Writing on Wet Paper

- Cover image (paper) x: has wet region.
- Only allowed to slightly modify the dry part.
- The received image (paper) y drys.
- Where the message is written?

An Equivalent Well-Known Problem

In information theory: writing in memory with defective cells.

- Writer known the location of stuck cells.
- Reader do not know that.
- How to correctly read that?
- How to write as many bits as possible?

A special case of the Gel'fand-Pinsker channel.

The Idea, Matrix Embedding Again!

Message $\mathbf{m} \in \{0,1\}^m$ in $y \in \mathbb{Z}^n$ via a shared parity matrix $\mathbf{D} \in \{0,1\}^{m \times n}$:

$$\mathbf{D}_{m \times n} \mathbf{y}_{n \times 1} = \mathbf{m}_{m \times 1}.$$

XOR is addition modulo 2.

$$\begin{pmatrix} 1 & 1 & 0 \\ 0 & 1 & 1 \end{pmatrix} \begin{pmatrix} 16 \\ 69 \\ 35 \end{pmatrix} = \begin{pmatrix} 1 \\ 0 \end{pmatrix}.$$

Wet Paper

In $\mathbf{x}$, we only change part of it.

- Dry part: $\mathbf{x}[j], j \in \mathcal{J} \subset \{1, \cdots, n\}$.
  - Can be changed.
- Wet part: $\mathbf{x}[j], j \notin \mathcal{J}$.
  - Cannot be changed, i.e. fixed.

Thus the change $\mathbf{v} = \mathbf{y} - \mathbf{x}$ has the property:

$$\mathbf{v}[j] = 0, j \notin \mathcal{J}.$$

A Constrained Equation

Under the constraints:

$$\mathbf{v}[j] = 0, j \notin \mathcal{J}.$$

Solving the following equation.

$$\begin{aligned} \mathbf{D}\mathbf{y} &= \mathbf{m} \\ \mathbf{D}(\mathbf{x} + \mathbf{v}) &= \mathbf{m} \\ \mathbf{D}\mathbf{v} &= \mathbf{m} - \mathbf{D}\mathbf{x}. \end{aligned}$$

Removing the Known Values

Using a permutation matrix $\mathbf{P}$ to sort fixed $\mathbf{v}[j]$ to the end.

$$\mathbf{Pv} = \begin{pmatrix} u_1 \\ u_2 \\ \vdots \\ u_{|\mathcal{I}|} \\ 0 \\ \vdots \\ 0 \end{pmatrix} = \begin{pmatrix} \mathbf{u} \\ 0 \end{pmatrix}$$

Continue

$$\mathbf{Dv} = \mathbf{m} - \mathbf{Dx} = \mathbf{z}$$

$$(\mathbf{DP}^{-1})(\mathbf{Pv}) = \mathbf{z}$$

$$\begin{pmatrix} \mathbf{H} & \mathbf{K} \end{pmatrix} \begin{pmatrix} \mathbf{u} \\ 0 \end{pmatrix} = \mathbf{z}$$

$$\mathbf{H}_{m \times |\mathcal{J}|} \mathbf{u} = \mathbf{z}.$$

Choosing the solution with the minimal number of changes.

