Some Significant Steganalysis Algorithms

LSB Embedding and the Histogram Attack

Giving a relative message length $q = m/n$:

$$
\begin{aligned}
E\{\mathbf{T}_s[2i]\} &= (1 - \frac{q}{2})\mathbf{T}_c[2i] + \frac{q}{2}\mathbf{T}_c[2i+1] \\
E\{\mathbf{T}_s[2i+1]\} &= \frac{q}{2}\mathbf{T}_c[2i] + (1 - \frac{q}{2})\mathbf{T}_c[2i+1].
\end{aligned}
$$

- Ineffective for random work embedding.

Sample Pairs Analysis

A very clever method!

- Use spatial correlation within images.
- More reliable and accurate.

Basic Idea

Giving a sequence of values $s_1, s_2, \cdots, s_n$.

- All adjacent pairs
  $\mathcal{P} = \{(u, v) = (s_i, s_{i+1}), 1 \leq i \leq n\}$.

$$(s_1, s_2), (s_2, s_3), \cdots, (s_{n-1}, s_n).$$

- Partition of $\mathcal{P}$:

	$v\%2 = 0$	$v\%2 = 1$
$u = v$	$\mathcal{Z}$	$\mathcal{Z}$
$u < v$	$\mathcal{X}$	$\mathcal{Y}$
$u > v$	$\mathcal{Y}$	$\mathcal{X}$

Partition of $\mathcal{P}$

Continue partitioning $\mathcal{Y}$ into $\mathcal{W}, \mathcal{V}$.

- $\mathcal{W}$: A small subset of $\mathcal{Y}$.

  $\{(u = 2k, v = 2k+1) \vee (u = 2k+1, v = 2k), k \in \mathbb{Z}\}.$

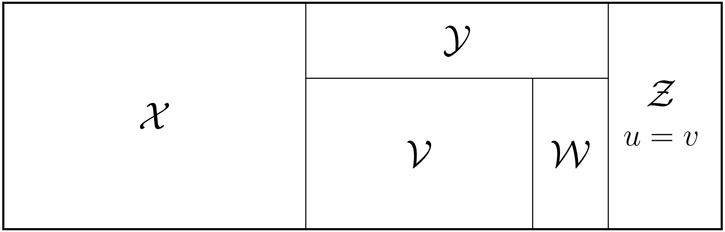
  or

  $$|u - v| = 1.$$

- $\mathcal{V} = \mathcal{Y} - \mathcal{W}$.

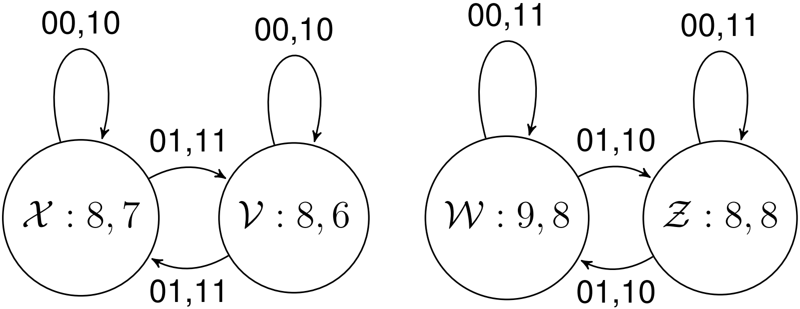
The bin of LSB: $\mathcal{W} + \mathcal{Z}$.

Partition of $\mathcal{P}$



A Finite State Machine

The **modification** patterns $\pi \in \{00, 01, 10, 11\}$ here (0 for unchanged) are not messages.

