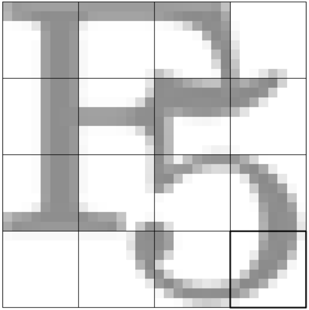
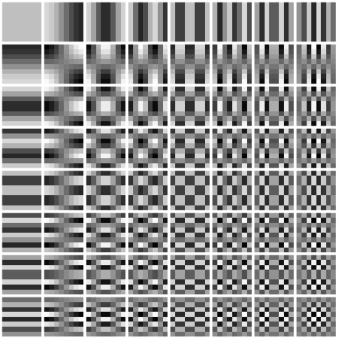
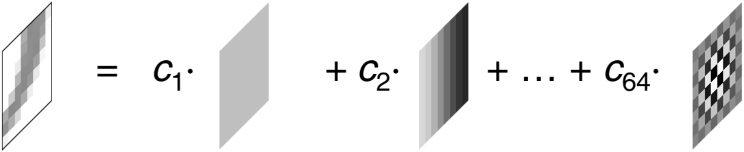
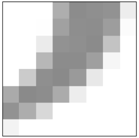
DCT Coefficients





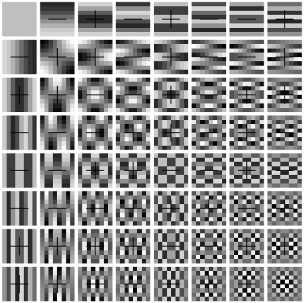


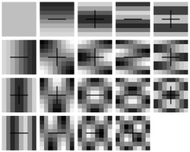
DCT Compression

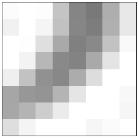


64 brightness values

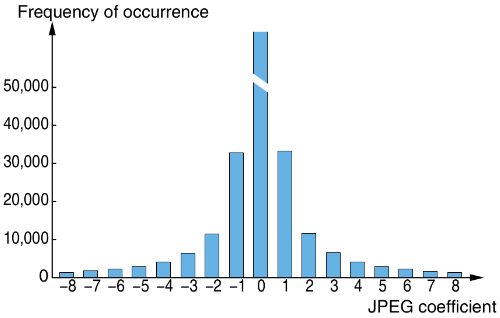
➽ 19 nonzero JPEG coefficients







DCT Characteristic Properties



$$P(X=1) > P(X=2) > P(X=3) > P(X=4)$$

$$P(X=1)-P(X=2) > P(X=2)-P(X=3) > P(X=3)-P(X=4)$$

Model-Based Steganography

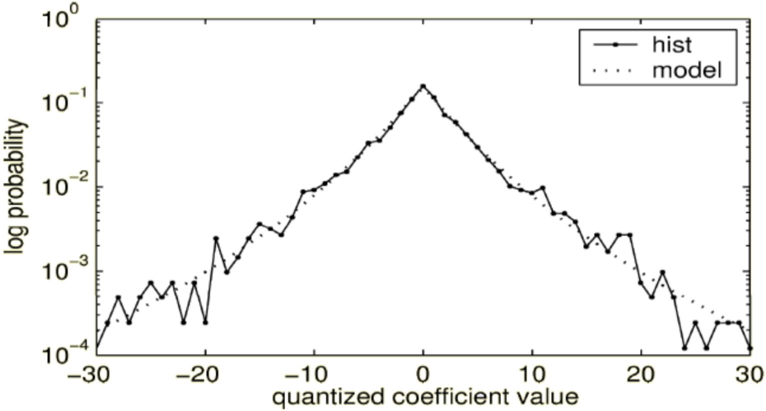
Generalized Cauchy model with probability density function (pdf)

- Generalized Cauchy distribution (GCD):

$$P(x) = \frac{p-1}{2s}\left|\frac{|x|}{s}+1\right|^{-p}.$$

- $p > 1, s > 0$ are the two parameters.

