Steganalysis of LSB Matching Revisited for Consecutive Pixels Using B-Spline Functions

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Outline

LSBM, LSBMR, AND EALSBMR

- Least significant bit matching steganography (LSBM) is a tough target for steganalyzers.
  - The HCF COM method (proposed by Harmsen and Pearlman) and its descendants.
  - Universal steganalytic algorithms, including Shi 78-D, Farid 72-D, Moulin 156-D, and Li 110-D.
  - No detectors have yet proven universally reliable.
- Using a pair of pixels as an embedding unit, the least significant bit matching revisited algorithm (LSBMR) dramatically reduces modification rate when the payload holds.
- The edge adaptive image steganography based on LSB matching revisited (EALSBMR) is one of the recent important achievements in this field.

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Overview of LSBMR for Consecutive Pixels

LSBMRCP: one of the LSBMR pixel pair selection schemes adopted by EALSBMR.

LSBMRCP embedding procedure

- Cover image $\Rightarrow$ a serial **I** of embedding units (x_i, x_{i+1}).
- Secret message $\Rightarrow$ a serial **M** of bits (m_i, m_{i+1}).
- After message embedding, (x_i, x_{i+1}) is modified as (x'_i, x'_{i+1}).
  - $m_i = \mathrm{LSB}(x'_i)$.
  - $m_{i+1} = f(x'_i, x'_{i+1}) = \mathrm{LSB}(\lfloor x'_i/2 \rfloor + x'_{i+1})$.
- both an increase and a decrease of x_i or x_{i+1} by one will change the value of $f(x'_i, x'_{i+1})$.

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LSBMR embedding algorithm for a pixel pair

if $m_i = \mathrm{LSB}(x_i)$ **then** ▷ x_i remains untouched
  if $m_{i+1} \neq f(x_i, x_{i+1})$ **then**
    $x'_{i+1} = x_{i+1} \pm 1$ ▷ x_{i+1} is modified
  else
    $x'_{i+1} = x_{i+1}$ ▷ x_{i+1} remains untouched
  end if
  $x'_i = x_i$
else ▷ x_i is modified
  if $m_{i+1} = f(x_i - 1, x_{i+1})$ **then**
    $x'_i = x_i - 1$
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Overview of EALSBMR

- EALSBMR is a region adaptive spatial domain LSB steganography.
- It uses the absolute difference between two adjacent pixels as the criterion for region selection, and adopt LSBMRCP as the data hiding algorithm.
- Decision of threshold T:
  - $EU(t) = \{(x_i, x_{i+1}) \mid |x_i - x_{i+1}| \geq t, \forall (x_i, x_{i+1}) \in V\}$
  - $T = \text{argmax}_t \{2 \times |EU(t)| \geq |M|\}$
- Cover image is first divided into blocks. Block size $Bz \in \{1, 4, 8, 12\}$. When $Bz > 1$, blocks are rotated with a random degree in the range of $\{0, 90, 180, 270\}$ in order to improve the security.

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Effect of LSBMRCP embedding

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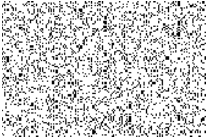
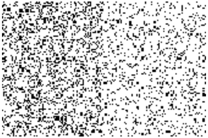
Effect of LSBMRCP embedding

An illustration of the imbalance

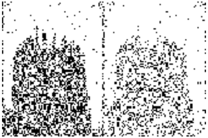


(a)



(b)

(c)



(d)

Steganalysis using B-spline Functions

- Data embedding $\Leftrightarrow$ add additive noise to the cover image. The more pixels get modified, the more the power of the additive stegonoise is added to the cover image.
- The power of the stegonoise in $\{x_i\}$ should be larger than that in $\{x_{i+1}\}$.
- For a given stegonoise series $\{\varepsilon_i\}$, its power is defined as its $\mathscr{L}^2$ norm:

$$\mathcal{IF} \triangleq \|\{\varepsilon_i\}\| = (\sum_{i=0}^{n}(\varepsilon_i^2))^{\frac{1}{2}}$$

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- But, how to get the good estimation of the stegonoise series for $\{x_i\}$ and $\{x_{i+1}\}$?