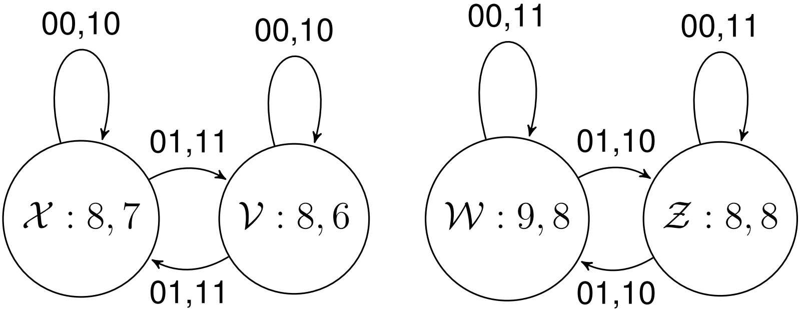


Transition Probability

Giving relative message length q, expectation of modification (i.e. 1) is $q/2$:

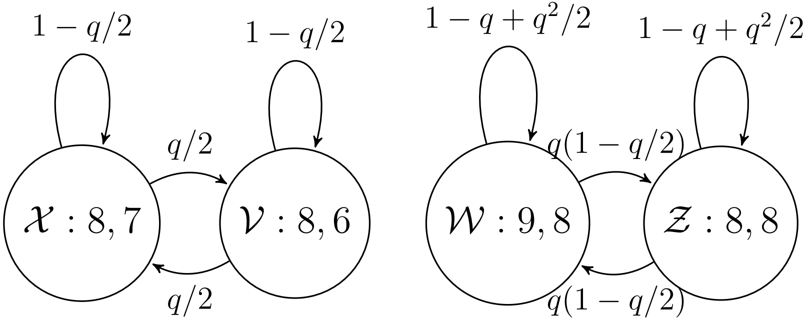
$$\rho(00,\mathcal{P}) = \left(1-\frac{q}{2}\right)^2$$
$$\rho(01,\mathcal{P}) = \rho(10,\mathcal{P}) = \frac{q}{2}\left(1-\frac{q}{2}\right)$$
$$\rho(11,\mathcal{P}) = \left(\frac{q}{2}\right)^2.$$

Put Them Together



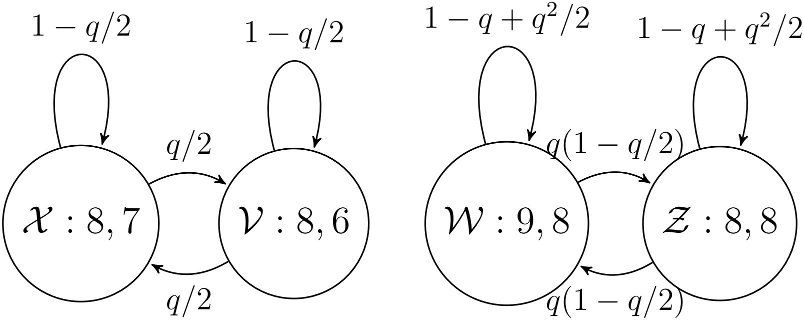
$$
\begin{aligned}
\rho(00, \mathcal{P}) &= \left(1 - \frac{q}{2}\right)^2 \\
\rho(01, \mathcal{P}) &= \frac{q}{2}\left(1 - \frac{q}{2}\right) \\
\rho(10, \mathcal{P}) &= \frac{q}{2}\left(1 - \frac{q}{2}\right) \\
\rho(11, \mathcal{P}) &= \left(\frac{q}{2}\right)^2
\end{aligned}
\Rightarrow
\begin{cases}
00, 10: & \rho_{00} + \rho_{10} = 1 - q/2 \\
01, 11: & \rho_{01} + \rho_{11} = q/2 \\
00, 11: & \rho_{00} + \rho_{11} = 1 - q + q^2/2 \\
01, 10: & \rho_{01} + \rho_{10} = q(1 - q/2)
\end{cases}
$$

Put Them Together



$$
\begin{aligned}
\rho(00,\mathcal{P}) &= \left(1-\frac{q}{2}\right)^2 \\
\rho(01,\mathcal{P}) &= \frac{q}{2}\left(1-\frac{q}{2}\right) \\
\rho(10,\mathcal{P}) &= \frac{q}{2}\left(1-\frac{q}{2}\right) \\
\rho(11,\mathcal{P}) &= \left(\frac{q}{2}\right)^2
\end{aligned}
\Rightarrow
\begin{cases}
00,10: & \rho_{00}+\rho_{10} = 1-q/2 \\
01,11: & \rho_{01}+\rho_{11} = q/2 \\
00,11: & \rho_{00}+\rho_{11} = 1-q+q^2/2 \\
01,10: & \rho_{01}+\rho_{10} = q(1-q/2)
\end{cases}
$$