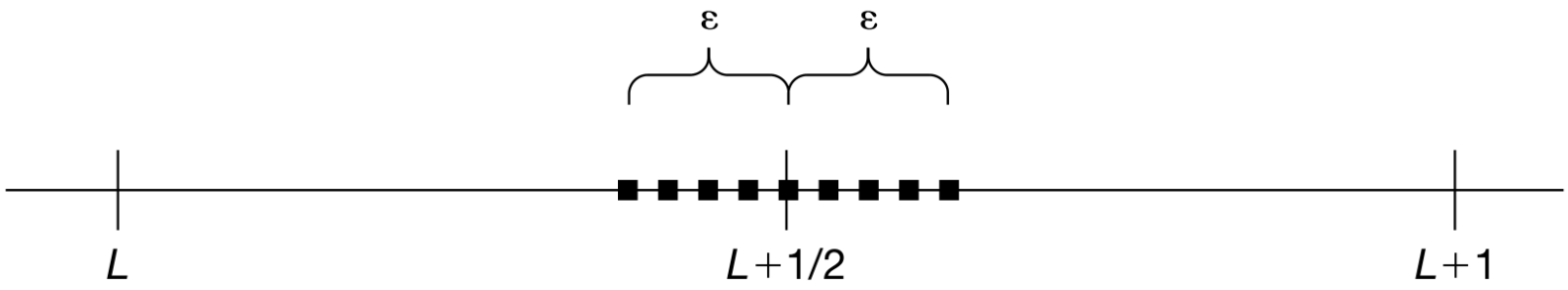
Acceleration

- Gaussian elimination: $O(|\mathcal{J}|^3)$.
- Matrix LT Process: much faster.

Perturbed Quantization

One of the most secure steganographic schemes known today.

$$J = \{j | j \in \{1, \cdots, n\},$$
$$\mathbf{u}[j] \in [L + 0.5 - \epsilon, L + 0.5 + \epsilon], L \in \mathbb{Z}\}.$$



Digital Watermarking and Steganography

by Ingemar Cox, Matthew Miller, Jeffrey Bloom, Jessica Fridrich, Ton Kalker

Chapter 13. Steganalysis

Lecturer: Jin HUANG

1949

As to steganography, Shannon declared that

- “systems are primarily a psychological problem” and did not consider them further.

Similar in the counter part: Steganalysis.

Detection

Two-class classification.

Error:

- False alarm.
- False detection.

Basic Strategy

- Explicitly model the probability distribution.
  - likelihood ratio test.
- High dimension leads to big challenge.
- Low dimensional space: features.
  - Histogram.
  - Fourier transform of the intensity histogram.
  - ...

Region Overlapping

Overlap of

- Cover work region.
- Stego Work region.

Boundary separation: hyperplane (SVM).

Targeted Steganalysis

Know the steganographic algorithm.

For example, LSB, a naive method:

- Increase the noise.
- The sum of the absolute values of the differences is large.
  - Between all pairs of neighboring pixels.
- Not reliable: texture ...

Histogram! Even estimate the length of the message.

Blind Steganalysis

Steganographic algorithm is unknown.

- Find a feature is sensitive to **all** methods.
  - We do not know.
  - Stimulate a new class of steganographic algorithm.

Training

Data set:

- Cover works and Stego works from many known steganalysis algorithms.
  - If one of them is used, Bingo!
  - It may work for similar/related unseen ones.
- Cover works only: one-class learning.
  - What is the normal ones looks like.
  - Do not need to be retrained when new embedding methods appear.

System Attacks

An example:

- 2006, a much more advanced encryption algorithm in DVD.
- Within months, the system had been broken.

System Attacks

An example:

- 2006, a much more advanced encryption algorithm in DVD.
- Within months, the system had been broken.
- ... read the secret key from memory.

A Stupid Case

In early implementation of F5

- JPEG header: “JPEG Encoder Copyright 1998, James R. Weeks and BioElectroMech”.

Stego Key

E.g. using dictionary attack.

- Follow the possible random walk path
  - Check the histogram (skip the correction).
  - Even read the message!
  - Or fake a massage.

Forensic Steganalysis

The warden can reliably determine the communication.

Block may not be good:

- Will alert Alice and Bob.
- No enough resource (political or economical).

So

- Try to read the message etc.

Attack

- Stego work only attack.
- Known cover attack.
- Known the algorithm attack.
  - Dictionary attack.

Cover Work Choosing

Spatial domain LSB on a decompressed JPEG.

- Spatial vs DCT: many to one.
- Re-compress it into JPEG.
- Decompress it back: the original cover work.
- Shorter message is more easy to detected!

Large Cover Work is not Good

For a fixed relative message length

- Features on smaller image is usually more noise.
  - Smaller image has less correlation to analysis.
- Noisy cover is better
  - Small noise over large one.

Presentation: Project 2

- E_SIMPLE_8
- D_SIMPLE_8

The key points

- different detect policy
  - reencoding method
- Performance: the plot of detection value
- Impact of the message length on the detection accuracy

Presentation: Project 3

- E_BLK_8
- D_BLK_8

The key points

- Correlation Coefficient.
- Hamming code/Trellis code.
- Impact of padding the message with two 0 bits.