Advances in Digital Image Steganography

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***Abstract*-The growing risk of cyber security needs to be urgently addressed as data is one of the most important assets to be taken care of during transmission over the internet. Data security generally means protecting data from intruders and unauthorized users or the persons other than the communicating parties. This not only provides high security but also prevent data from modification. To improve the security features in case of data transfers over the internet, the techniques that have been known till now are like Cryptography, Steganography. Where Cryptography is defined as the method to conceal information by encrypting plaintexts to cipher texts and later transmitting it to the intended recipient using an unknown key, on the other hand Steganography provides or say extends security further to a high level by hiding the cipher text into text, image or other formats. Watermarking and fingerprinting are the other two technologies used parallel with steganography in the field of data hiding. Watermarking is the practice of imperceptibly altering work to embed a secret message, concerned with the protection of intellectual property, while unique marks are embedded in the cover object that are received by different people in fingerprinting. In this paper, we are presenting some views in the development of image steganography, the particular field is selected because of its good capability to hide data without easily discoverable by the human visual system.**

Keywords-Image Steganography, steganography techniques, Image, Steganographic algorithm

I. INTRODUCTION

Cryptography alone was not capable enough to for secure transmission of various types of information over the internet. This weakness of cryptography becomes the source to widely research on steganography, to conceal information in more secure manner. Steganography with the Greek word " Stegos + grafia" literally means, "covered + writing"[1].

The steganography includes various different types of methods to hide information behind some covering data. The covering data can be text, image which are hiding the information like text and image. Hiding the data by taking the cover object as image is referred as image steganography. In digital steganography, images are widely used as cover object because of the binary representation of the pixel intensity whose redundant bits are used to hide the information. Almost any media that can be encoded into a bit stream can be hidden in a digital image.

The idea of steganography mainly circulates around avoiding the use of busy communication channels between the communicating people.

The approach of a person while sending the secure data a file when communicated after encryption and then this image with hidden message is transferred between the sender and the receiver across the communication channel then the encrypted file can be easily suspected by the intruder. This paper tries to give a smart overview on image steganography. Starting from brief knowledge about steganography,

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cryptography and other data hiding techniques, remaining paper comprises of how and when steganography came into existence for the first time (in ancient times) in section-2. Section-3 briefs about the applications of the steganography which shows its increasing importance in today's digital world. Section-4 is all about steganography basic terminology and its types. Section-5 comes with the detailed description of Image steganography for our readers.

On the other hand, Section-6 explains the detailed criteria for evaluating the performance of a steganographic algorithm. In section 7, the detailed description of the image steganography techniques is given. Finally, Section 8 comes with the conclusion.

II. BEGINNING PHASE OF STEGANOGRAPHY

Steganography can be defined as the hiding of information messages within other media, without being noticed by the human eye. The first steganographic technique was developed in ancient Greece around 440 B.C. Herodotus is the first Greek historian, who used steganography to convey a message against Persian king. What he has done was he shaved the hair of his messenger than write a message on his head. Later, he wait that hair growth occurs again and could hide that message. Steganography is thus an art of covered writing that is not seen by any person other than the intended recipient. Steganography continued development in the early 1600s by Sir Francis Bacon. During times of war, invisible inks were used in steganography extensively. The British and American forces used various forms of Invisible Inks in American Revolutionary War. Invisible Ink used mainly were milk, vinegar, fruit juice, and urine, for the hidden text. The receiver used heat and light to read or decode them. World War II introduced microdots by the Germans. Null ciphers i.e. unencrypted messages with real messages embedded in the current text were also used to pass secret messages [2].

III. APPLICATIONS OF STEGANOGRAPHY

3.1 Covert Communication:

Covert communication means when two parties are communicating then the third party is unable to view the secret data. Though the secret message has been transferred without converting it into unintelligible form, the third party is unable to find its existence. Thus, in steganography aims to hide the message to be hidden rather than hiding about the parties which are communicating with each other while cryptography just change the main secret message to be transferred between the communicating parties, making it not readable by any third party. In cryptography, the third party is aware of the secret communication taking place between the sender and the receiver, but is unable to read the secret message.

Information hiding is the process of hiding secret information behind any cover object such that the changes done to the cover object are not visible to the human eye. The various aspects of covert communication system are usually covered by the information hiding in various forms.

