Detecting LSB Steganography in Colour and Grayscale images

Team Photons

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Repo URL: https://github.com/Digital-Image-Processing-IIITH/project-photons

Overview

Paper

Detecting LSB Steganography in Color and Grayscale Images (2001)

Jessica Fridrich, Miroslav Goljan, and Rui Du

Problem Description

Detecting whether an image contains a hidden message and estimating its length using RS steganalysis

Steganography

Hiding data in data (in both cases, it could be an image, text, audio, video, etc)

The message is usually encrypted before hiding it, although it can also be hidden as plaintext

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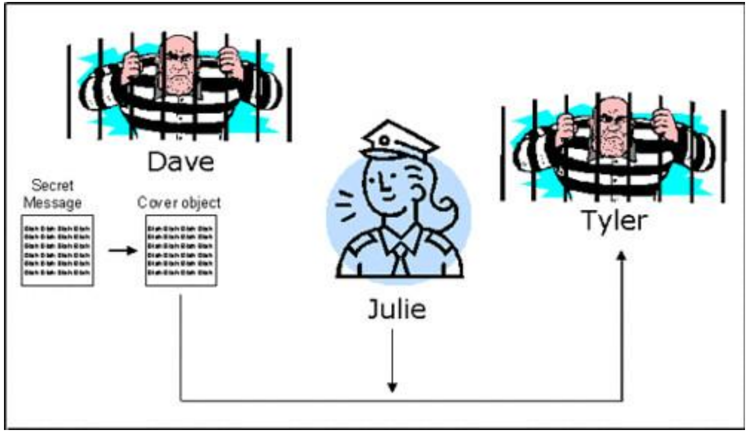
Taking the first letter of every word:
PERSHING SAILS FROM NY JUNE I

