BIT INVERTING MAP METHOD FOR IMPROVED STEGANOGRAPHY SCHEME

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To my virtuous professors who taught me in a truthful, fair, and honorable way

To my colleagues in the Universiti Teknologi Malaysia

To all those who contributed to the success of this research

I dedicate this research to you

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ABSTRACT

Achieving an efficient and accurate steganography scheme for hiding information is the foremost priority in the information and communication technology era. The developed scheme of hiding the secret message must capable of not giving any clue to the adversaries about the hidden data. In this regard, enhancing the security and capacity by maintaining the Peak Signal-to-Noise Ratio (PSNR) of the steganography scheme is the main issue to be addressed. This study proposes an improved Bit Inverting Map (BIM) method and a new scheme for embedding secret message into an image. This newly developed scheme is demonstrated to increase the security and capacity to resolve the existing problems. A binary text image is used to represent the secret message instead of normal text. Three stages implementations are used to select pixels before random embedding to select block of (64×64) pixels, followed by the Knight Tour algorithm to select sub-block of (8×8) pixels, and finally by the random pixels selection. The proposed BIM is distributed over the entire image to maintain high level of security against any kind of attack. One-bit indicator is used to decide if the secret bits are inserted directly or inversely, which enhanced the complexity of embedding process. Color and gray images from the standard dataset (USC-SIPI) including Lena, Peppers, Baboon, and Cameraman are implemented for benchmarking. Self-captured images are used to test the efficacy of the proposed BIM method. The results show good PSNR values of 72.9 and these findings verified the worthiness of the proposed BIM method. High complexities of pixels distribution and replacement of bits will ensure better security and robust imperceptibility compared to the existing scheme in the literature.

ABSTRAK

Mencapai skema steganografi yang cekap dan tepat untuk menyembunyikan maklumat adalah keutamaan yang paling utama dalam era teknologi maklumat dan komunikasi. Skema yang dibangunkan untuk menyembunyikan mesej rahsia mestilah mampu untuk tidak memberikan apa-apa petunjuk kepada musuh mengenai data tersembunyi. Dalam hal ini, meningkatkan keselamatan dan kapasiti dengan mengekalkan Nisbah Tertinggi Isyarat-Hingar (PSNR) skema steganografi adalah isu utama yang perlu diberi perhatian. Kajian ini mencadangkan kaedah penambahbaikan Peta Bit Menyongsang (BIM) dan skema baru untuk menerapkan mesej rahsia ke dalam imej. Kaedah baru ini dibangunkan untuk meningkatkan keselamatan dan keupayaan bagi menyelesaikan masalah yang sedia ada. Satu imej teks binari dan bukannya teks normal digunakan untuk mewakili mesej rahsia. Tiga tahap pelaksanaan digunakan untuk memilih piksel sebelum pembenaman rawak untuk memilih blok piksel (64 × 64), diikuti oleh algoritma *Knight Tour* bagi memilih sub-blok piksel (8 × 8), dan akhirnya pilihan piksel secara rawak. Kaedah BIM yang dicadangkan diserakkan ke seluruh imej untuk mengekalkan tahap keselamatan yang tinggi terhadap sebarang serangan. Penunjuk satu-bit digunakan untuk membuat keputusan jika bit rahsia dimasukkan secara langsung atau secara songsang, iaitu bertujuan meningkatkan kerumitan proses pembenaman. Warna dan imej kelabu dari set data piawai (USC-SIPI) termasuk *Lena, Peppers, Baboon* dan Jurukamera dilaksanakan sebagai penanda aras. Imej kendiri digunakan untuk menguji keberkesanan kaedah cadangan BIM. Hasil kajian menunjukkan nilai-nilai PSNR yang baik iaitu 72.9, dan penemuan ini mengesahkan kepentingan kaedah BIM yang dicadangkan. Kerumitan taburan piksel yang tinggi dan pengantian bit menjamin keselamatan yang terbaik dengan ketegaran yang berkualiti berbanding skema sedia ada dalam kesusasteraan.

