Image Steganography Analysis and Detection

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Presentation Outline

Image Steganography

- Steganography is the process of hiding a secret message within a larger one in such a way that someone can not know the presence or contents of the hidden message
- Aim - To develop a detection system which is capable of detecting the alteration in image both its format and signature thereby predicting the actual type of forged file

Challenges in Forged File Discovery

- Images without watermarking as digital signatures can be easily manipulated.
- With the advent of new photo editing software - hiding critical informations are easy and unpercievable
- Task to detect mix of scaled or compressed images as one is difficult
- Incorporating machine learning techniques for feature analysis and decision making to classify the image to be forged or not
- Tamper detection to check for change in the file format extension

Presentation Outline

Image Steganography Review paper [1]

- A detailed literature review on a variety of different methods, algorithms, and schemes in image steganography is conducted in order to analyse and investigate them
- Methods used:
  - Modified LSB(Least Significant Bit) Technique
  - Modified LSB Technique with AES authentication mechanism
  - Steganography approach based on LSB in digital image
  - IMStego-Java based Tool with reduced PSNR in conventional LSB approach
- Different Spatial and Transform techniques are realised
- Literature review demonstrating the popular steganographic techniques

Image Steganography Based on Modified LSB Substitution Method and Data Mapping [2]

- Steganographic method working on the principle of Modified LSB Technique with specific intend of reducing the number of 1's in the secret data
- Methods:Each pixel value of host image is changed if value of secret bit is 1 otherwise the LSB of each pixel value will remain unchanged
- Limitation :
  - Less secure
  - Limited pixel quality
- State-of-the-art methods in terms of PSNR,SSIM
- Future work:Better data mapping mechanism for reduced storage and computational performance

Digital Image Steganography Using Modified LSB and AES Cryptography[3]

- This method ensures enhanced security of digital images
- Steps involved:
  - The secret message is transformed to cipher text by AES cryptography [
  - The cipher text is hidden inside the image using the modified LSB method
- Methods:Replacing LSB of cover image with the bits of the concealed message and manipulating the LSB plane of the cover image
- Limitation :
  - Less secure:Easy to decrypt secret message
  - Less performance
- Modified LSB shows improved performance based on PSNR,SSIM metrics
- Future work:Performance Improvement based on storage or computatational time

Image Steganography with Modified LSB and AES Encryption standards

Couple		
House		

Figure: Image Steganography with Modified LSB and AES

Boundary-based Image Forgery Detection by Fast Shallow CNN[4]

- Network (SCNN) capable of distinguishing the boundaries of forged regions from original edges in low resolution images SCNN is designed to utilize the information of chroma and saturation
- Methods:Based on SCNN:
  - Sliding Windows Detection (SWD)
  - Fast SCNN
- Methodology:
  - SWD: We start by picking a certain window of an image
  - Window is feed into SCNN and compute a confidence score to predict whether it is tampered
  - Confidence score and probablity map is maintained
  - Then the window slides over and outputs another confidence score
  - After sliding the window through the entire image, a complete probability map is constructed

Boundary-based Image Forgery Detection by Fast Shallow CNN[4]

- Fast SCNN :
  - Takes entire image as the input
  - Produces feature maps by processing the entire image with Conv layers
  - Extract feature vectors with dimension from feature maps and feed them into fully-connected layers
  - The parameters of Fast SCNN are all trained by SCNN on the patch dataset
- Limitation :
  - Less secure:Easy to decrypt secret message
  - Less performance
- Modified LSB shows improved performance based on PSNR,SSIM metrics
- Future work:Performance Improvement based on storage or computatational time

A Review on Deep Learning based Image Steganalysis [5]