Illustration of GCD



Two-Class Pattern Classification

Two components in a cover work (c_{inv}, c_{emb}):

$$\begin{aligned} p_0 &= P(c_{emb} = 0 | c_{inv} = MSB_7(2i)) \\ &= \frac{T_c[2i]}{T_c[2i] + T_c[2i+1]} \\ &= 1 - P(c_{emb} = 1 | c_{inv} = MSB_7(2i)). \end{aligned}$$

The probability of $2i$ in the bin $(2i, 2i+1)$.

Arithmetic Decompress and Compress

Map a uniformly distributed bitstream to a new bitstream with specific distribution.
Presentation: Arithmetic Coding

- `http://en.wikipedia.org/wiki/Arithmetic_coding`
- `http://www.cs.cmu.edu/~aarti/Class/10704/Intro_Arith_coding.pdf`

Reverse Compression

- In embedding:

  uniformly distributed bitstream
  $\xrightarrow{\text{Decompress}}$
  GCD distributed bitstream

- In detection:

  GCD distributed bitstream
  $\xrightarrow{\text{Compress}}$
  uniformly distributed bitstream

Embedding Efficiency

The average number of embedded bits per unit distortion.

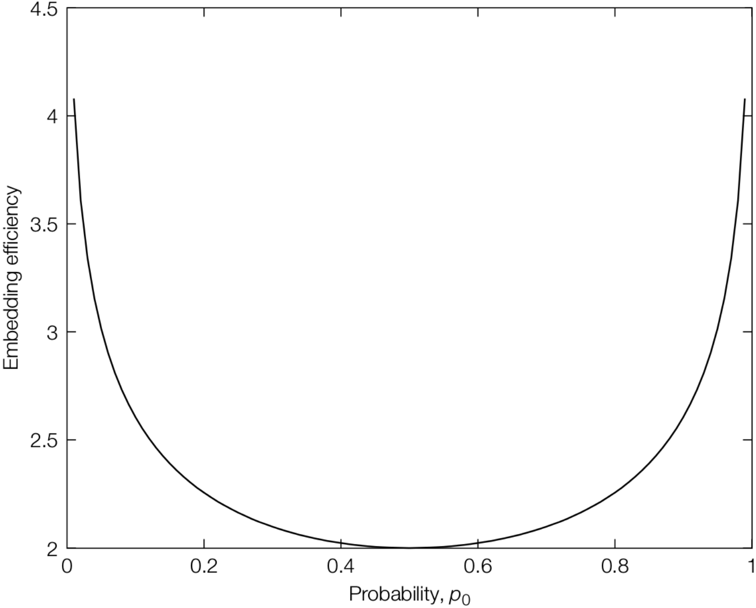
- LSB: $2 = 1/0.5$.
  - 1 bit: for a uniform distribution binary sequence.
  - Change: 50% of chance to change.
  - Efficiency:
$$\frac{1}{0.5}.$$

Embedding Efficiency

The average number of embedded bits per unit distortion.

- LSB: $2 = 1/0.5$.
- Model Based:
  - Information:
    $$H(p_0) = -p_0 \log_2 p_0 - (1-p_0)\log(1-p_0).$$
  - Change:
    $$p_0(1-p_0) + (1-p_0)p_0 = 2p_0(1-p_0).$$
  - Efficiency:
    $$\frac{-p_0 \log_2 p_0 - (1-p_0)\log(1-p_0)}{2p_0(1-p_0)}.$$