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LIST OF ABBREVIATIONS

BIM	-	Bit Inverting Map
DCT	-	Discrete Cosine Transform
DE	-	Difference Expansion
DFT	-	Discrete Fourier Transform
EMD	-	Exploiting Modification Direction
FFT	-	Fractional Fourier Transform
GA	-	Genetic Algorithm
HDWT	-	Haar Discrete Wavelet Transform
HVS	-	Human Visual System
JPEG	-	Joint Photographic Experts Group
KT	-	Knight Tour
LSB	-	Least Segnificant Bit
LZW	-	Lempel Ziv Welch
MSB	-	Most Significant Bit
OPAP	-	Optimal Pixels Adjustment Process
PDF	-	partial difference equation
PND	-	Random
PoV	-	Pairs of Values
PSNR	-	Peak Signal-to-Noise Ratio
PVD	-	Pixel Value Differencing
RGB	-	Red, Green and Blue
RPE	-	Random Pixel Embedding
SIS	-	Steganography Image System
TCP/IP	-	Transmission Control Protocol/Internet Protocol
WFFT	-	Weight Fractional Fourier Transform

LIST OF SYMBOLS

e -   Exponential

u -   New x Pixel

v -   New y Pixel

π -   Mathematical Constant

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CHAPTER 1

INTRODUCTION

1.1   Introduction

In the last decade, problems related to the security of hiding information has received considerable attention. Lately, security of hiding data in images has become attractive to the vision community due to widespread application domain in diversified fields of studies particularly in image security and steganography.

Current study addresses some key issues related to security in terms of understanding related to the great unsolved problems of data embedding in an image. A comprehensive solution is expected to open tremendous application possibilities ranging from medical (Aroukatos *et al*., 2016; Fathimal and Rani, 2016) to military (Tuncer and Avci, 2016).   Presently, the major difficulties relate to the lack of (a) increasing the security of data hiding, (b) payload capacity because the existing one typically has limited data capacity to embed, and (c) maintaining the robustness of the system while increasing the security. The three main issues illustrate in Figure 1.1.
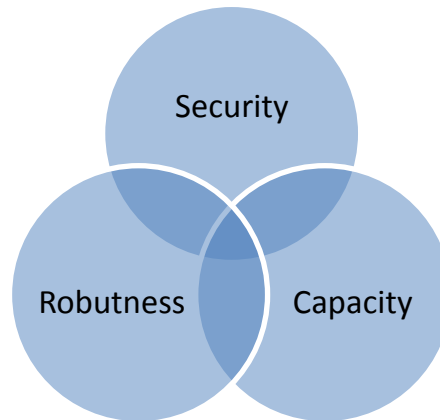
Figure 1.1   Three key issues for information hiding

Since the rise of the internet one of the most important factors of information communication is the security of the information. Many methods have been developed in the literature in order to keep the message secret. Information hiding is the practice of concealing messages or information within other non-secret images or data, and it is synonymous with the word steganography.

There are many types of information hiding, as information can be hidden in a text, image, video, audio, or protocol. Each has its pros and cons. On the other hand, most media on the internet use images due to availability and ease of use (Singh *et al*. 2016). Thus hiding information in the image gains more facilities in terms of reliability, capacity, and the ability to hide information without being observed by intruder. Hiding text into images is called steganography, and there are many types of data to be hidden in different host media as shown in Figure 1.2.
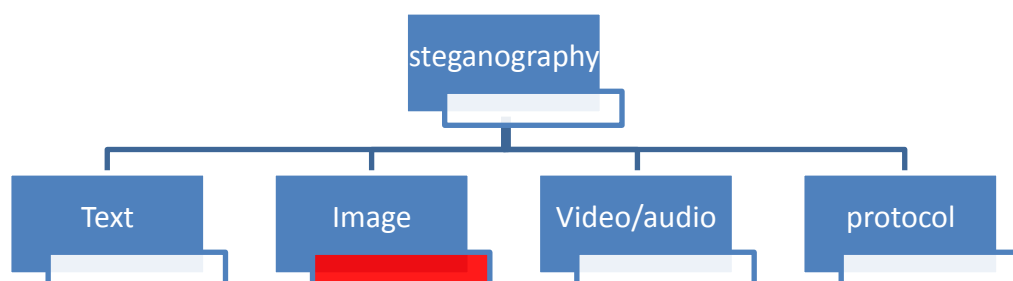
Figure 1.2   Steganography domain

Steganography is the art of hiding sensitive data like text within media in a manner that is not visible or noticeable. Images are used as hosting media because of the ability to absorb large amounts of data and the difficulty of intruders to observe this data.