Put Them Together



Count in and out:

$$
\begin{aligned}
|\mathcal{X}'| &= |\mathcal{X}|(1 - q/2) + |\mathcal{V}|q/2 \\
|\mathcal{V}'| &= |\mathcal{V}|(1 - q/2) + |\mathcal{X}|q/2 \\
|\mathcal{W}'| &= |\mathcal{W}|(1 - q + q^2/2) + |\mathcal{Z}|q(1 - q/2).
\end{aligned}
$$

Some Math

To solve q, we have equalities

$$\begin{aligned}
|\mathcal{X}'| &= |\mathcal{X}|(1 - q/2) + |\mathcal{V}|q/2 \\
|\mathcal{V}'| &= |\mathcal{V}|(1 - q/2) + |\mathcal{X}|q/2
\end{aligned}$$

$$\Rightarrow$$

$$\begin{aligned}
|\mathcal{X}'| - |\mathcal{V}'| &= (|\mathcal{X}| - |\mathcal{V}|)(1 - q) \\
&= |\mathcal{W}|(1 - q) \qquad \textbf{Assume } |\mathcal{X}| = |\mathcal{Y}| \\
|\mathcal{W}'| &= |\mathcal{W}|(1 - q + q^2/2) + |\mathcal{Z}|q(1 - q/2) \\
&= |\mathcal{W}|(1 - q)^2 + (|\mathcal{W}| + |\mathcal{Z}|)q(1 - q/2) \\
&= |\mathcal{W}|(1 - q)^2 + \gamma q(1 - q/2) \\
&= (|\mathcal{X}'| - |\mathcal{V}'|)(1 - q) + \gamma q(1 - q/2)
\end{aligned}$$

Continue

Because $|\mathcal{W}'| = |\mathcal{P}| - |\mathcal{X}'| - |\mathcal{V}'| - |\mathcal{Z}'|$:

$$
\begin{aligned}
&|\mathcal{P}| - |\mathcal{X}'| - |\mathcal{V}'| - |\mathcal{Z}'| = \\
&\quad (|\mathcal{X}'| - |\mathcal{V}'|)(1 - q) + \gamma q(1 - q/2) \\
&\frac{\gamma}{2} q^2 + (|\mathcal{P}| - |\mathcal{X}'| - |\mathcal{V}'| - |\mathcal{Z}'|) = \\
&\quad (|\mathcal{X}'| - |\mathcal{V}'|) - (|\mathcal{X}'| - |\mathcal{V}'|)q + \gamma q \\
&\frac{\gamma}{2} q^2 + (|\mathcal{P}| - 2|\mathcal{X}'| - |\mathcal{Z}'|) = \\
&\quad - (|\mathcal{X}'| - |\mathcal{V}'| - \gamma)q \\
&\frac{\gamma}{2} q^2 + (|\mathcal{X}'| - |\mathcal{V}'| - \gamma)q + (|\mathcal{P}| - 2|\mathcal{X}'| - |\mathcal{Z}'|) = 0.
\end{aligned}
$$

More Compacted Form

$$
\begin{aligned}
0 &= \frac{\gamma}{2}q^2 + (|\mathcal{X}'| - |\mathcal{V}'| - \gamma)q + (|\mathcal{P}| - 2|\mathcal{X}'| - |\mathcal{Z}'|) \\
&= \frac{\gamma}{2}q^2 + (|\mathcal{X}'| - |\mathcal{V}'| - |\mathcal{W}'| - |\mathcal{Z}'|)q \\
&\qquad + (|\mathcal{X}'| + |\mathcal{Y}'| + |\mathcal{Z}'| - 2|\mathcal{X}'| - |\mathcal{Z}'|) \\
&= \frac{\gamma}{2}q^2 + (2|\mathcal{X}'| - |\mathcal{P}|)q + (|\mathcal{Y}'| - |\mathcal{X}'|).
\end{aligned}
$$