Covert communication has been used nowadays for both legal and illegal activities. The legal activities aim to hide data from the third party such that the information exchange occurs between the people of defence services. The data is communicated covertly in order to maintain its confidentiality between the sender and the receiver only. The illegal activities shows the covert communication which aims to harm the country, its people and other important things. Such communication has got criminal intentions like the intentions of the terrorists that use steganography in order to exchange weapons, to plan attacks and other harmful activities. Even the industrial espionage, as the industries do not remain far from the ill effects of covert communication when the trade secrets have been shared illegally. Various steganographic techniques have been used for data hiding [3].

3.2 Copyright protection related:

Copyright protection has been defined in oxford dictionary as- the exclusive legal right, given to its assignee or originator in order to print or publish some film or artistic or music content for a mixed number of years.

Currently, a number of different Digital Rights Management techniques are used to protect standards from copyright abuse. Digital watermarks embedding is one of the techniques chosen by ISO and IEC.

The web content, the DVD and CD, The computer forensics department used copyright protection laws in order to prevent copying of their content.TCP/IP packets (a unique ID can be embedded into an image) to analyze the network traffic of particular users, and also checksum embedding [4]. Petitcolas [5] in Medical Imaging Systems to maintain confidentiality between patients image data like DNA sequences, patient's name, contacts etc. Such information can be hidden behind image secretly. Steganography thus provide authentication that no other security tool may ensure. copyright control provide high protection for keeping such information safely thus reducing time and cost to store them.

IV. STEGANOGRAPHY AND ITS TYPES

4.1 Steganography

Steganography is an art of covered writing that is not seen by any person other than the intended recipient. Figure1 shows the model of the steganographic system. Steganographic system is generally made up of mainly cover object, secret message, stego-key, stego-system encoder, stego object and stego-system decoder. Generally, innocent looking carriers, e.g., pictures, audio, video, text, etc. that hold the hidden information are called as Cover object. On the other hand, Stego key is an additional piece of information, such as a password or mathematical variable, required to embed the secret information. The process of applying stego key in order to hide secret message inside the cover object is called as stego system encoder. The combination of hidden data-plus-cover object is known as the stego object. Stego system decoder is the process of applying the same stego key over the stego object in order to separate the hidden message from the cover object.

There are five types of steganography [6,7] discussed below:

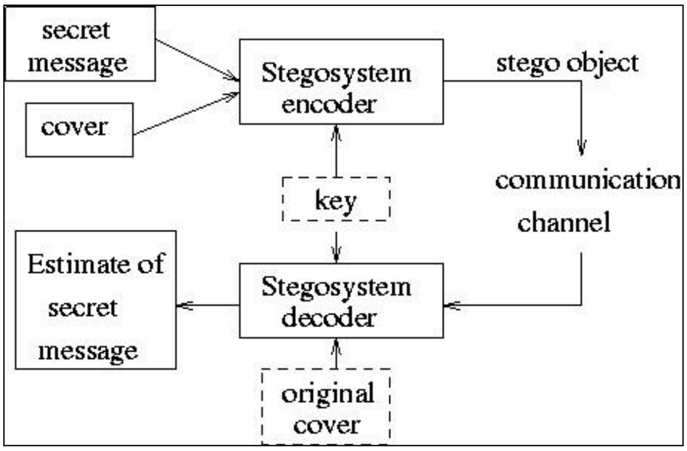

Fig1. Model of Steganographic systems

1.Text Steganography: This steganography involves hiding data behind every nth letter of every words of text message in text files.

2. Image Steganography: Hiding the data behind the cover image is referred to as image steganography. Pixel intensities are converted into binary representation to hide information in the most redundant bits.

3. Audio Steganography: It consists of hiding information inside the audio files like WAV, MP3, AU etc.

4. Video Steganography: Steganography that hide any kind of files or data in a digital video of formats like H.264, MPEG, MP4, AVI is called video steganography. In digital media, video is usually considered as the combination of pictures.

5. Network or Protocol Steganography: The objects which are used as cover media are network protocol like TCP, UDP, ICMP, IP etc.

V. IMAGE STEGANOGRAPHY

Digital Images-

Digital images have a finite set of digital values, called picture elements or pixels. Digital image consists of fixed number of rows and columns of pixels. In digital computing world, grayscale digital image is an image in which the value of each pixel carries intensity information, shades of gray, varying from black at the weakest intensity to white at the strongest. Today, grayscale images intended for visual display are commonly stored with 8 bits per pixel. Thus, 256 different types of intensities of grey are used.