1.2 Problem background

Most of the effort devoted to hiding information in order to secure the system as best as possible in a way that keeps the image that contain the hidden message is eye-catching. Several approaches are proposed for image steganography (Gupta, 2015; Rai. *et al*., 2015). However, hiding data in carrier image has attracted great interest in terms of security; in contrast, other media like text and protocol are mostly ignored. Security, capacity, and embedding methods remain far from being achieved and research in these fields is ongoing. These issues are discussed in the following sections.

1.2.1 Security Issues in Steganography

Currently, the internet plays a vital role in the field of data transmission and communication. More than ever, data security is required due to privacy issues, as information transmitted over the World Wide Web is sensitive including medical diagnostics, financial, and military information, thus the need for some mechanism for protection from outsiders or intruders. (Rai (2015), Sedighi (2016), Rani (2016)).

Due to the popularity of using images in many applications, images have become a very accepted choice among other existing media to host the secret message. Security of the data embedded based on the method that handles the secret message inside the cover image and the security issue still remains an outstanding challenge. At present attackers have become more expert and have more knowledge about security, thus finding or developing new techniques has become a problem that deserves attention in order to safeguard the sending of information between acknowledged parties Amritha *et al,.* (2016).

1.2.2   Embedding Method Issues in Steganography

Reducing the amount of secret message embedded to the system has led to improve the security of a steganography system via reducing bits in the cover image. This happen when secret bits are significantly less than which available bits in the hosting image Al-Dmour and Al-Ani, (2016); Kuo, (2016). The researches on steganography and steganalysis have attracted more interest during past decade Vikranth *et al*., (2015); Rai *et al.,* (2015). Despite the fact that steganography system only considers the bits to be of little importance, there remains a trace that can be detected by attacks. From this point of view it is easy to imagine the importance of embedding method and how users should be cautious.

Many of the methods introduced in literature regarding embedding secret message all follow the same direction in terms of placing of embedding in digital hosting image. The best place to embed a secret in an image is Least Significant Bit (LSB) (Akhtar, 2016). There are many advantages for using LSB e.g. simple to understand and easy to use, and the main issue is that LSB cannot be noticed by the naked eye and allows high payload capacity for secret message. Each method suggested in literature has advantages and disadvantages in terms of special domain, and one of these methods is LSB Shelke and Jagtap, (2015) as shown in Figure 1.3.
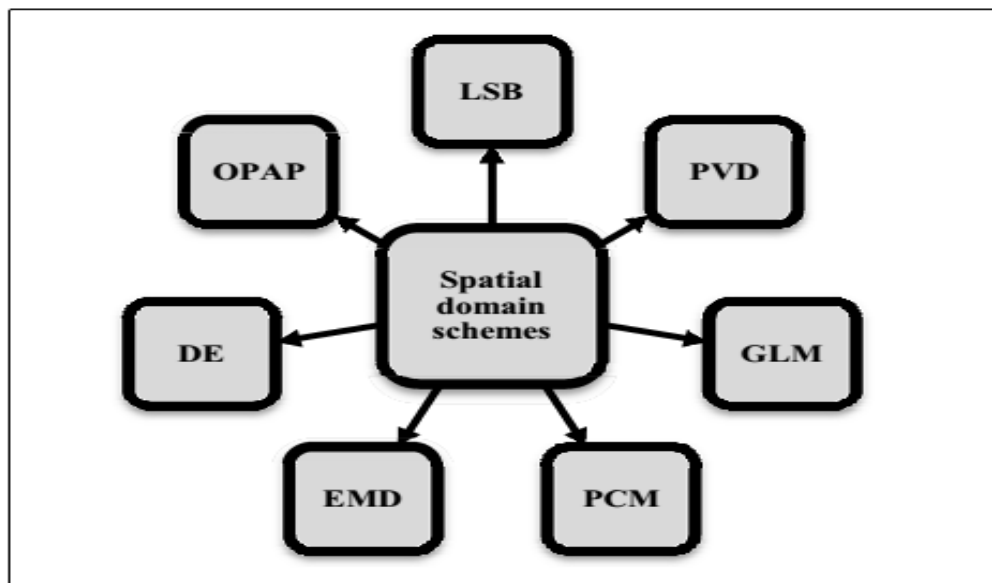
Figure 1.3   Embedding methods for spatial domain