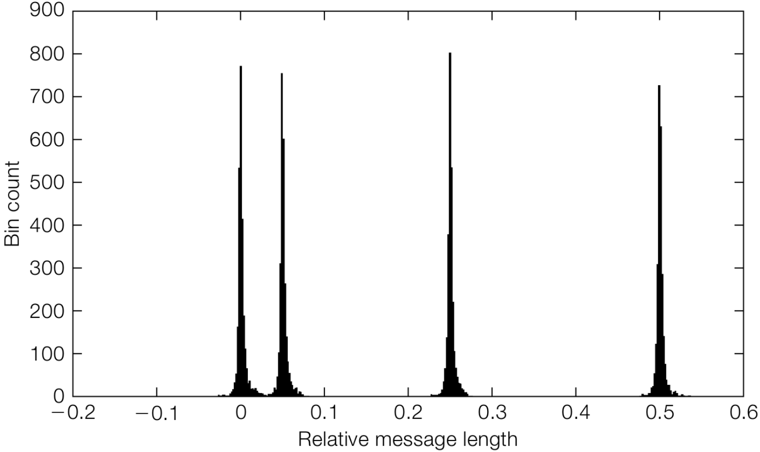
The Solution

- $\gamma = |\mathcal{W}| + |\mathcal{Z}| = |\mathcal{W}'| + |\mathcal{Z}'|$.
- If $\gamma = 0$, $|\mathcal{X}| = |\mathcal{X}'| = |\mathcal{Y}| = |\mathcal{Y}'| = |\mathcal{P}|/2$.

$$0q^2 + 0q + 0 = 0.$$

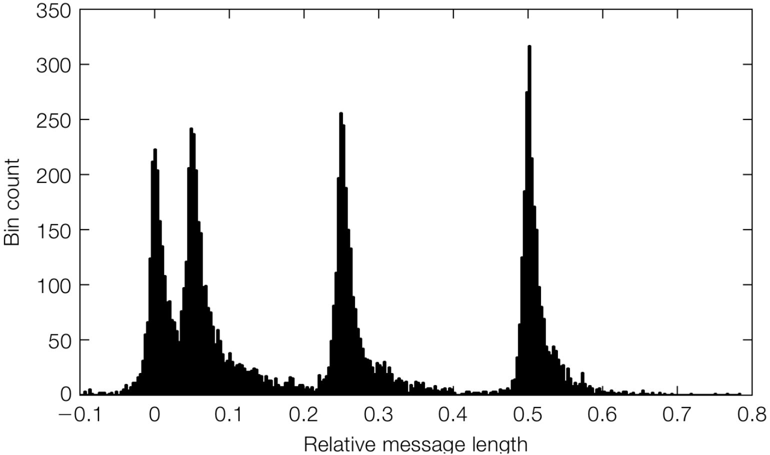
- If two complex conjugate roots:
  - Taking the real parts.
- If has a negative root:
  - $p = 0$.

JPEG



$$q = 0.05, 0.2, 0.5.$$

Raw Scan



$$q = 0.05, 0.2, 0.5.$$

Analysis

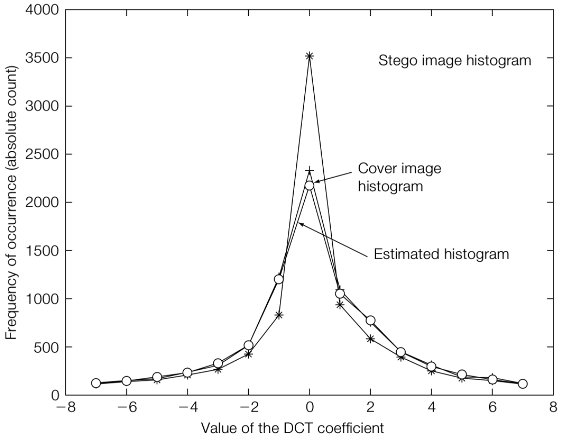
- Noisy has negative influence.
- Estimation for short message is not robust.
- Sample
  - Local is better
  - Thus neighboring pairs.

