Image Forensics and Steganalysis

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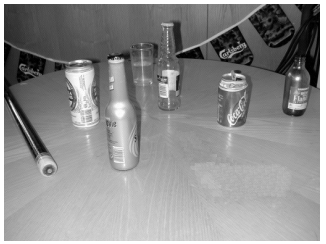
1. Examples
   - Tampering
   - Different Security Scenarioes
2. Steganography and Steganalysis
   - Steganography
   - JPEG and F5
   - The Markov Based Model
   - Double Compression
   - Conditional Probability Features
3. Our group
4. Conclusion

How worrying is the Iranian weaponry?

- Picture from AFP.
- One of the rockets really fired
- Some rockets are the product of PhotoShop...
- The image was retracted after publication

Crime Scene Photography



- What did the crime scene look like?
  - Photography is vital evidence
- Photography can be altered...
  - What can we prove?

Who were actually there?

- Former Culture Secretary James Purnell
- Late for the meeting.
  - Arrived after three other MPs had to leave.
- James Purnell was added to the picture
- (BBC News - 28 September 2007)

Is the photo real?

- Does it show reality?
- Or has its author exercises artistic licence?
  - tampering with evidence
  - adding grandeur to a story
  - computer generated images
- For example
  - Merging images
  - Erasing details or objects

Where does the photo come from?

- Objective: add credibility to claims
- All information about the image is potentially useful...
- Which camera took the image?
- Time of day, time of year, etc.
- Subsequent image processing
  - contrast, compression, brightness, etc.

Is there more than meets the eye?

- Additional information hidden in the image?
  - known as *steganography*

Three important questions

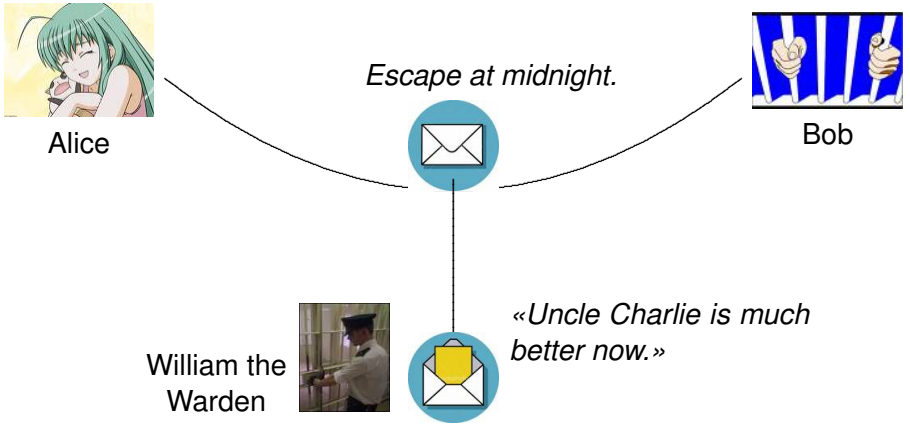
1. Is the photo real?
2. Where does the photo come from?
3. Is there more than meets the eye?

User scenarios

- News agency, news paper, etc.
  - can we trust images from the public?
  - they can get thousands of images in a day
- Forensics and Court of Law
  - what can we prove?
  - what is the truth?
  - is the image real or synthetic?
- Intelligence services
  - is there secret communications hidden in the image?

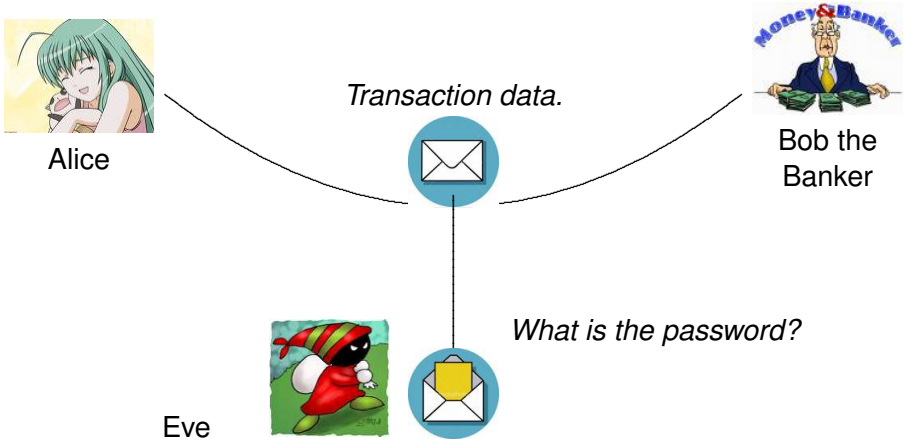
The basic problem

Simmons Crypto'83



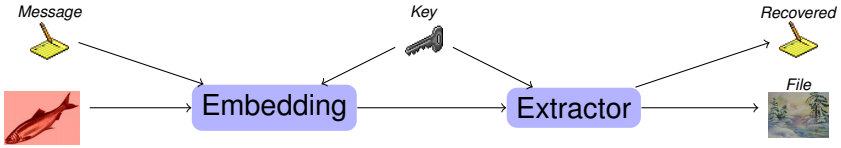
The basic crypto-problem

Encryption



The data hiding system

Watermarking System



- Security depends on the confidentiality of the algorithm.

