OutGuess - Practical Steganography

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Overview

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Introduction

Steganography hides the fact that communication is happening, *e.g.* holiday picture with hidden message in least significant bits.

We say:

> a **hidden message** is embedded into the redundant data of the **cover-medium** to create the **stego-medium**.

Introduction

- Steganographic systems
  - *classical*: used to rely on keeping encoding system secret
  - *modern*: only detectable if secret information known
- Invasive nature of systems might leave detectable traces. Secrecy of the information is not degraded, but its hidden nature is revealed, defeating purpose of steganography.
- **How to do it better**?

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Introduction

Minimize required modifications:

- for a specific hidden message, find image that matches the data the best
- other tricks:
  - probabilistic embedding
  - error-correcting codes
  - plausible deniability, ...

$\rightarrow$ Need flexible framework to play with: OutGuess

Prerequisites

- Steganography remains undetected only if original image is unknown. Otherwise comparison to original reveals changes.
- **Easy** in practice.
- Create your own pictures with digital cameras, nobody will suspect anything when you send holiday pictures to friends.

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Construction

- Split embedding into two separate steps:
  - extraction of redundant data; can be modified without destroying cover medium
  - selection of bits in which hidden data will be placed
- Extraction process passes information for each bit to selector:
  - how *detectable* are changes to this bit
  - is this bit *locked*, *i.e.* can it be changed?

Construction

Extraction Process

Redundant data is extracted, modified and then written back.

The extraction process

- depends heavily on data format, might be non-deterministic
- for JPEG use the LSB in the discrete cosine transform coefficients

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Construction

Locked Bits

A Bit

- that is locked may not be modified
- becomes locked when it has been used to carry information, or modification destroys content of cover medium

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Construction

Detectability

- Detectability is used as bias in selection process
- selector tries to minimize modified bits and detectability of changes
- different embeddings have different accumulated bias, the one with lowest detectability wins

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Construction

Selection Process

Alleged RC4 stream is

- used to encrypt hidden message
- used to create PRNG (pseudo random number generator)
- initialized with user-chosen secret key

Selection with iterator function using the PRNG.

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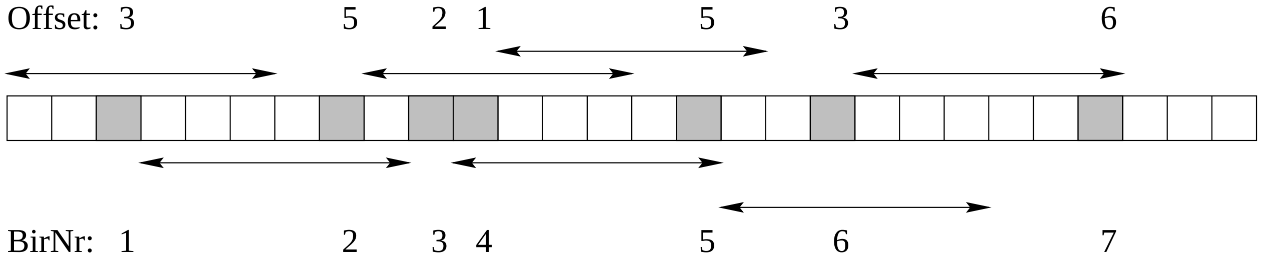
Construction



- Iterator is initialized
  - with a bitmap (the extracted redundant data)
  - and the PRNG.
- Each call returns the next selected bit. All returned bits are evenly spread over bitmap.