Illustration

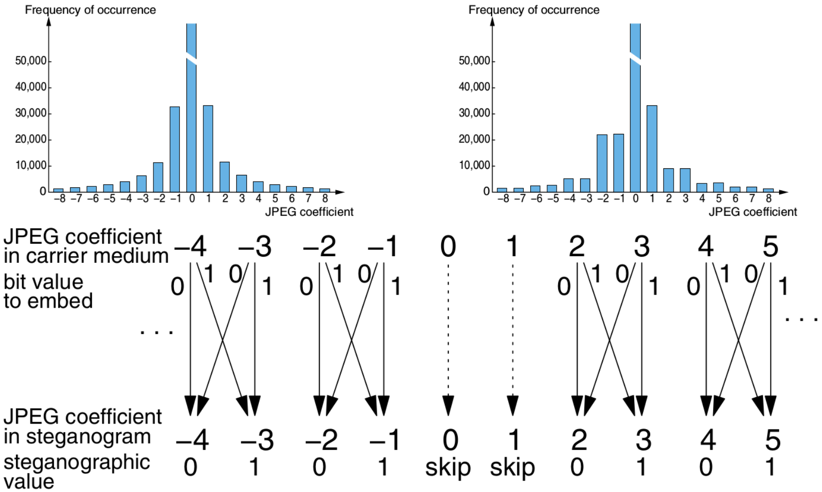


The Cost of Correction

Losing capacity.

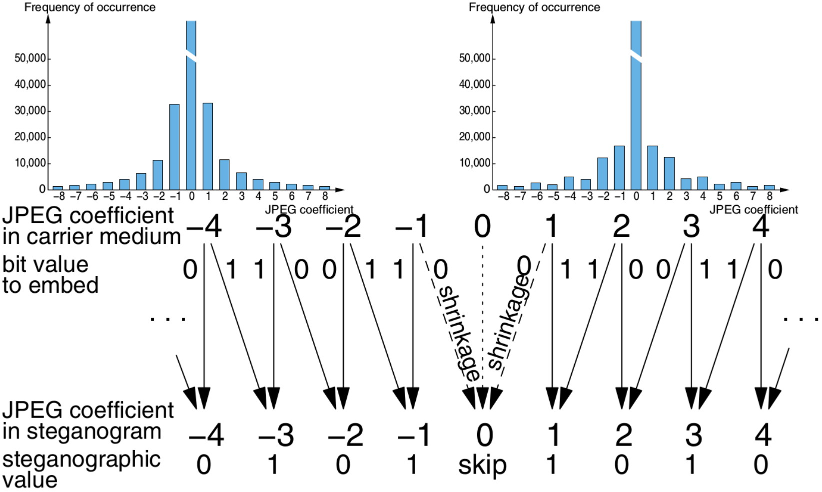
- F3, F4, F5, ...

Jsteg

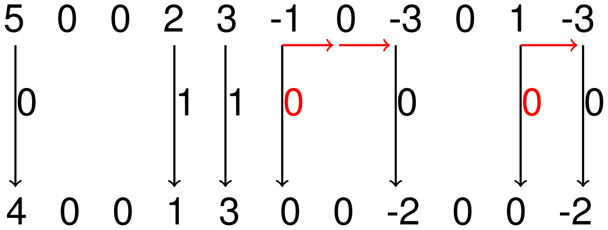


Frequency of occurrence
50,000
40,000
30,000
20,000
10,000
0
−8 −7 −6 −5 −4 −3 −2 −1 0 1 2 3 4 5 6 7 8
JPEG coefficient
Frequency of occurrence
50,000
40,000
30,000
20,000
10,000
0
−8 −7 −6 −5 −4 −3 −2 −1 0 1 2 3 4 5 6 7 8
JPEG coefficient
JPEG coefficient in carrier medium
−4 −3 −2 −1 0 1 2 3 4 5
bit value to embed
0 1 0 1 0 1 0 1 0 1 0 1 0 1 0 1
. . .
. . .
JPEG coefficient in steganogram
−4 −3 −2 −1 0 1 2 3 4 5
steganographic value
0 1 0 1 skip skip 0 1 0 1

F3


Frequency of occurrence
50,000
40,000
30,000
20,000
10,000
0
−8 −7 −6 −5 −4 −3 −2 −1 0 1 2 3 4 5 6 7 8
JPEG coefficient
Frequency of occurrence
50,000
40,000
30,000
20,000
10,000
0
−8 −7 −6 −5 −4 −3 −2 −1 0 1 2 3 4 5 6 7 8
JPEG coefficient
JPEG coefficient in carrier medium
−4 −3 −2 −1 0 1 2 3 4
bit value to embed
0 1 1 0 0 1 1 0 0 1 1 0 0 1 1 0
shrinkage
shrinkage
. . .
. . .
JPEG coefficient in steganogram
−4 −3 −2 −1 0 1 2 3 4
steganographic value
0 1 0 1 skip 1 0 1 0

F3 Algorithm



Embedding 01100.