- Steganalysis based on deep learning approach
- Classified as the following categories:
  - Spatial Image Steganalysis
  - JPEG Domain Steganalysis
- Deep Learning based Steganalysis
  - Spatial Domain Steganography Steganalysis based on Deep Neural Network Design
    - Spatial Rich model(SRM)
    - Steganalysis Based on Fusion Approach
    - Steganalysis methods based on Learning Strategy
  - Jpeg Domain Steganography Steganalysis based on Deep Learning
    - Convolutional Neural Network(CNN) with 20 layers
    - CNN with 32 layers combined with SCA-GFR
    - CNN with four 5 x 5 high pass filters, which include a KV filter, a point filter, and 2 Gabor filters, are used to detect stego noise introduced by JPEG-domain embedding scheme

A Review on Deep Learning based Image Steganalysis [5]

- Limitation and Mitigation:

- Acquisition and representation of statistical characteristics: Using Generative Adversarial Network(GAN)
- Low payload steganographic image detection: Combination of neural neteork design and various other techniques like training sample creation and learning
- Generalization of steganalysis: Combine Transfer Learning and Deep Learning
- Quantitative and locating image steganalysis based on deep learning

- Future work: Challenges resolution by adapting new learning and training sample techniques

Steganalysis of RGB Images Using Merged Statistical Features of Color Channels[6]

- The steganalysis process is based on supervised machine learning, utilizing the Support Vector Machine (SVM) binary classifiers implementation in MATLAB
- Proposed Model:
  - Based on merging features of single color channels into a multi-channel feature set, without consideration to the correlation between color channels
  - Accuracy of model is evaluated with uncompressed RGB clean image and stego image
  - Feature Selection - Statistical Textural Features
    - Single Channel - Statistical and Traditional Feature Set
    - Multi Channel - Consists of GLCM features Contrast,Correlation,Energy and Homogeneity, as well as other textural features such as Entropy in the study of textural features of images, and have been used in many steganalysis research works

Single Channel Features in Statistical Textural Features

TABLE I. SINGLE CHANNEL FEATURES

Feature Name	Feature Description
CC-LR	Correlation coefficient between left and right half-bytes
CoV-FB	Coefficient of variation of full-bytes
CoV-RHB	Coefficient of variation of right half-bytes
GLCM-FB	Contrast, Correlation, Homogeneity, Energy, of full-bytes
GLCM-RHB	Contrast, Correlation, Homogeneity, Energy, of right half-bytes
GLCM-3LSB	Contrast, Correlation, Homogeneity, Energy, of 3LSB part of byte
GLCM-2LSB	Contrast, Correlation, Homogeneity, Energy, of 2LSB part of byte
Entropy-FB	Entropy of full-bytes

Steganalysis of RGB Images Using Merged Statistical Features of Color Channels[6]

- Dataset : The selected cover image type is uncompressed RGB-BMP, in three channels, without the alpha channel [Two independent datasets are used, for double validation of the proposed model [The first validation dataset consists of 1500 clean images in TIFF format with alpha channel, that were downloaded from the Natural Resources Conservation (NRC) image dataset [
- Dataset : The CALTECHs birds images dataset [14], which is in a compressed color JPEG format [A set of 1500 CALTECH images were converted to BMP format and resized to 512 X 512 pixels [

Steganalysis of RGB Images Using Merged Statistical Features of Color Channels[6] [

Fig. 1. Sample NRC cover image

Fig. 2. Sample CALTECH cover image

Fig. 3. Large secret image House.bmp, 360×360, 379 KB, 50% payload

Fig. 5. Small secret image Harvard.jpg, 354×520, 63 KB, 12.5% payload

Steganalysis of RGB Images Using Merged Statistical Features of Color Channels[6]

- Experimental Work:
  - Embedding : Secret messages are embedded using Spatial Steganography
    - Each Channel in each pixel were Embedded with 2 bits or 4 bits by replacing the least significant bits [For single channel embedding, only the NRC cover images were used, in which the Blue color channel of each pixel was embedded using 2-bpc
    - The processes of embedding have produced five stego datasets: NRC-LSB2, NRC-LSB4, CALTECH-LSB2, CALTECHLSB4, and NRC-2LSB-Blue
  - Features Extraction: Using build in functions of MATLAB
  - Classification using SVM Classifier
  - Evaluation metrics :True Negative(TN),True Positive(TP), False Negative(FN) , False Positive(FP) and Detection Accuracy(DA)