Steganalysis using B-spline Functions

- For a given suspected stego image, good estimation of the stegonoise series $\Rightarrow$ good estimation of the original pixel series from the suspected stego one.
- Let the approximation of the original pixel series be a polynomial spline which can be constructed from a weighted sum of shifted B-splines.
- The polynomial spline establishes a sort of compromise between approximation and smoothness, which is controlled by an intuitive parameter S and can be calibrated depending on the variance of stegonoise σ^2.

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- The polynomial spline establishes a sort of compromise between approximation and smoothness, which is controlled by an intuitive parameter S and can be calibrated depending on the variance of stegonoise σ^2.
- Unfortunately, the theoretical calibration formula is infeasible in practice. But we put forward a computable approximation.

Steganalytic Feature

- The power of the noise introduced during the image capture and post-processing procedure is usually distributed evenly over the spatial domain. Cover image: $\mathcal{IF}_1 \approx \mathcal{IF}_2$.
- Stego image generated by LSBMRCP: $\mathcal{IF}_1 > \mathcal{IF}_2$.

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Discriminator for the presence of LSBMRCP steganography

$$\begin{array}{ll} \mathcal{IF}_1/\mathcal{IF}_2 \approx 1 & \text{for a cover image}, \\ \mathcal{IF}_1/\mathcal{IF}_2 > 1 & \text{for a LSBMRCP stego image}. \end{array}$$

Estimation of Embedding Rate

- When calculating $\mathcal{IF}_1$ and $\mathcal{IF}_2$, embedding rate $\nearrow \Rightarrow \sigma^2 \nearrow \Rightarrow S \nearrow$.
- Suppose the result smoothing B-spline based on S_c represents the original cover image.
- Given a LSBMR stego image, calculate $\mathcal{IF}_1/\mathcal{IF}_2$ using a progressively increasing S which starts from 0.
  - $S < S_c$, the result spline still contains stegonoise, $\mathcal{IF}_1 > \mathcal{IF}_2$.
  - $S > S_c$, $\mathcal{IF}_1 \approx \mathcal{IF}_2$.
- The critical point S_c lies in the interval in which the value of $\mathcal{IF}_1/\mathcal{IF}_2$ falls from larger than 1 to approximately equal to 1.
- $S_c \Rightarrow \sigma^2 \Rightarrow$ the estimation of embedding rate.

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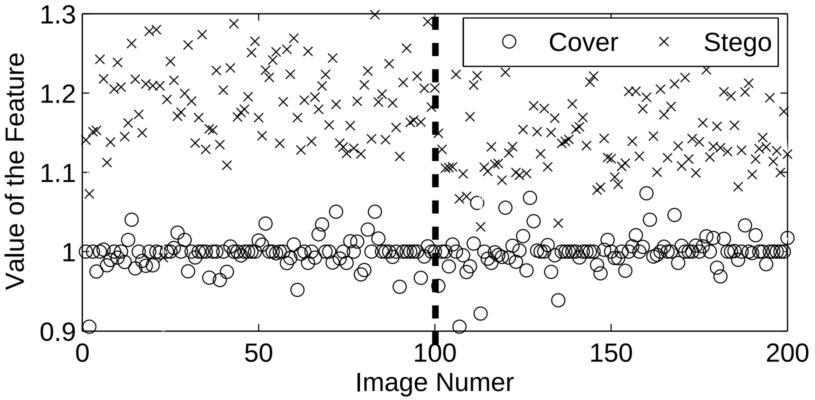
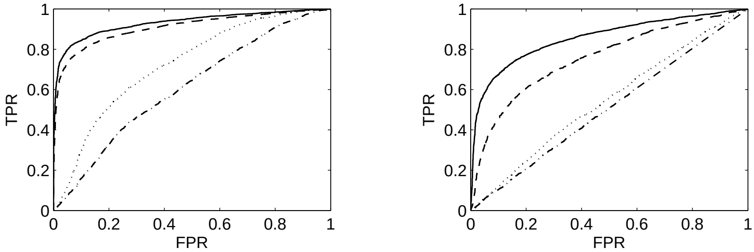
Plot of Steganalytic features

Steganalytic features of 200 cover images and the corresponding LSBMRCP stego images (Left half, with 50% embedding rate), and EALSBMR stego images (Right half, with 50% embedding rate, *Bz*=1).



