Lewis-Barni, at reduced complexity
- Poor robustness of Solanki – domain mismatch
Results

Other attacks

- We have seen effect of JPEG 2000 compression
Results

Other attacks

- We have seen effect of JPEG 2000 compression
- Effect of other attacks is similar:
Results

Other attacks

- We have seen effect of JPEG 2000 compression
- Effect of other attacks is similar:
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Results

Other attacks

- We have seen effect of JPEG 2000 compression
- Effect of other attacks is similar:
  - JPEG compression
  - AWGN noise addition
## Results

### Visual Performance

<table>
<thead>
<tr>
<th>Method</th>
<th>PSNR</th>
<th>SSIM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lewis-Barni</td>
<td>59 dB</td>
<td>1.0000</td>
</tr>
<tr>
<td>Solanki</td>
<td>55 dB</td>
<td>0.9996</td>
</tr>
<tr>
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(d) Lewis Barni
(e) Solanki
(f) Tree Based
Data hiding and IDS codes to solve synchronization issues
Conclusion

- Data hiding and IDS codes to \textit{solve} synchronization issues
- \textit{Novel} perceptual mask
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- Data hiding and IDS codes to solve synchronization issues
- Novel perceptual mask
  - Low complexity
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- **Novel** perceptual mask
  - Low complexity
  - Good visual performance
Conclusion

- Data hiding and IDS codes to solve synchronization issues
- **Novel** perceptual mask
  - Low complexity
  - Good visual performance
- **Readily applicable** for forensic applications