1.2.3   Capacity

A good steganography technique aims to provide capacity, which is defined as the maximum secret information that can be embedded into cover image (Akhtar, *et al.,* 2016). One of the weaknesses effecting steganography system is capacity. In the proposed system, LSB method is used for embedding the data. This method actually uses only one bit of the pixel to embed in. To solve this problem Huffman coding Sun, (2016) is used to compress the secret message before embedding. Increasing the capacity payload in cover image is critical, because when evaluating the method by one of the staganalytic methods (chi-square) which perform statistical analysis on embedding data, increasing capacity makes the stego image weak against attacks. Two types of attack considered in this study are very important. First, Chi-square X^2 (Al-Dmour, and Al-Ani, 2016) where an attack is sensitive to payload capacity because statistical analysis of the image, and the second is Human Visual

System (HVS) Zargar and Singh, (2016) where an attack is sensitive to exchanging in LSB. Increasing secret data payload capacity in stego image also effects the robustness of the system. In conclusion, the background problem of increasing the capacity of secret message is no easy task and a balance must be kept between security and robustness.

1.3   Steganography model

Steganography refers to the method used to hiding data in digital hosting media to hide the presence of the information. Stego image is the image with hidden information inside while cover image is the image without hidden information and ready to handle it. Some security problems arise with steganography for illegal data embedded via terrorists when the terrorist information used is spread around (Amritha *et al*., 2016; Li *et al.,* 2011). Steganography in the modern day refers to data or files that have been hidden inside digital image which cannot be detected by human senses. There are two parties using steganography; the sender which sends the stego image with stego key and the receiver which extracts this stego image according to information inside stego key (Seyyedi *et al*., 2016). A good model is one that has maintained the stego image and received this stego image without any doubt of attack and intrusion. Figure 1.4 shows the model of steganography.
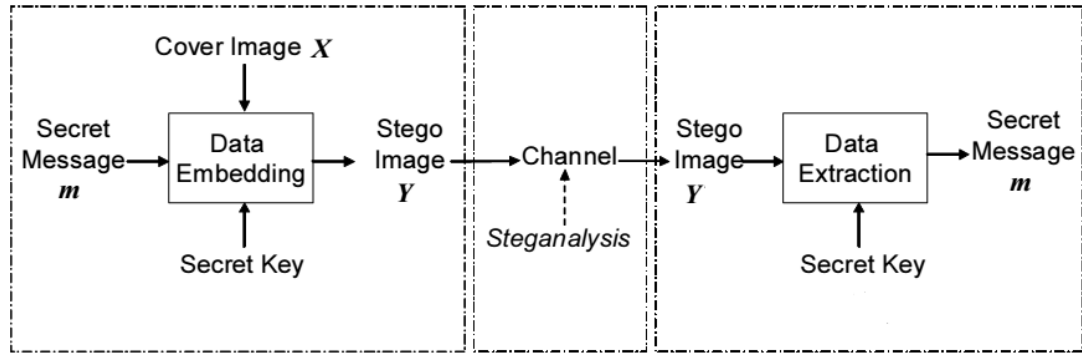
Figure 1.4   The model of steganography and steganalysis

Adoption of a strong and safe method for embedding data in stego image makes the steganography model more robust and suitable. Secret key, sometimes called stego key, includes all the information needed for extracting secret data from stego image. Any weakness in one stage of this model will render the entire model ineffective.