An RGB image has three channels: red, green, and blue while a grayscale image has just one channel.

5.2 Images Formats-

There are various formats used on the internet like jpg, gif, tiff, png, bmp. All these file types or formats are used to encode the digital images. The need of file formats actually varies according to the need of compression. Few file formats are found to be quite large which means more disk usage and slow speed of downloading them. The classification of file formats varies largely depending upon the number of columns constituting the image. Few colours in an image mean it can be reduced in size.

5.3 Images Compression

There exist two types of compressions to compress digital images. The compression is applied using compression algorithms over the digital images. The lossless compression algorithm does not make compromises with the accuracy of the digital image because the information is discarded nowhere while algorithm aiming lossy compression introduces some degradation of image in order to cut short the file size, because they might store the color information at lower resolution rather than the image itself. On the other hand to cut short the file size using lossless compressing algorithm includes replacing the recurrent pattern of a file with some kind of shorter abbreviation.

5.4 Detection technique for Image steganography

Even though stego-images can rarely be spotted by the naked eye, they usually leave behind some type of fingerprint or statistical hint that they have been modified. It is those discrepancies which an analysis tool may be able to detect. Since some techniques and their effects are commonly known, a statistical analysis of an image can be performed to check for a hidden messages in it. A widely used technique for image scanning involves statistical analysis. Most steganographic algorithms that work on images, assume that the least significant bit is more or less random. This is however, an incorrect assumption. While other techniques also include [8]:

Steganography-only attack: Analysis of only steganography medium can occurs.

Known-carrier attack: Both the carrier as well as the steganographic medium are available for analysis.

Known-message attack: As the name says the hidden message is known earlier.

Chosen-steganography attack: Both steganography medium and the steganographic algorithm are known and thus can be used to attack.

Chosen-message attack: Steganography algorithm along with the hidden message is known and thus used for future analysis to create steganography media.

Known-steganography attack: The carrier, steganography medium and the steganography algorithm, the three important aspects of steganography are known.

VI. EVALUATION CRITERIA FOR IMAGE STEGANOGRAPHY:

Each of the algorithms proposed for image steganography is proved to be efficient in one or few of the factors in order to make a good steganographic algorithm. It is hardly seen that a steganographic algorithm fulfils all of the mentioned criteria because if they are strong in one of the factors then they are weak in others. Factors [9] are:

6.1 Imperceptibility-. Imperceptibility refers to perceptual transparency i.e. no visual artifacts on the stego-image. It should be as high as possible.

6.2 Invisibility – Steganographic algorithm invisibility lies in its strength of being unnoticed by the human visual system. If the tampering done to the image is easily seen by the human eye then it means the algorithm does not go well on the invisibility aspect of a good steganographic algorithm.

6.3 Payload capacity – It is the ability to hide a good amount of data behind the cover object such that we can say a steganographic algorithm has got a good embedding capacity or payload capacity. The hiding capacity is represented in bits per pixel.

6.4 Security-Security means the ability to survive from transformations like cropping, scaling, filtering, addition of noise, and from different attacks.

6.5 Robustness against statistical attacks – A good steganographic algorithm must show robustness against statistical attacks. It is so because a steganalyst try to perform statistical tests on cover-image data in order to find the hidden secret message. A signature as an embedding information inside the stego-image should be avoided by steganographic algorithm because it is easily detected by the statistical analysis.

6.6 Robustness against image manipulation – Image manipulation includes activities like cropping and rotation of image. Thus, a good steganographic algorithm must be robust against image manipulation and must take care of hidden message in such situations of changes in image as cropping of image or rotation of image can actually destroy the message hidden behind the cover image.

6.7 Independent of file format – Different file formats used in image steganography can confuse the steganalysts to think about the cover image format instantly. A good steganographic algorithm is able to hide secret information behind any image file format.

6.8 Unsuspicious files – All characteristics of a steganographic algorithm may result in images that are not used normally and are of abnormal file size, requiring further investigation of the image by a steganalyst. Depending upon the particular requirement, the steganographic algorithm has been classified under three levels as high, medium and low. A high level means that the algorithm completely satisfies the requirement, while a low level indicates that the algorithm has a weakness in this requirement. A medium level indicates that the requirement depends on outside influences, for example the cover image used. LSB in GIF images has the potential of hiding a large message, but only when the most suitable cover image has been chosen..