Comparisons of ROC curves

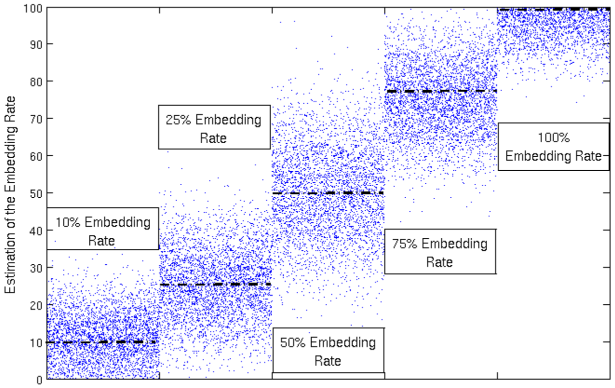
The different curves stand for: our proposed method against LSBMRCP (solid), and EALSBMR ($Bz = 1$) (dashed); Li-1D against LSBMRCP (dotted), and EALSBMR ($Bz = 1$) (dash-dot). (a) 50% embedding rate. (b) 25% embedding rate.



(a) (b)

Estimation of embedding rate

Estimated value of the embedding rate for LSBMRCP stego images with embedding rate of 10%, 25%, 50%, 75% and 100%.



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- Our method CAN NOT attack EALSBMR with $Bz > 1$.

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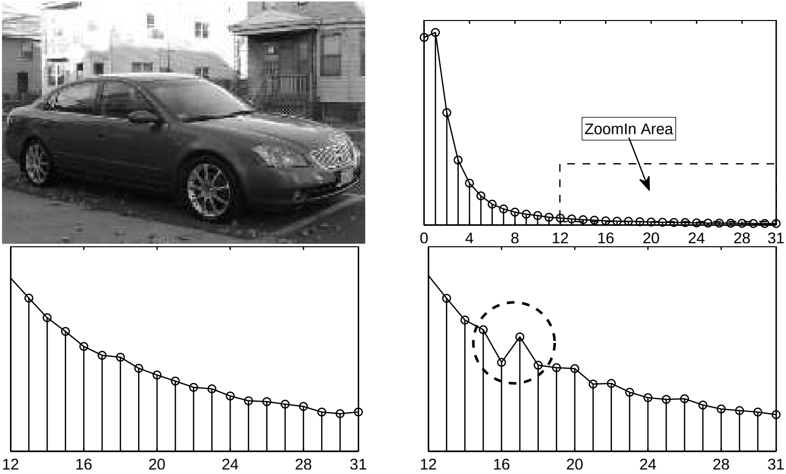
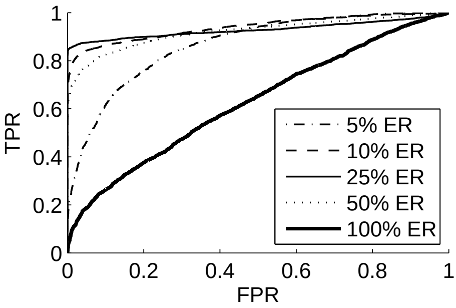
Steganalysis of EALSBMR using B-spline fitting

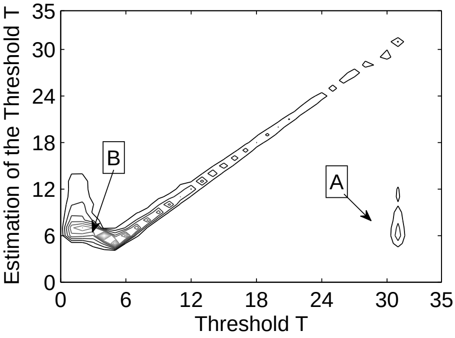


Steganalysis of EALSBMR using B-spline fitting

Comparison of ROC curves:



The contour graph of the number of the EALSBMR stego images:



⋆ Has been submitted to IEEE Signal Processing Letters. ⋆

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Future work

- "The embedding units located at the sharper regions have better hiding characteristics than those at the smoother/flat regions." $\Rightarrow$ "make full use of the sharper edges in a cover image as far as possible".
- Is it a good steganographic scheme? $\Rightarrow$ target steganalysis of existing edge adaptive steganographic methods.
- Most steganographic/steganalytic algorithms are derived within a purely discrete framework. Can we do some research in this field based on a real-valued picture function defined over the real plane $\mathbf{R}^2$?

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    - Application of B-spline technology in steganalysis.
    - Steganalytic algorithm derived directly from a real-valued picture function.

The End

Q & A