Side-Informed Steganography with Additive Distortion

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Side-Informed Steganography

P
RAW
high resolution
high bit depth
uncompressed

...
Side-Informed Steganography

\[ P \rightarrow T \rightarrow U \]

- Precover
- Resized grayscale
- DCT domain
- …

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\[ P \xrightarrow{T} U \xrightarrow{Q} X \]

- **P**: precovers
- **U**: unquantized cover
- **X**: quantized cover
- **e**: quantization error

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\[ P \xrightarrow{T} \text{quantized cover} \rightarrow \text{quantization error} \rightarrow \rho \]

- \( P \): precover
- \( T \): transformation
- \( U \): unquantized cover
- \( Q \): quantization
- \( X \): embedding costs
- \( \rho \): embedding costs
Side-Informed Steganography

- \( P \): precover
- \( U \): unquantized cover
- \( X \): quantized cover
- \( \rho \): embedding costs
- \( Y \): stego
- \( e \): quantization error

\[ P \xrightarrow{T} U \xrightarrow{Q} X \xrightarrow{\rho} Y \]
Side-Informed Steganography

- **P**: precover
- **U**: unquantized cover
- **X**: quantization error
- **Q**: quantized cover
- **Y**: stego
- **T**: embedding costs

**Diagram:**
- **P** → **T** → **U** → **Q** → **X** → **Y**
- **ρ**: embedding costs
- **e**: quantization error
Previous Art

GIF
Embedding-while-dithering [Fridrich, IHW 1999]

JPEG
Perturbed Quantization [Fridrich, ACM MMSec 2004]
MMEx [Kim, IHW 2006]
BCHopt [Sachnev, ACM MMSec 2009]
EBS [Wang, ICASSP 2012]
NPQ [Huang, ACM IH&MMSec 2013]
SI-UNIWARD [Holub, ACM IH&MMSec 2013]
UED [Guo, TIFS 2014]
UERD [Guo, TIFS 2015]
Embedding limited to **binary** operation
Either rounding as is or "to the other side"

Changing an element "to the other side"
has positive cost

**MMEx:**
\[ \rho_{ij} = 1 - 2|e_{ij}| \]

**BCHopt:** (simplified)
\[ \rho_{ij} = \left(q(1 - 2|e_{ij}|)/2\right)^2, \]
\[ q \text{ is the quantization step} \]

**SI-UNIWARD:**
\[ \rho_{ij} = (1 - 2|e_{ij}|)\rho_{ij}^{(J-UNIWARD)} \]
Proposed Method – Cost Modulation

Applicable to any additive stego scheme $A$ that uses costs $\rho_{ij}^{(A)}$

**Ternary** embedding instead of binary

**General** formula for modulating the costs

$$\rho_{ij} = (|U_{ij} - Y_{ij}| - |U_{ij} - X_{ij}|) \rho_{ij}^{(A)}$$

$$= \begin{cases} 
(1 - 2|e_{ij}|) \rho_{ij}^{(A)} & Y_{ij} = X_{ij} + \text{sign} (e_{ij}) \\
0 & Y_{ij} = X_{ij} \\
\rho_{ij}^{(A)} & Y_{ij} = X_{ij} - \text{sign} (e_{ij}) 
\end{cases}$$

$$[U_{ij}] + 1$$

$$U_{ij}$$

$$[U_{ij}] = X_{ij}$$

$$e_{ij}$$

$$[U_{ij}] - 1$$

$$U_{ij}$$

$$Y_{ij} = X_{ij} + \text{sign} (e_{ij})$$

$$Y_{ij} = X_{ij}$$

$$Y_{ij} = X_{ij} - \text{sign} (e_{ij})$$

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Costs extracted from the **unquantized** cover rather than the quantized cover.
Experimental Setup

Precover source:
BOSSBase v1.01 consisting of 10000 full resolution RAW image files

Unquantized covers:
Images converted using ufraw to RGB TIFF. All further processing was done in Matlab rather than ImageMagick.

Feature set:
Spatial Rich Model (dim 34671) [Fridrich, TIFS 2012]
J+SRM [Kodovský, SPIE 2012]

Classifier:
Ensemble of FLDs [Kodovský, TIFS 2012]

Performance measure:
Average out-of-bag error $\bar{E}_{OOB}$ (estimate of $P_E = \frac{1}{2} (P_{FA} + P_{MD})$)
SI and Processing Considered

**Spatial domain**
- HILL [Li, IEEE ICIP 2014]
- S-UNIWARD [Holub, EURASIP 2014]
- Resizing, Color Conversion, Quantization

**JPEG domain**
- J-UNIWARD [Holub, EURASIP 2014]
- JPEG Compression
Experiment 1 - Resizing

RAW
full-size
color

convert, gray

$P$
8 bit
crop, resize
(full-size
grayscale)
(Lanczos 3)

$U$
double

$512 \times 512$
grayscale

ufraw output: 24bit TIFF
Experiment 1 – Resizing (HILL)

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Experiment 1 – Resizing (S-UNIWARD)

![Graph showing payload vs. OOB error]
Resizing – Selection Channel

Last operation before quantizing: Resizing with Lanczos 3 in Matlab
Experiment 2 – Color Conversion

RAW full-size color

convert, crop

24 bit 512 × 512 color

0.2989R + 0.5870G + 0.1140B

double 512 × 512 grayscale

ufraw output: 24bit TIFF
Experiment 2 – Color Conversion (HILL)

![Graph showing payload vs. side information for original, binary, and ternary representations.]

- **Original**
- **Binary**
- **Ternary**
- **ρ from U**
Experiment 2 – Color Conversion (S-UNIWARD)

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Experiment 3 – Quantization

RAW
full-size
color

convert, gray, crop

16 bit
512 × 512
grayscale

quantize to 8 bit

double
512 × 512
grayscale

ufraw output: 48bit TIFF
Experiment 3 – Quantization (HILL)

Payload (bpp)

\[ \frac{E_{\text{OOB}}}{\rho} \]

- **original**
- **binary**
- **ternary**
- \( \rho \) from \( U \)

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Experiment 3 – Quantization (S-UNIWARD)

The graph shows the relationship between Payload (bpp) and \( \bar{E}_{OOB} \) for different quantization methods: original, binary, and ternary. The graph includes data points for \( \rho \) from the set \( U \).
Experiment 4 – JPEG Compression

RAW
full-size
color

convert, gray, crop, resize

P

DCT

8 bit
512 × 512
grayscale

double
512 × 512
grayscale

ufraw output: 24bit TIFF
Experiment 4 – JPEG Compression (J-UNIWARD, QF 75)

\[ \overline{E}_{\text{OOB}} \]

Payload (bpnzac)

0 0.1 0.2 0.3 0.4 0.5 0.6

\[ 0 0.2 0.4 \]

\[ \text{original} \]
\[ \text{binary} \]
\[ \text{ternary} \]
\[ \times \rho \text{ from } X \]
\[ \square \rho \text{ from } U \]
\[ \text{SI-UNI} \]
Conclusion

We present general steganographic method of using side-information for any domain any cost-based steganography any transformation with quantization

Improves on previous state-of-the-art by allowing ternary embedding (effective when quantization is fine) extracting the costs from the unquantized cover (effective when quantization is coarse)

Source codes available at dde.binghamton.edu/download