6.9 Temper resistance-Temper resistance means the survival of the embedded data in the stego-image when attempt is done to modify it. Finally, computational complexity refers to the computational cost of embedding and extraction. It should be as low as possible.

The ideal steganographic algorithm has high level in every requirement. But, from the algorithms listed here, not a single algorithm satisfies all the factors.

VII. TECHNIQUES USED IN IMAGE STEGANOGRAPHY

7.1 Spatial domain techniques

The spatial domain steganography technique [10] used the pixel gray levels and colour values of the cover image directly for hiding and encoding the message bits, in such a manner that they are not visible by human vision system. These are the various techniques used till now in which pixel embedding has been done directly on the pixels, the methods usually varies in selecting the criteria of order of pixels.

A. LSB Technique: The Least Significant Bit embedding technique [12] is a technique which is used to hide the data behind the cover image such that it cannot be seen by human eye. The images used as cover images are generally in 8-bit , 24-bit format. Select the message that is to be hidden behind the cover image. Embed the required number of bits in order to hide the MSB (Most Significant Bit) of the message behind the LSB (Least Significant Bit) of the cover image. Since the MSB contains the most important information of the image and the LSB contains the least important information of the image, it does not cause much difference in the image and thus we can obtain the stego image which looks similar to the original image. Our proposed algorithm i.e. Row into Column Modify Stegano-Algorithm is also the implementation of LSB technique

1. Select a 8-bit grayscale cover image.
2. Generate a cover matrix for this cover image with element x_{ij}.
3. Now divide the message to be hidden into n frames of 8-bit length each.
4. Generate matrix (for message) of dimension nx8 for the message matrix with element b_{ij}. Let each row be R1, R2,.......Rn.,each of length 8 bit.
5. Now find 8 locations of pixels using some pseudo-random sequence generator (for inserting each row) for each frame. Thus, n matrices(element a_{ij}) has been generated by pseudo-random generator for insertion of each row. Let each matrix be pixel matrix.
6. Our aim is to insert the each row of message matrix only into first column (containing LSB of each random pixel) of pixel matrix generated each time randomly.
7. The row of the message matrix has been decided by calculating Matching Factor(MF).
8. Matching factor=$\sum x_{jt}$ where x_{jt} =1 if $a_{jt} = b_{ij}$ and otherwise x_{jt}= 0 where i,j,t={1,2,3,....8}.
9. After calculating the M.F. of each row with the first column (containing LSB of each random pixel), row with maximum M.F. has been assigned to first column. If two or more rows have same M.F. then row is assigned to the first column on FCFS basis
10. Once the row has been assigned, we continue finding another row with maximum matching factor (from the remaining set of rows) with the first column (containing LSB of each random pixel) of new pixel matrix.
11. Similarly all the rows of the message matrix has been assigned to the first column (containing LSB of each random pixel) of the pixel matrix generated randomly for each row.
12. Obtain the stego image after replacing the first column (containing LSB of each random pixel) of each pixel matrix by each row of maximum matching factor.
13. Now keep the order of the insertion of the row of the message matrix in a separate matrix.
14. Calculate Peak signal to noise ratio (PSNR) and Normalized Cross-Correlation (NCC).

B. PVD Technique:

The PVD-based methods [13] enhanced the embedding capacity without introducing obvious visual artifacts into stego images. The method involves, finding the number of embedded bits from the difference between the pixel and its neighbor. The larger the difference, the more secret bits can be embedded. PVD Technique is more imperceptible than LSB-Technique (when having same embedding capacity).

C. Edge based:

As the name of this method [14] says, the information is actually hidden into the three LSBs

(Least Significant Bits) of those pixels of the cover image that makes the edge of the cover image. These edges are actually extracted using the edge detection algorithm.

D. Random pixel selection:

Using such method [15] , the pixels in which dat hiding occurs are selected randomly. There are various other algorithms to select such pixels at random. It can be pseudo-random generator, prime-sequence generator, Fibonacci series etc.

E. Pixel mapping method (MPP): A pixel with all its 8 counter- clockwise neighbouring pixels is selected so that they lie at the boundary of the image. Selection is done using some mathematical function on the intensity of the seed pixel and its 8 neighbors . Two or four bits of the secret message are then embedded in the neighbouring pixels based on some features of seed pixel [16].

F. Pixel connectivity:

A morphological processing starts at the peaks in the marker image and spreads throughout the rest of the image based on the connectivity of the pixels. Connectivity defines which pixels are connected to other pixels. A group of pixels that connected based on Connectivity types called an Object.