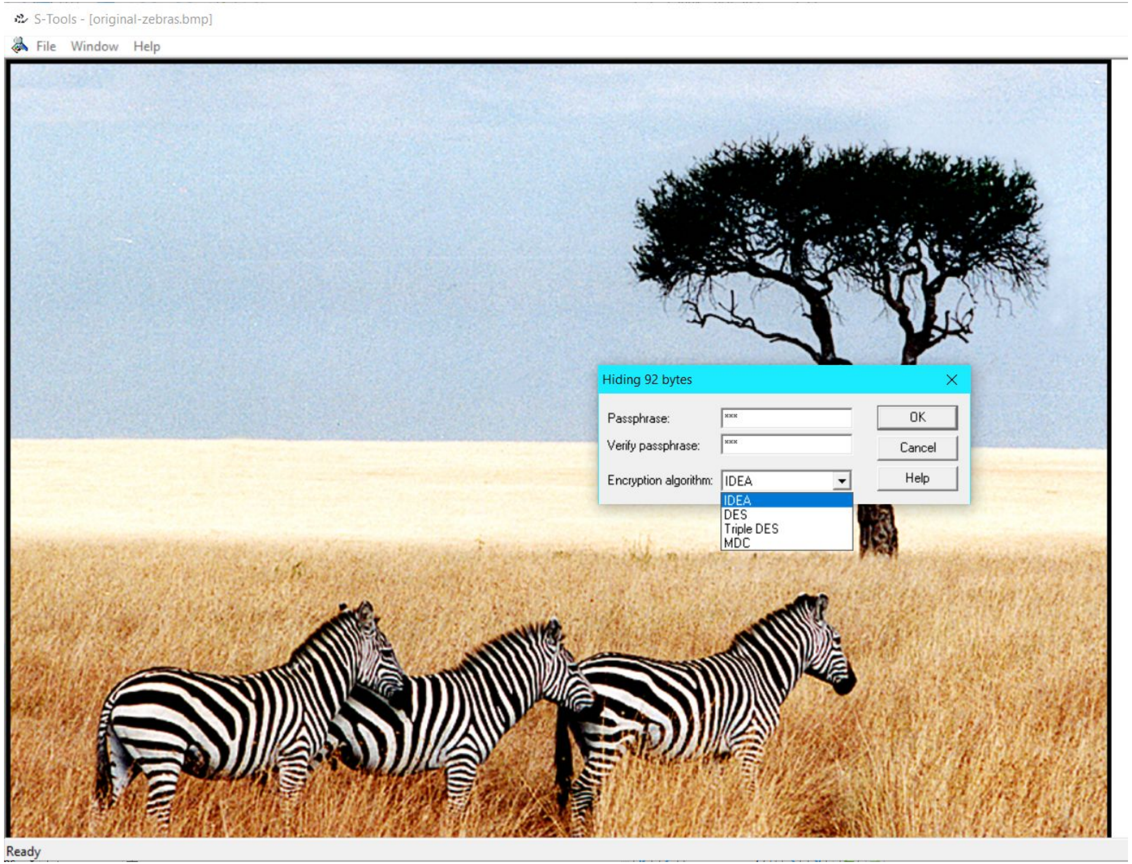
Steganalysis

Trying to detect secret data that may be hidden in some other data

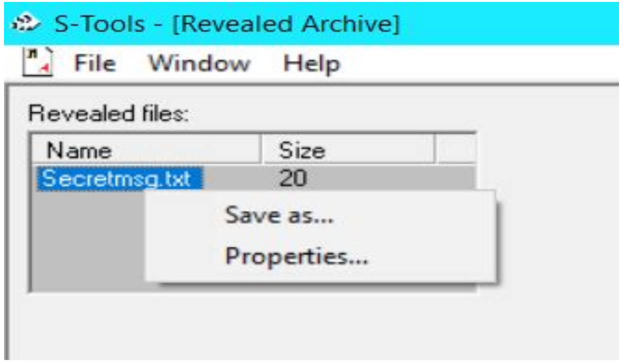
It is not necessary to be able to read the secret message to “break” a steganographic system