Construction

- Iterator can be reseeded to adapt its behaviour, resulting in different embeddings for each different seed.
- Next bit is selected within interval. The interval depends on the size of the remaining data.
- Hidden message is prepended with header containing
  - a 16-bit seed and
  - the length of the hidden message

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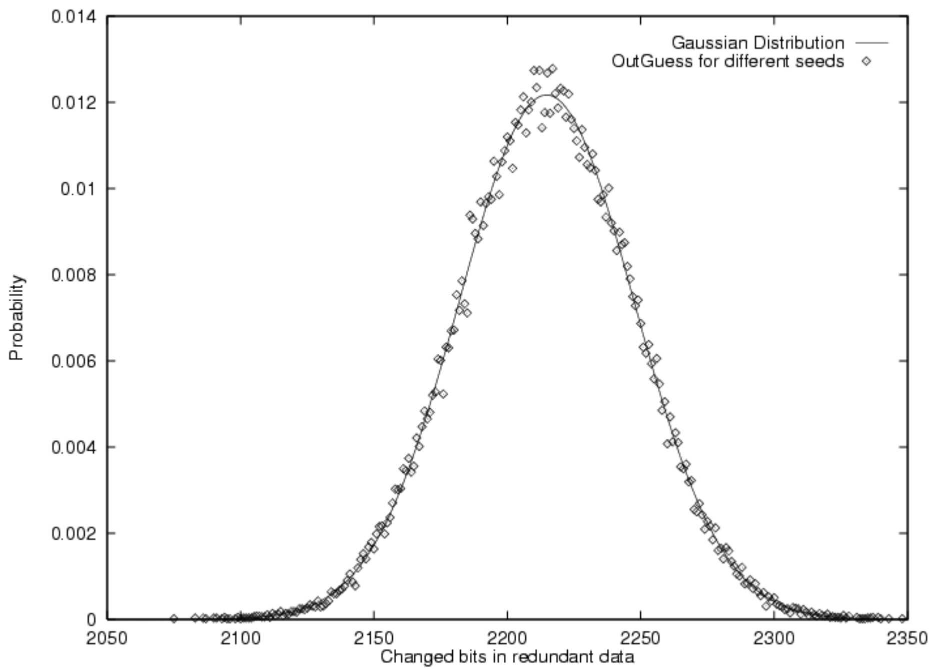
Minimizing Modifications



Seed creates a family of PRNGs.

- Number of changed bits is Gauss-distributed.
- Mean is close to 50% of bits in hidden message.

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Minimizing Modifications

- Iterator can be reseeded with a freely chosen seed.
- Seed at lower end of Gaussian distribution reduces number of bits that need to be modified.
- Unfortunately, we observe $\frac{\sigma^2}{\mu} \approx const.$
- Varying the seed allows us to
  - skip locked bits
  - hide multiple data sets

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Minimizing Modifications

- Modifications of locked or detectable bits can be avoided by introducing errors into hidden data
- requires error-correcting codes: $[n, k, d]$
- t errors can be corrected, with $d = 2t + 1$
- **but** error encoding increases size of data

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Minimizing Modifications

- number of modified bits remains the same, if
  - $\frac{n}{2} - t = \frac{k}{2}$ or
  - $d = n - k + 1$ holds.
- those are the maximum separable distance codes (MDS)
- repetition code $[n, 1, n]$ is the only binary MDS code.
- choose to not modify t bits from each code block

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Minimizing Modifications

- a more knowledgeable observer might detect modifications and conclude use of steganography
- multiple hidden messages in stego-medium provide **plausible deniability** if one of them is inconspicuous
- framework supports multiple embeddings with locking bits and new iterations for each message
- probabilistic embedding and error correction allow us to skip conflicts on locked bits

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Analysis and Future Work

- analyse embedding for JPEG
  - modifications of redundant data could lead to impossible DCT coefficients
  - how does the detectability heuristic help to avoid detection?
  - can heuristic be improved by analysis of possible DCT coefficients?
- image selection to find image with best representation of hidden message

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Conclusion

- probabilistic embedding and error correction with MDS codes are new contributions to steganography
- OutGuess is available at
  `http://www.outguess.org/`
- Acknowledgments
  - Andrew Carra for early discussions on minimizing modifications
  - Sean Coffey for help on error-correcting codes

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