G. Pixel intensity or GLV:

The method [17] involves using the concept of odd and even numbers to map data within an image. This technique involves one-to-one mapping between the binary data and the selected pixels (selection depends upon some mathematical function) in an image by modifying the gray level values of these pixels.

H. Texture based:

This technique [18] involves dividing the message image and the cover image into blocks of specific size. Now, it aims to find that block from the cover image whose texture pattern is most similar to the block of the message image so as to give the least distortion feature.

I. Histogram based:

The message to be hidden is embedded inside the image histogram [19]. Pairing of peak points and zero points is done to achieve low embedding distortion with respect to providing low data hiding capacity.

J. Spread spectrum: The core of spread spectrum image steganography (SSIS) [20] is a spread spectrum encoder. These devices work by modulating a narrow band signal over a carrier. The carrier's frequency is continually shifted using a pseudorandom noise generator feed with a secret key. In this way the spectral energy of the signal is spread over a wide band, thus decreasing its density, usually under the noise level. To extract the embedded message, the receiver must use the same key and noise generator to tune on the right frequencies and demodulate the original signal. A casual observer won't be able even to detect the hidden communication, since it is under the noise level.

K. Palette based: The palette based image steganography [21] is similar to the commonly used LSB method for 24 bit colour images (or 8 bit grayscale images). After the palette colours are sorted by luminance, it embeds the message into the LSB of indices pointing to the palette colours. Message recovery is simply achieved by selecting the same pixels and collecting the LSBs of all indices to the ordered palette.

7.2 Transform domain techniques

The transform based techniques instead of embedding the data into the bits of the pixels intensities directly, image first get transformed using domain like frequency domain (DCT, DFT), wavelet domain (DWT)etc and then data is hidden behind the transformed image and then the image is retransformed. Since it is a complex way of hiding secret information behind image, image manipulation becomes harder for the warden. The various transform domain techniques are:

A. Discrete cosine transform (DCT) based technique:

DCT [22] is a general orthogonal transform for digital image processing and signal processing. Important features include high compression ratio, small bit error rate, good information integration ability and good synthetic effect of calculation complexity. DCT allows an image to be broken up into different frequency bands namely the high, middle and low frequency bands to embed some watermarks. Mostly the middle frequency bands are chosen because it does not scatter the watermark information.

B. Discrete fourier transform (DFT) based technique: The DFT based technique is similar to the DCT based technique but it utilizes the Fourier transform instead of cosine which makes it lack resistance to strong geometric distortions. Though, it increases the overall complexity of the process**.**

C. DWT based: A wavelet is a small wave which oscillates and decays in the time domain. The Discrete Wavelet Transform (DWT) [23] is a relatively recent and computationally efficient technique in computer science. Wavelet analysis is advantageous as it performs local analysis and multi-resolution analysis. To analyze a signal at different frequencies with different resolutions is called multi-resolution analysis (MRA). This method transforms the object in wavelet domain, processes the coefficients and then performs inverse wavelet transform to represent the original format of the stego object.

D. IWT based: Filters like DCT, FFT have floating point coefficients. Thus, when the input data consist of sequences of integers (as in images), the resulting filtered outputs no longer consist of integers, which doesn't allow perfect reconstruction of the original image. However, with the introduction of Wavelet transforms that map integers to integers the output can be completely characterized with integers [24].

E. DCVT based: Curvelet transform is the new member of the evolving family of multiscale geometric transforms [25]. Since it represents edges better than Wavelet, Curvelet transform offers an effective solution to the problems associated with image steganography using Wavelets and DCT (Discrete Cosine Transform).

VIII. CONCLUSION

The detailed description of Image steganography has been presented in this review. There exist various approaches for hiding secret information behind the cover image. Every detail regarding what type of image format is best suited and depending upon what type of requirement can decide that a particular steganographic algorithm is good or not. On the other hand, three different levels are used to tell the strength and weakness of a steganographic algorithm in particular parameter or requirement. Different techniques to embed data inside the cover image have also been explained to the reader. The paper emerges with the idea to think about what types of factors should be kept in mind in order to come up with a new steganographic algorithm. The analysis shows that the transform domain techniques are best for the attack resilient system with relatively lower data capacity and higher complexity while the spatial domain is best for limited complexity systems and also provides greater options for techniques selection for the systems with limited computational power.

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