What Is the Problem in F3?

In normal work

- Decreasing

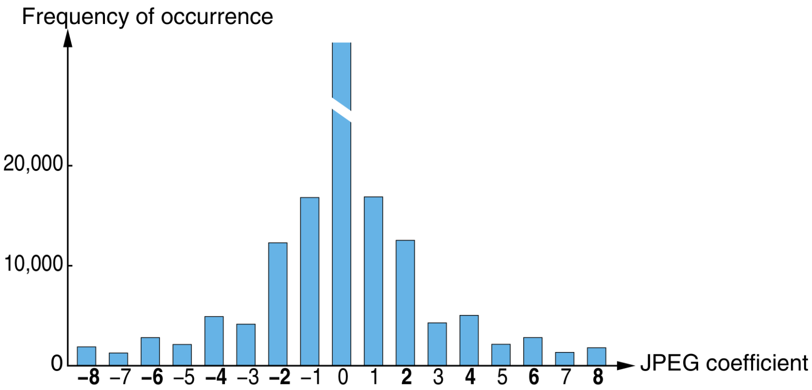
$$P(2i-1) > P(2i).$$

In Steganographic work

- More on even.

$$P(2i-1) < P(2i).$$

Defects of F3

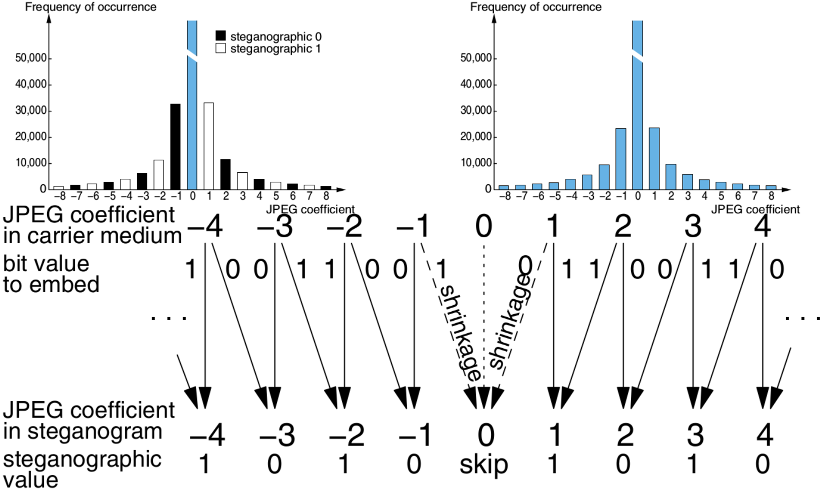


Reason

Repeated embedding after shrinkage.

- Happens for embedding 0 only.
- Equivalent to add more 0 into the message code.