Definitions

The tools

Definition (Stego-system)

A system which allows Alice and Bob to communicate secretly without Eve knowing that any secret communication is taking place.

Definition (Steganography)

The study of (and art of developing) stego-systems.

Definition (Steganalysis)

The art of detecting whether secret communications is taking place or not.

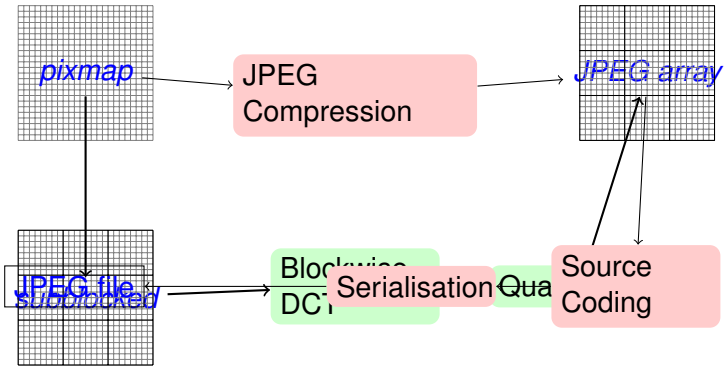
Steganalysis

Using Machine Learning

- Most recent steganalysis systems use Machine Learning
  - or related statistical techniques
- Most often a two-class SVM is used (natural vs. steganogram)

1. Extract features (statistics) from the image
   - Multi-dimensional floating point vector
2. Train the system
   - Input two ensembles of feature vectors
   - The system will estimate a model
3. Testing
   - Input the estimated model + Images from each class
   - Output classification decisions – Estimate accuracy
4. Real use
   - Input: model; feature vector from a suspicious image

JPEG images



JPEG Steganography

- Many stego-algorithms work on the JPEG Array
  - Integer matrix
- E.g. Jsteg
  - Ignore $+1$ and 0 coefficients
  - Embed in the least significant bit of each coefficient
  - Extract by taking $c \mod 2$

The F5 Algorithm

by Andrea Westfeld

- Better preservation of image statistics
- JPEG coefficient magnitudes are always decreased
- Matrix coding (source coding) is used
  - coding to match the cover
  - minimise the number of modifications

Typical JPEG Steganography

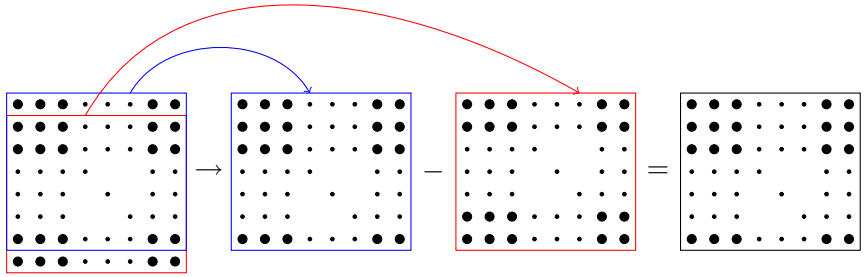
- Modulate information on the cover
  - ± 1 changes to coefficients
- Independent modifications
  - Independence of the cover
  - Independence of individual coefficients
- This is the problem of steganography
  - Image coefficients are *not* independent
  - The modifications become detectible noise

The Markov Based Model – Overview

Yun Q Shi *et al*

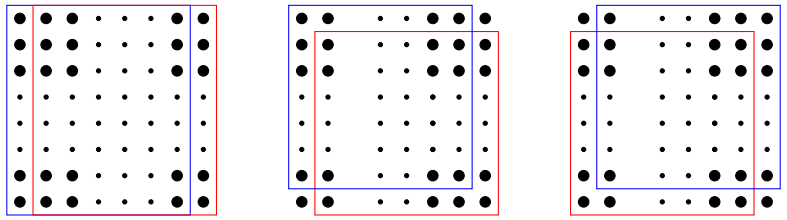
- Consider the absolute value of the JPEG array
- Difference matrix – differences between adjacent coefficients
- Model the difference matrix
  - First-order Markov model
- Estimate a Transition Probability Matrix
  - which forms our features

The difference array



- $F_v(i,j) = |J_{i,j}| - |F_{i+1,j}|$
- To reduce complexity, the difference array is capped at $\pm T$
  - Large (small) values are reduced (increased) to the capping value.