Steganography - software / tools

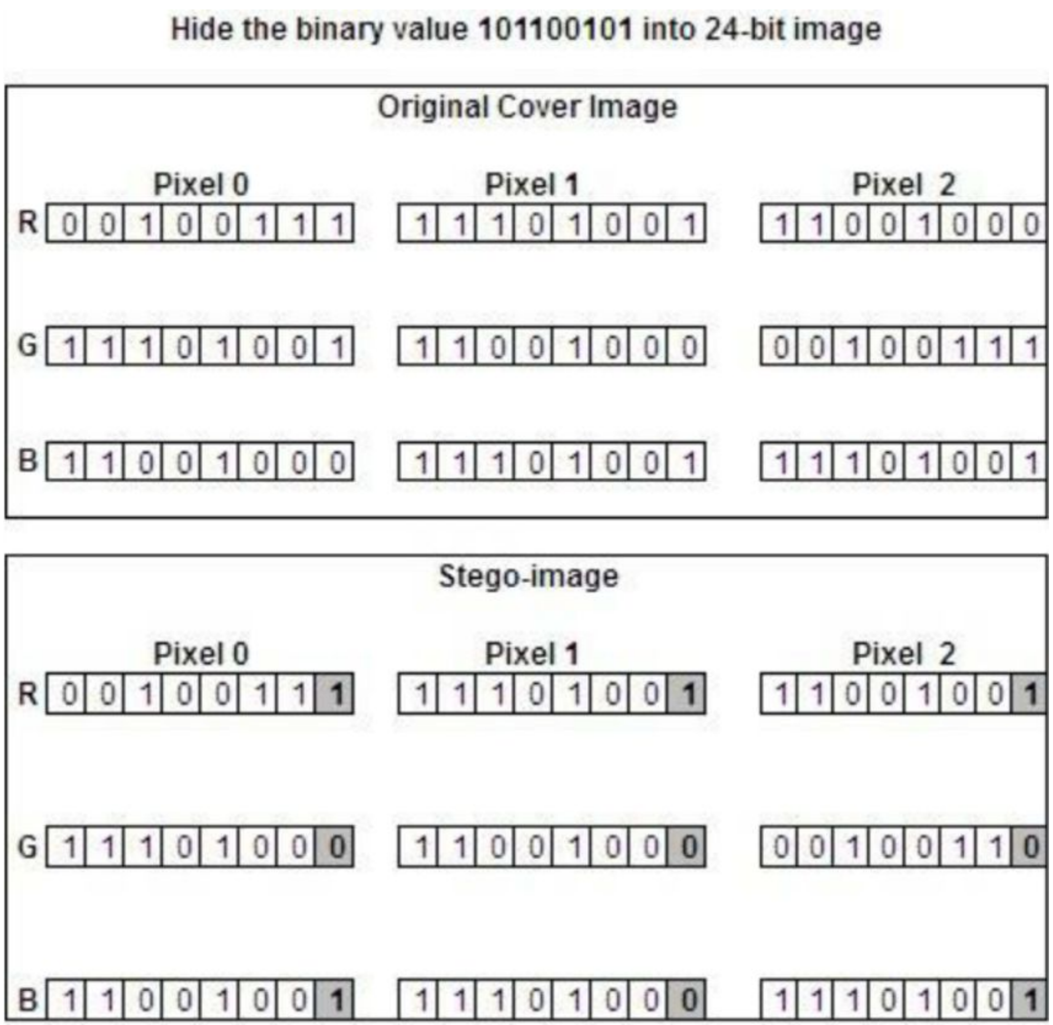


Example:
Using S-Tools to communicate secretly by encrypting and hiding a message in an image



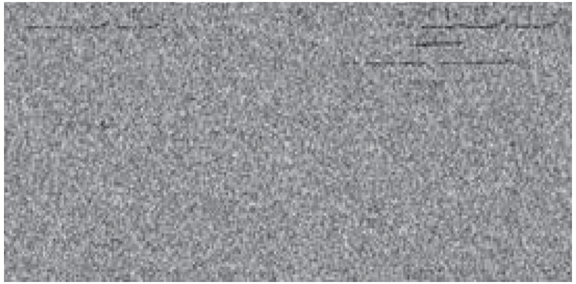
An example of LSB steganography

LSB steganography is a common steganographic approach in which the message bits are stored in the LSBs of an image (LSB embedding)



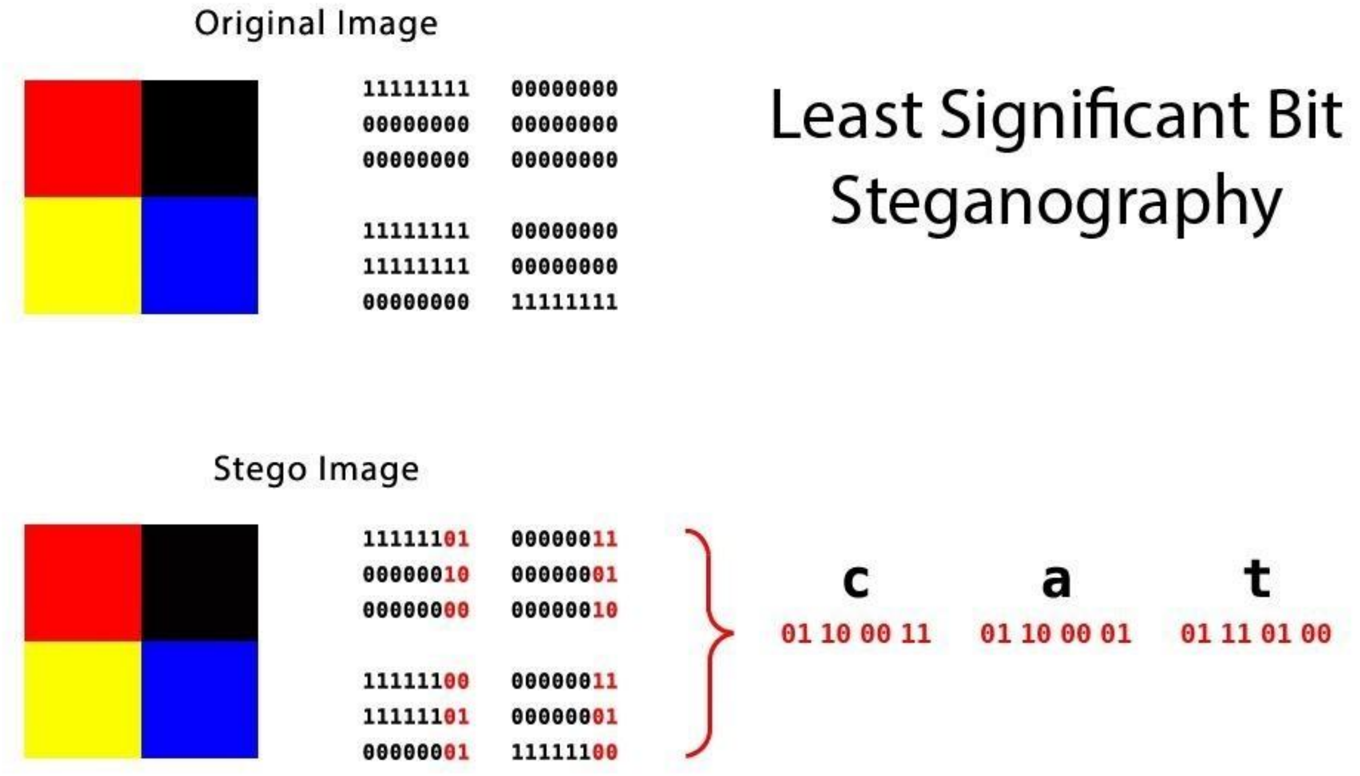
Why are LSBs usually used to hide a message?