Steganalysis of RGB Images Using Merged Statistical Features of Color Channels[6]

- Limitation:
  - Does not apply to compressed images with lossey compression
  - Performance and Storage consideration for Multi channel
  - Capacity of hiding data is low
- Future Work : The proposed steganalysis model can be evaluated using
  - Lower embedding rates
  - Different media types : audio and video
  - Flexibility to work with transform domain

Large-Scale JPEG Image Steganalysis Using Hybrid Deep-Learning Framework[7]

- Deep Learning in Image Steganalysis is still in its initial stage-A generic hybrid deep-learning framework for JPEG steganalysis incorporating the domain knowledge behind rich steganalytic models
- Stages in JPEG Steganalysis:
  - The first stage is hand-crafted, corresponding to the convolution phase followed by for rich model :
    - Quantization phase
    - Truncation phase
  - The second stage is a compound deep-neural network containing multiple deep subnets, in which the model parameters are learned in the training procedure

Large-Scale JPEG Image Steganalysis Using Hybrid Deep-Learning Framework[7]

- Proposed Model:
  - Preliminaries:
    - The principal part of CNN is a cascade of alternating convolutional layers, regulation layers (eg. BN layers) and pooling layers
- Working :
  - Each neuron unit receives inputs from a previous layer, performs a dot product with weights and optionally follows it with a nonlinear point-wise activation function
  - CNNs can be trained using backpropagation
- Quantisation and Truncation in Steganalysis:
  - Convolution with series of kernal to derive varied noise residuals
  - Quantisation
  - Truncation
  - Aggregation

Large-Scale JPEG Image Steganalysis Using Hybrid Deep-Learning Framework[7]

- Hybrid Deep Learning Approach :
  - Takes Decompressed JPEG images and performes Convolution and Quantisation,Truncation
  - The second stage is a compound deep CNN network in which the model parameters are learned in the training procedure
- Future Work :
  - Incorporation of Adversarial Machine Learning into current hybrid framework
  - Exploration of the application of hybrid framework in the field of multimedia forensics

Large-Scale JPEG Image Steganalysis Using Hybrid Deep-Learning Framework[7]

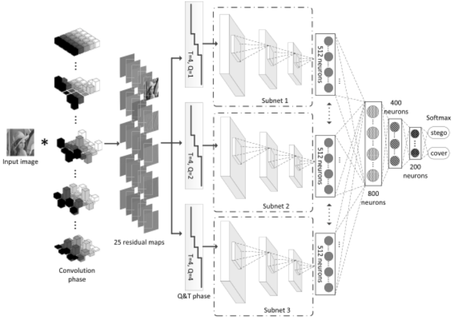


Fig. 1. Conceptual architecture of one implementation of our proposed hybrid deep-learning framework with twenty-five 5×5 DCT basis patterns and three Q&T combinations.

Figure: Hybrid Deep Learning Framework

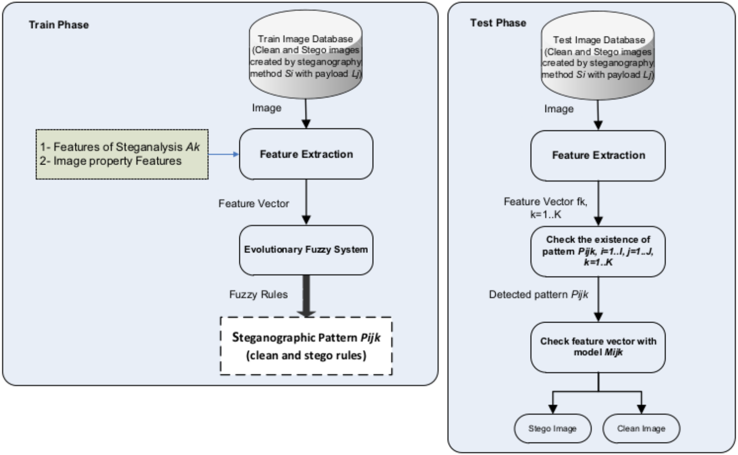
Steganalysis based on Steganography Pattern Discovery[8]