The other three difference arrays



- Horizontal, and major and minor diagonal

Transition Probability Matrix

- For $s, t \in \{-T, -T+1, \ldots, T-1, T\}$, we estimate
  - $M^v_{s,t} = P(F_v(i+1,j) = s | F_v(i,j))$
  - $M^h_{s,t} = P(F_h(i,j+1) = s | F_h(i,j))$
  - $M^d_{s,t} = P(F_d(i+1,j+1) = s | F_d(i,j))$
  - $M^m_{s,t} = P(F_m(i,j+1) = s | F_m(i+1,j))$
- This gives four matrices
  - $M^x = [M^x_{s,t}]$
- $4(2T+1)^2$ features
  - Shi *et al* suggested $T = 4$ for 323 features
- Performance around 90%–98% accuracy

The F5 implementation

- JPEG based stego-algorithms should work on the JPEG array
- This is what F5 (and Jsteg) Software actually do:

1. Load and Decompress the Image
   - Internal Spatial Representation
   - Compression Parameters are discarded
2. Compression and Embedding as an integrated process
   - Compression implemented by tweeking existing compression routines
   - Usually using default parameters
3. Save the comressed image

Double Compression

- The F5 software recompresses the image
  - Usually using a different compression factor
  - Known as *Double Compression*
- This normally causes artifacts
- Typical Steganalysis classifiers
  - Compare Clean images against F5 processed images
  - What is detected?
  - Double Compression or Steganography?

Alternative Experiment

- New training set
  1. Steganograms from F5 (with a hidden message)
  2. Cover images processed by F5 without a message
- Thus both of classes are doubly compressed
- Our classifier will have to work on the embedding only

1st vs. 2nd Order Markov Models

Performance

- Ignoring Double Compression

	Message length (bytes)		
	618	1848	4096
1st Order	89.5%	93.5%	98.0%
2nd Order	99.1%	99.1%	98.6%

- F5 vs. doubly compressed (clean) images

	Message length (bytes)		
	618	1848	4096
1st Order	50.2%	84.3%	97.9%
2nd Order	50.0%	55.6%	70.6%

Complexity

- Shi *et al*'s technique uses 323 features
- Computationally costly, to extract and to train
- We have proposed a simpler set
  - achieving similar performance

Basic ideas

1. The Markov Model is flawed
   - probability distribution of each coefficient is
     - determined by preceeding coefficients
     - independent of position
   - it should depend on the frequency (position in a subblock)
2. The transition probability matrix is too fine-grained
   - too many features to compute

The coefficients considered

	x_h	y_h	z_h				
x_v	x_d						
y_v		y_d					
z_v			z_d				

The CP Features

Definitions

- Triplet (x, y, z) as in figure
- Three posterior events
  - $A_1 : y > z$; $A_2 : y = z$; $A_3 : y < z$
- Three prior events
  - $B_1 : x > y$; $B_2 : x = y$; $B_3 : x < y$
- Nine features per triplet (x, y, z)
  - $P(A_i|B_j)$ fro $i, j = 1, 2, 3$
- 27 features in total
  - A 54-feature variant (six triplets) was less effective

Performance

CP Features

- Computation – Markov Model based technique in parenthesis
  - Training 770ms (150ms) on 2480 images
  - Classification 0.2ms (same) per image
  - Feature Extraction 114ms (13s) per image
- Accuracy (large message, 4kB)
  - 97.2% for both CP and Markov Model
  - 95% confidence interval is $(95.3\%, 99.2\%)$

Steganalysis and Image Forensics

and Machine Learning

- Steganalysis
  - Development of Scientific Methodology
  - New feature sets
- sister team on Image Forensics
- sister group in Biologically Inspired Methods

Coding Theory

Applications in Data Hiding

- Deletion/Insertion Correction
  - for use in Watermarking
  - Geometric Distortions
- Wet Paper and Dirty Paper Coding
  - Distortion Minimisation in Watermarking and Steganography
- Construction/Non-Existence of Codes

Information Security

- Security in Contact-Less Payment Systems
  - are they sufficiently secure
- sister group in E-voting

Next project

- Information Forensics is a booming area
  - Image Forensics in particular
  - The methods and methodology are largely shared with Steganalysis
- Is there room for collaboration?
  - Machine Learning
  - Sound methodology