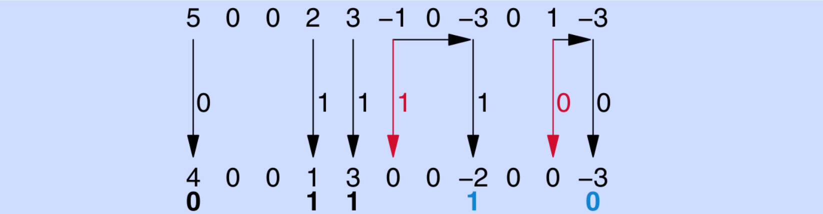
F4



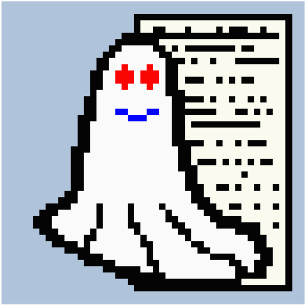
Frequency of occurrence
steganographic 0
steganographic 1
50,000
40,000
30,000
20,000
10,000
0
−8 −7 −6 −5 −4 −3 −2 −1 0 1 2 3 4 5 6 7 8
JPEG coefficient
Frequency of occurrence
50,000
40,000
30,000
20,000
10,000
0
−8 −7 −6 −5 −4 −3 −2 −1 0 1 2 3 4 5 6 7 8
JPEG coefficient
JPEG coefficient in carrier medium
−4 −3 −2 −1 0 1 2 3 4
bit value to embed
1 0 0 1 1 0 0 1 0 1 1 0 0 1 1 0
shrinkage
shrinkage
. . .
. . .
JPEG coefficient in steganogram
−4 −3 −2 −1 0 1 2 3 4
steganographic value
1 0 1 0 skip 1 0 1 0

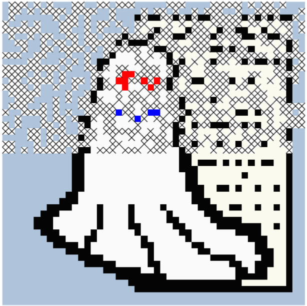
F4 Algorithm

- Steganographic interpretation
  - Positive coefficients: LSB
  - Negative coefficients: inverted LSB
- Skip 0, adjust coefficients to message bit
  - Decrement positive coefficients
  - Increment negative coefficients
  - Repeat if shrinkage occurs



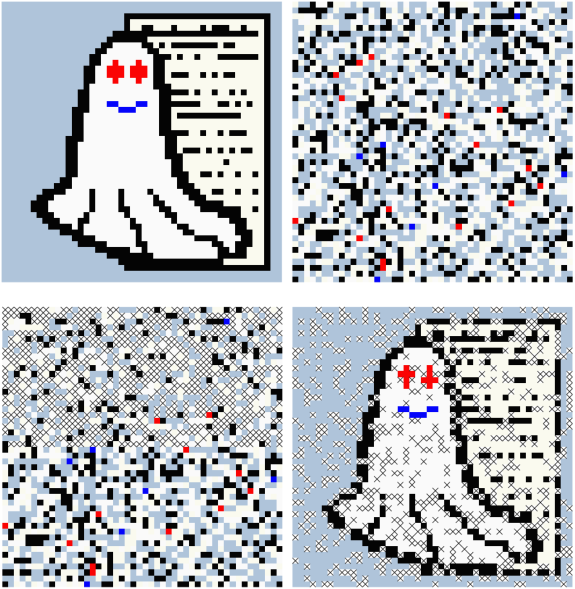
F4 Defects





Compare similar blocks or reverse fitting GCD.

Random Walk



More Payload?

Example: Embedding 1736 bits

- F4: 1157 changes.
- F5: 459 changes by matrix encoding.
  - Embedding efficiency: 3.8 bits per change.

Matrix Encoding

Embedding b_1, b_2 to x_1, x_2, x_3 with at most 1 change.

$$b_1 = LSB(x_1) \text{ XOR } LSB(x_2)$$
$$b_2 = LSB(x_2) \text{ XOR } LSB(x_3)$$

- Four equal probability cases.
- Change x_i accordingly.

Example

$$b_1 = LSB(x_1) \text{ XOR } LSB(x_2)$$
$$b_2 = LSB(x_2) \text{ XOR } LSB(x_3)$$

0,0	1,0	0,1	1,1
/	$\bar{x}_1$	$\bar{x}_3$	$\bar{x}_2$

Efficiency:

$$2/(3/4) = 8/3 > 2.$$

A Hamming Code

$$\begin{pmatrix} 1 & 1 & 0 \\ 0 & 1 & 1 \end{pmatrix}$$

Presentation: Matrix Embedding

- The idea of parity matrix.
- Efficiency.