- SPD Approach:
  - Evolutionary method Steganalysis to extract the signature of stego images against clean images via fuzzy ifthen rules
  - Blind steganalysis on the discovered knowledge, suitable trained models for steganalysis can be employed and stego images will be detected with high accuracy
  - Using SPD, we can predict the type of steganography method from a stego image [Employing SPD can enhance the approaches, which assume that a special steganography method is used
  - The effect of SPD before applying steganalysis methods has been investigated by some steganography and steganalysis techniques and it has been validated using some image databases
  - The second stage is a compound deep CNN network in which the model parameters are learned in the training procedure

Steganalysis based on Steganography Pattern Discovery[8]

- Steps carried out in SPD :
  - Image Feature Selection, Two Groups as methods:
    - Filtering :Select feature subsets independently from the learning classifiers and do not include learning
    - Wrapping :Wrap around a certain learning algorithm that can assess the selected feature subsets in terms of estimated classification errors and then build the final classifiers
  - Fuzzy rule generation : Iterative Rule Learning approach, each individual codes one rule and in each iteration of Genetic Algorithm (GA) a new rule is adapted and added to the rule set, iteratively

The block diagram of Steganography pattern discovery [8]



Steganalysis based on Steganography Pattern Discovery[8]

- Feature vector generation
  - 274 dimension Steganalyser
  - 324 dimension Feature Vector - First order and second order histograms.
  - Wavelet based Steganalysis
  - 14 dimensional Feature Vector

Steganalysis based on Steganography Pattern Discovery[8]

- Fuzzy rule generation - Evolutionary method searches for a relatively smaller if-then-rules
- Certinity Factor for Fuzzy Rules :
  - Calculate the compatibility of each training sample
  - For clean and stego images, calculate the relative sum of the compatibility grades of training samples with rule R_j [
  - The grade of certainty CF_j for clean images [
- Evolutionary Fuzzy Algorithm
  - Initiation.
  - Generation.
  - Replacement.
  - Inner Cycle Termination Test.
  - Outer Cycle Termination Test.
  - Weight Adjustement.

Steganalysis based on Steganography Pattern Discovery[8]

- Evolutionary Method :
  - Extracts signature of stego images against clean images using Fuzzy if-then-rules statements
  - The Steganalyzer trained to detect only one steganography method at once
- Limitations :
  - Using Fuzzy rules increases computational complexicity
  - Only 4 Class Feature Classification - Limited Features

A Novel Image Steganography Method via Deep Convolutional Generative Adversarial Networks[9]

- A novel Steganography without Embedding (SWE), which does not need to modify the data of the carrier image, appeared to overcome the detection of machine-learning-based steganalysis algorithms
- SWE method based on deep convolutional generative adversarial networks.
  - Generative Adversarial Network (GAN)
    - GAN and discriminative model [
    - The henerative model deceives the discriminative model via generated images that appear like real images while the discriminative model judges whether the images are real or unreal.
  - Deep Convolutional Generatice Adversarial Network (DGAN)
    - Deep convolutional generative adversarial networks (DCGANs) are an extension of GANs in which the models are deep convolutional networks
    - Currently, GANs are widely used for the following works:

A Novel Image Steganography Method via Deep Convolutional Generative Adversarial Networks[9] [

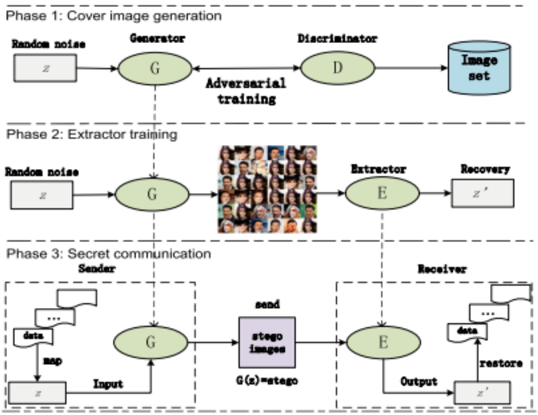


FIGURE 1. The proposed steganography framework using DCGANs for SWE.