The change in colour is undetectable for the human eye



Also, for most images, the LSB plane is essentially random and does not contain any easily recognizable structure

Why are LSBs usually used to hide a message?



Scope

- Detecting the percentage of LSBs that have been flipped in an image
  (helps to estimate the length of the hidden message)
- Not uncovering the hidden message itself
  (If the hidden message is in the form of ciphertext, this would require cryptanalysis)

RS Steganalysis

A statistical technique that was developed mainly to detect a message scattered across the LSBs of randomly chosen pixels in a stego-image
(doesn’t work so well for sequentially embedded messages)

This technique does not depend on the specific algorithm that may have been used for steganography

3 main ideas discussed in the paper:

1. Obtaining RS diagram from empirical experimentation on original cover images
2. Method to estimate RS curves from a (potentially) stego-image
3. Estimating the length of the hidden message and checking its accuracy

Procedure to obtain RS diagram

- Image is divided into disjoint groups of adjacent pixels
- Discriminaton function measures the smoothness of a group of pixels
- Flipping functions (F_0 , F_1 , F_{-1}) flip the LSB of a single pixel
- For every group, check the discrimination function’s value before and after flipping
  - A mask M is created to apply flipping functions to a group of pixels
- Calculate the percentage of regular groups (R), singular groups (S) and unusable groups (U)

We will see how the number of regular groups and singular groups change with LSB randomization (for example, LSB steganography)

RS Steganalysis - Discrimination function

It measures the smoothness / regularity of a group of pixels

Noisy group → higher value of discrimination function

The pixels within a group are traversed in a zigzag manner to evaluate the discrimination function. This ensures that neighboring pixels are listed together

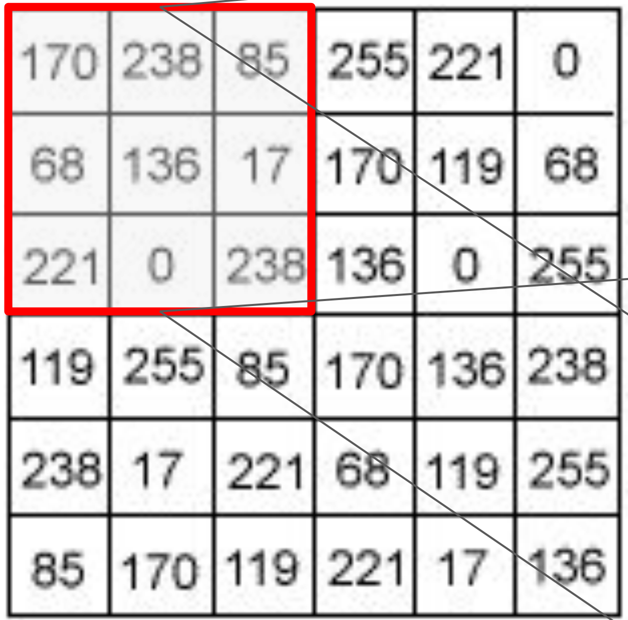
170	238	85	255	221	0
68	136	17	170	119	68
221	0	238	136	0	255
119	255	85	170	136	238
238	17	221	68	119	255
85	170	119	221	17	136