1.4   Problem Statements

Some researchers in the literature introduced different methods for hiding secret information in image, or in other words, new steganography system has been developed (Hamed, *et al.*, 2016; Rai *et al.*, 2015). This research aims to develop method based on Bit Inverting Map (BIM) for hiding data in an image. In this research, the focus is on embedding secret message in reliable hosting image. There are three main problems:

     i.   How to increase the capacity of the system while maintaining the Peak Signal-to-Noise Ratio (PSNR).

    ii.   How to embed the payload capacity of secret message.

   iii.   How to maintain the robustness and imperceptibility of the system.

In order to answer these primary questions, a set of secondary research questions that address the problem in detail are posed as follows:

    i.   How to design and develop secure approach using Bit Inverting Map which provides high hiding capacity and security?

    ii.   How to improve the steganography system to achieve high capacity?

    iii.   How to evaluate and test steganography system using standard and self-created images.

This study proposes use improved Bit Inverting Map (BIM) for embedding the secret message in an image. Fibonacci decomposition is used to increase both capacity and robustness of the system. To increase the capacity of embedding secret message, Huffman coding is used to compress the message 30% before embedding. Three types of evaluation are used to evaluate the results including PSNR, Chi-square attack, and HVS attack, all with different criteria.

1.5   Objectives of the Study

The main goal of this research is to improve the security of hiding information in an image by using a new embedding method based on BIM. Therefore, this thesis is carried out in order to fulfil the following objectives:

    i.   To design new hiding method of improved steganography scheme for embed secret message into the image.

    ii.   To propose Bit Inverting Map method for increasing payload capacity while maintaining the PSNR.

    iii.   To integrate random and knight tour algorithms to improve security.

iv.   To evaluate the improved Bit Inverting Map using standard dataset to benchmark with literature and to test the Bit Inverting Map with new images taken by mobile.

Due to the spread of Internet and its applications that require security information and widely used digital images through the internet, developing a new security system is of utmost necessity especially with the applications that use images. It is worth developing such a system that considers the use of highly secret message capacity inserted in trusted media. Many applications at the present time used images as a main factor, and for this reason, this research tries to come up with a new technique to serve these applications.

1.6   Scope of the Study

This research focuses on introducing the best security improved Bit Inverting Map in terms of steganography and maintaining of the PSNR, robustness, and imperceptibly. Some existing techniques are used with the improved Bit Inverting Map. The scope of this research covers the following points:

i.   Improved Bit Inverting Map focus is on embedding text files in image media with condition of steganography.

ii.   Manipulation of the image such as rotation, zooming, scaling, etc. is not considered in this study

iii.   Improved Bit Inverting Map is evaluated using standard dataset (colour and gray) such as Lena, Lake, Cameraman, Baboon, Peppers, Barbara, and Elaine. All images are on a scale of 512 × 512 pixels.

iv. Improved Bit Inverting Map has been tested using images taken by mobile phone such Masjid, UTM gate, and Santa Claus.

v. Results are evaluated using PSNR, Chi-square attack, and Human Visual System (HVS) attack.

1.7 Significance of the Study

It is hoped that the improved Bit Inverting Map will overcome the challenges of existing steganography system and remain consistently reliable. It will be able to increase the security of such system and high PSNR at the same time. Furthermore it is expected to minimize problems associated with payload capacity dependency. Existing studies on steganography system revealed some methods that are lacking in data embedding (Vikranth, *et al.* (2015) and Rai, *et al.* (2015)). However, proposed method that show encouraging result in terms of security and capacity. Currently, numerous applications aim to use image steganography especially in security, medical, military, and industries fields. Security, capacity, and robustness are the main weaknesses in any steganography system and the improved Bit Inverting Map is believed to overcome such shortcoming.

1.8   Thesis Organization

This thesis is organized in six chapters excluding the introductory chapter as follows: In Chapter 2, we present an overview of the data hiding technique in general followed by principles of steganography techniques and some classification on image hiding. The advantages and weaknesses of each study are discussed. In Chapter 3, the research methodology and the full framework and explained in detail. In Chapter 4, we explain the evaluation criteria for steganography system and PSNR evaluation. Chapter 5 presents a results of chi-square attack and HVS attack and all the results of the proposed methods are evaluated in this chapter, whereas in Chapter 6, we summarize our contributions and discuss limitations and future work.

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