Figure: Steganography Framework using DCGAN and SWE.

A Novel Image Steganography Method via Deep Convolutional Generative Adversarial Networks[9]

- The Proposed Image Steganography without embedding:
  - Train DCGANs on an image set and obtain generator G after DCGANs convergence.
  - Train a CNN's model, called the extractor E, based on the recovery errors from a large number of random noise vectors.
  - The sender and the receiver hold the network and parameters of G and E, respectively.
- Cover Image Generation
  - Secret message is segmented S_i and then map each segment S_i to noise vector z_i .
  - Generate a cover image stegoi from the noise vector z_i with the help of DCGANs
- Training of the Extractor
  - We design the CNNs, called the extractor E, to recover the secret data from stego images generated by G .
  - Has four convolutional fully connected layer .

A Novel Image Steganography Method via Deep Convolutional Generative Adversarial Networks[9]

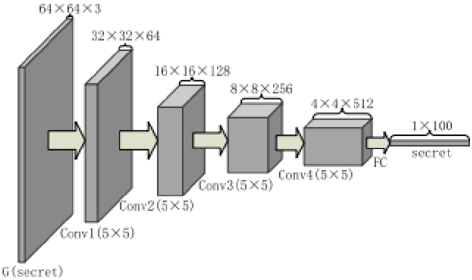


FIGURE 3. The structure of extractor E.

Figure: The structure of Extractor - E.

A Novel Image Steganography Method via Deep Convolutional Generative Adversarial Networks[9]

- leak-Relu activation function and batch normalization in each layer with no pooling layer or dropout operation
- Afully connected layer is used after last convolutional layer
- Train E to extract information from the generated stego images from G
- The training procedure of the extractor is,

Formula

$$L(E) = \sum_{i=1}^{n} (z - E(stego)^2) \tag{1}$$

A Novel Image Steganography Method via Deep Convolutional Generative Adversarial Networks[9]

- Secret Communication
  - Sender holds the CNNs model G and the corresponding network parameters of G and the receiver holds the CNNs model E and the corresponding network parameters of E

Steganography Algorithms Recognition based on Match Image and Deep Features Verification[10]

- Sub section of steganalysis.
- Match image is generated by **Gaussian Filtering** on testing image to remove the possible stego signal.
- CNN model is trained on test images to extract deep features from test and match images.
- Proposed system also works better with unknown dataset.
- Related work:
  - Residual filters in steganalysis : Stego data to be placed in highly noise area to make it undistinguishable from noise component.
  - Convolutional Neural Network for steganalysis: Convolution followed by deep inner product to extract features. Finding local features.

Steganography Algorithms Recognition based on Match Image and Deep Features Verification[10]

- Motivation and Analysis of Cover Source Mismatch (CSM)
  - Difficult approach
  - Stego signal S obeys Gauss distribution

$$S \sim N(0, \sigma^2) \tag{2}$$

  - Variable-controlling approach is adopted.
  - Motivation :
    - Match image should not contain stego signal.
    - Match and test image should be similar.