$$|170 - 238| + |238 - 68| + |68 - 221| + |221 - 136| + |136 - 85| + |85 - 17| + |17 - 0| + |0 - 238|$$

$$= 68 + 170 + 153 + 85 + 51 + 68 + 17 + 238$$

$$= 850$$

RS Steganalysis - Flipping functions



1	0	1
0	1	0
1	1	0

=

171	238	84
68	137	17
220	1	238

Negative Mask

-1	0	-1
0	-1	0
-1	-1	0

=

169	238	86
68	135	17
222	-1	238

RS Steganalysis - Regular and Singular groups

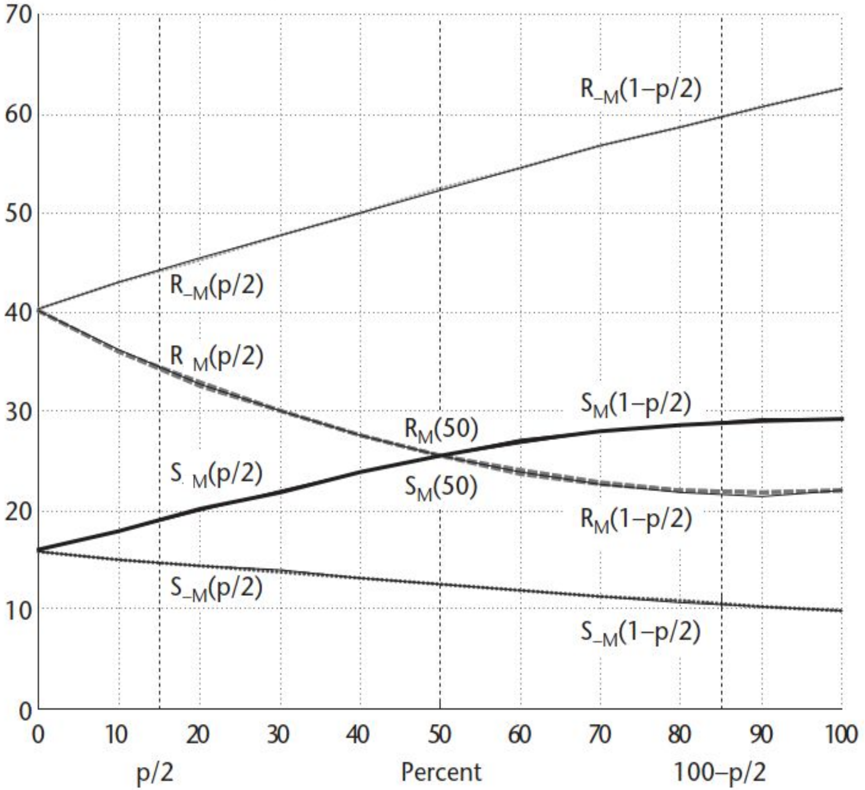
$$\text{Regular groups:} \quad G \in R \Leftrightarrow f(F(G)) > f(G)$$
$$\text{Singular groups:} \quad G \in S \Leftrightarrow f(F(G)) < f(G)$$
$$\text{Unusable groups:} \quad G \in U \Leftrightarrow f(F(G)) = f(G)$$

R_M denotes the percentage of regular groups in the image using mask **M**
R_{-M} denotes the percentage of regular groups in the image using mask **-M**
S_M denotes the percentage of singular groups in the image using mask **M**
S_{-M} denotes the percentage of singular groups in the image using mask **-M**