Extension

- One point: histogram
- Sample pairs.
- Sample more: 2×2 neighboring pixels.

Blind Steganalysis Using Calibration

- Shift 4 pixels and re-compress.



In General

$$f_i = \|F_i(J_1) - F_i(J_2)\|.$$

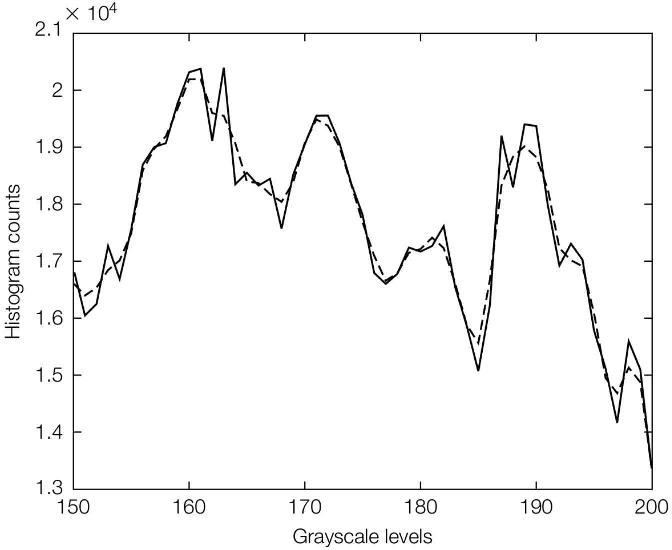
- J_1: stego JPEG image.
- J_2: shift and re-compress stego JPEG image.
- Find efficient F_i or training.

In Spatial Domain

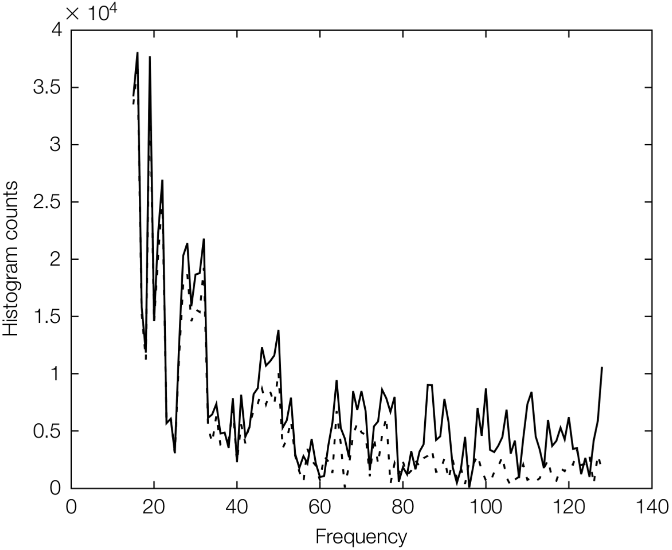
Just using different feature.

- Steganographic method: adding noise.
- Smooth the work a little bit and check the difference.

Illustration



Illustration



A Basic Method

Compute the noise residual from a smoother F:

$$\mathbf{r} = \mathbf{s} - F(\mathbf{s}).$$

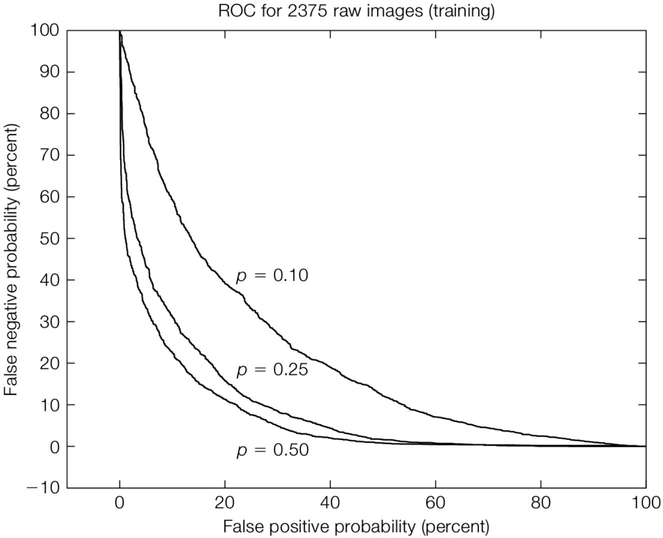
Then use $k = 1, 2, \cdots$ moments as the feature:

$$\mu_k = \sum (\mathbf{r} - \bar{\mathbf{r}})^k.$$

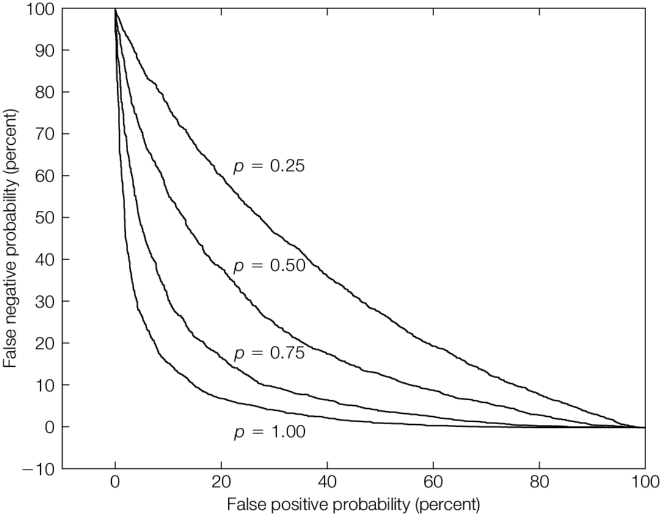
Classification via Fisher linear discriminant.

More details in the book.

Raw Digital Camera

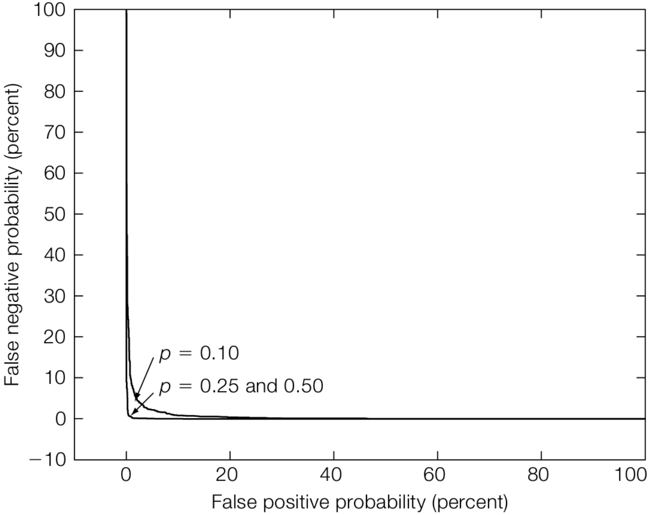


Raw Scans



100
90
80
70
60
50
40
30
20
10
0
−10
False negative probability (percent)
p = 0.25
p = 0.50
p = 0.75
p = 1.00
0
20
40
60
80
100
False positive probability (percent)

JPEG



100
90
80
70
60
50
40
30
20
10
0
−10
0
20
40
60
80
100
False negative probability (percent)
False positive probability (percent)
p = 0.10
p = 0.25 and 0.50

Analysis

- Noise!
  - It is better to pick noise image as the cover for steganography.

Presentation: Project F3+F4

Steganography system: F3+F4

The key points

- Show the DCT coefficients histogram.
- Difference between Digital watermarking and Steganography.

Presentation: Project F5

Steganography system: F5

The key points

- Analysis of the embedding efficiency of different matrix encoding.
  - the number of modification bits.
- Impact of random walk.