Steganography Algorithms Recognition based on Match Image and Deep Features Verification[10]

- Obtaining match image:
  - Obtained by reference.
  - Gaussian filter is used on test image to remove stego signal.
  - Two dimensional Gaussian distribution

$$G(x,y) = \frac{1}{2\pi\sigma^2} exp(-\frac{x^2+y^2}{2\sigma^2}) \tag{3}$$

  - Match image generation :

$$I_{\mathrm{m}} = conv2(I_{\mathrm{t}}, K_{\mathrm{G}}) \tag{4}$$

- CNN-extracted deep features
- Using low dimensional representation of image.
- Modelled CNN for extracting features.
- Performance Analysis
- Feature Normalisation
- Weighted similarity and Inner product similarity.

Steganography Algorithms Recognition based on Match Image and Deep Features Verification[10]

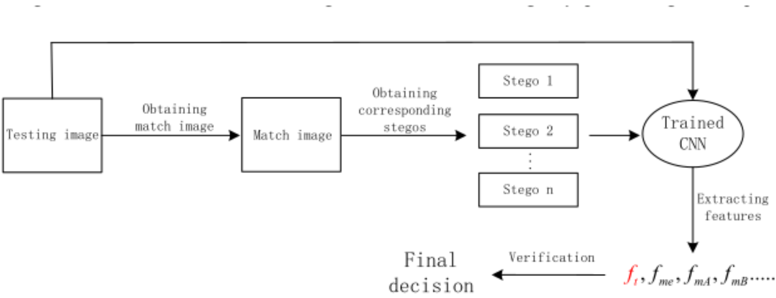


Figure: Framework of match steganalysis.

Steganography Algorithms Recognition based on Match Image and Deep Features Verification[10]

- Works even with unseen cover images.
- Computational processing higher than that of the conventional method.
- Future work:
  - More practical Matching of images.
  - More accurate similarity function.
  - Reducing the computational complexcity.

Presentation Outline

- **Image Steganography Review paper [1]**, International Journal of Advanced Research in Computer and Communication Engineering(IJARCCE) , Mohammed A Saleh ,DOI.
- **Digital Image Steganography Using Modified LSB and AES Cryptography[2]** , International Journal of Computer Science and Network Security(IJCSNS) ,Subhash Panwara , Shreenidhi Damanib , Mukesh Kumar DOI [
- **Boundary-based Image Forgery Detection by Fast Shallow CNN [3]** , 2018 24th International Conference on Pattern Recognition (ICPR) , Zhongping Zhang , Yixuan Zhang , Zheng Zhou , Jiebo Luo , DOI

- **Boundary-based Image Forgery Detection by Fast Shallow CNN [4] [** , 2018 24th International Conference on Pattern Recognition (ICPR) , Zhongping Zhang , Yixuan Zhang , Zheng Zhou , Jiebo Luo , DOI.

- **A Review on Deep Learning based Image Steganalysis [5].** , 2018 IEEE 3rd Advanced Information Technology, Electronic and Automation Control Conference (IAEAC) ,Yong-he TANG, Lie-hui JIANG, Hong-qi HE, Wei-yu DONG , DOI.

- **Steganalysis of RGB Images Using Merged Statistical Features of Color Channels[6]** , 2018 11th International Conference on Developments in eSystems Engineering (DeSE) , Zaid I. Rasool , Mudhafar M. Al-Jarrah ,Saad Amin , DOI.

- **Large-Scale JPEG Image Steganalysis Using Hybrid Deep-Learning Framework[7]** , IEEE Transactions on Information Forensics and Security , Jishen Zeng , Shunquan Tan , Bin Li , Jiwu Huang , DOI.

- **Steganalysis based on steganography pattern discovery[8]** , Journal of Information Security and Applications , Hedieh Sajedi , DOI.

- **A Novel Image Steganography Method via Deep Convolutional Generative Adversarial Networks[9].** , IEEE Access , Donghui Hu 1 , Liang Wang1 , Wenjie Jiang , Shuli Zheng , Bin Li , DOI.

- **Steganography Algorithms Recognition based on Match Image and Deep Features Verification[10].** , Multimedia Tools and Applications Journal ,Xu Xiaoyu ,Sun Yifeng Wu, Jiang , Sun Yi DOI.