As per the statistical hypothesis, for the original cover image,

- ★ $R_M \cong R_{-M}$ and $S_M \cong S_{-M}$
- ★ $R_M >> S_M$

RS Steganalysis - RS diagram



RS-diagram of an image. The x-axis is the percentage of pixels with flipped LSBs, the y-axis is the relative number of regular and singular groups with masks M and −M. Here, M = [0 1 1 0]

The authors collected experimental evidence that R_{-M} and S_{-M} are modeled well by straight lines, while R_M and S_M are modeled well by second-degree polynomials

The principle of RS steganalysis is to estimate the four curves of the RS diagram for a stego-image, and calculate their intersection using extrapolation.

p = Length of the message expressed as a percentage of the total image pixels

p/2 = Percentage of LSBs flipped by a message of length p, on an average

1-p/2 = The percentage of LSBs which are flipped (as compared to the original cover image), when all the LSBs are flipped in a stego-image

RS Steganalysis - Extrapolation and Length Estimation

The x-coordinate of the intersection point of R_M and S_M is given by a root of the quadratic equation

$$2(d_1 + d_0)x^2 + (d_{-0} - d_{-1} - d_1 - 3d_0)x + d_0 - d_{-0} = 0,$$

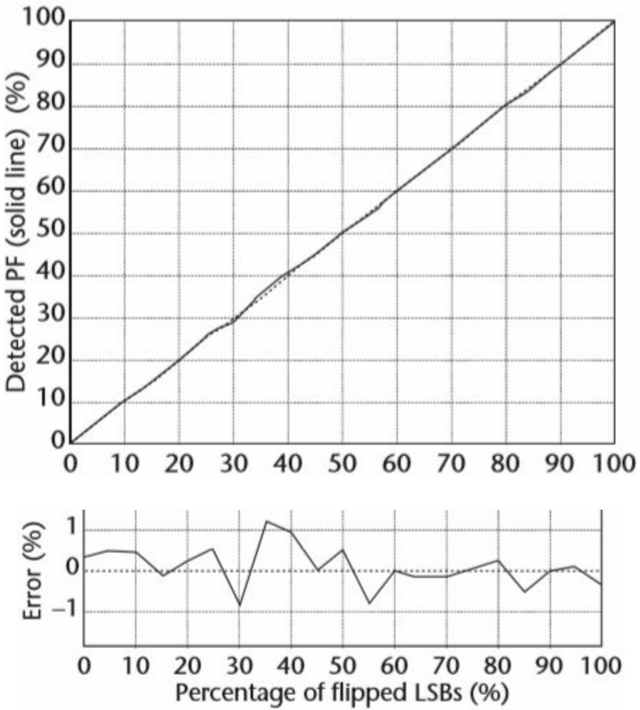
where

$$d_0 = R_M(p/2) - S_M(p/2)$$
$$d_1 = R_M(1 - p/2) - S_M(1 - p/2)$$
$$d_{-0} = R_{-M}(p/2) - S_{-M}(p/2)$$
$$d_{-1} = R_{-M}(1 - p/2) - S_{-M}(1 - p/2)$$

The message length p can be estimated using $p = x/(x - 1/2)$

RS Steganalysis - Extrapolation and Length Estimation

The error between detected p and actual p
(detected % of flipped pixels v/s actual % of flipped pixels), as observed by the authors:



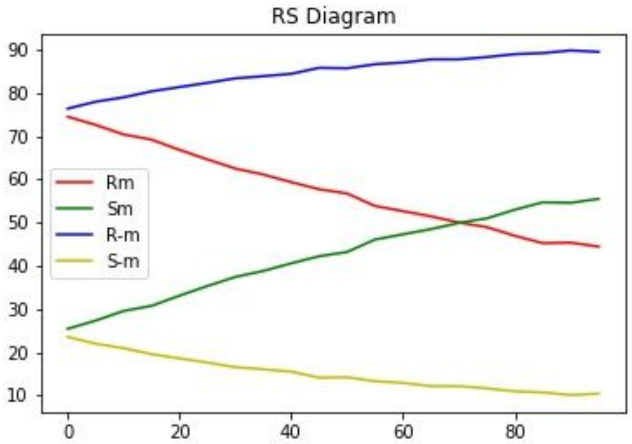
The accuracy of length estimation is affected by:

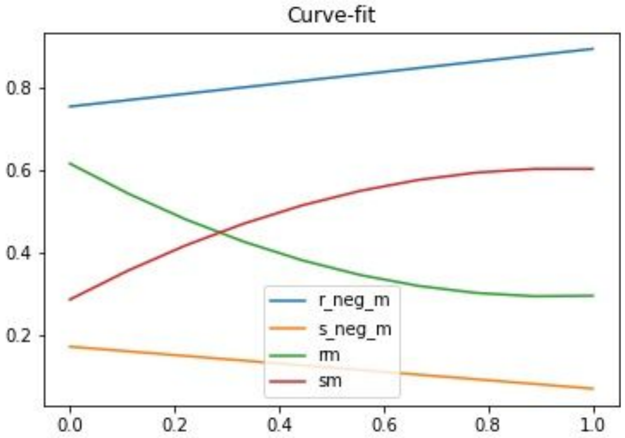
1. Initial bias
   Non-zero message length detected in an original cover image

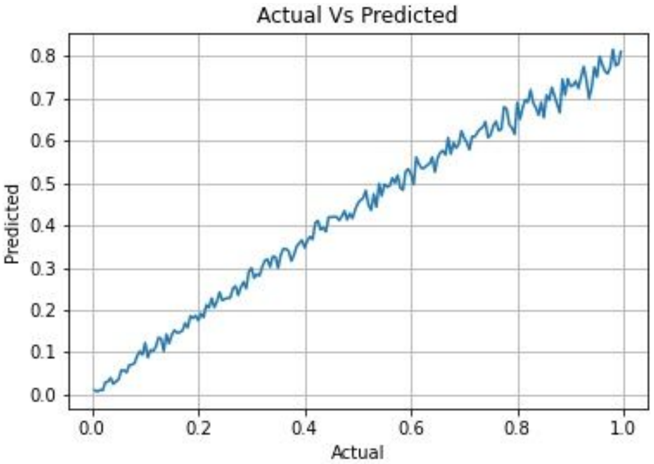
2. Noise
   In noisy images, the difference between R_M and S_M is small

3. Message placement
   More accurate for randomly scattered messages than sequential / locally concentrated messages

RS Steganalysis - Our result







Contribution

Difficult to define clear-cut task boundaries as we regularly had meetings that lasted for hours and coded together.

Understanding the literature of the paper was pretty hard as the equations were without explanations and had to fiddle around lot of literature to get to a proper understanding for the implementation.

Finding Initial Bias and Finding roots caused hurdles as the proof was not provided.

Roughly:

Pratik Bulani - Discrimination Function, Flipping Operations, Counting R and S groups
Shivani Hanji - Finding roots of extrapolation equation, Polynomial fitting, Experimenting with RS diagram
Dhawal S - Counting R and S groups, Scattered LSB flipping, Curve Fitting
Saptarshi - Scattered LSB Flipping and Zigzag mask for discrimination Function, Actual Vs Predicted steg-testing

Contribution (cont.d) - Experimentation
(Done by all team members)

Testing with S tools and Stepic (steganography software)

Experimenting with different Masks

Testing with (SimpleLSBFlipping) Sequential Flipping vs Random Scattering Flipping.

Tried various ways of finding roots of quadratic equation and fitting the quadratic curve on the points

Different ways to integrate Color channels in the existing procedure for grayscale

Tested with homogenous images (with very less variation in color intensity) to check the R,S,U groups.

Researched various ways to find the $R_M(½)$ and $S_M(½)$

Tested with various images to check the graph of actual p vs predicted p

Tested various formats of images for generating RS diagram

1980 .bmp mislead us. Check the link: https://image.online-convert.com/convert-to-bmp