ROBUST RECURSIVE WATERMARKING TECHNIQUE IN DISCRETE WAVELET TRANSFORM

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To my beloved parent
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who taught me never give up , supporting me spiritually throughout my life and
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ABSTRACT

Presently, data sharing and information searching is easier to perform on the internet and has resulted in the digital contents becoming widely available and easily accessible. However, many users abuse these contents through piracy and forgery practices, thus there is a need for copyright protection which can be achieved with digital watermarking. A robust digital watermark should be able to withstand intentional and unintentional attacks but the various available techniques for watermarking have yet to attain the best defence performance against these attacks. This study proposed an alternative watermarking technique referred as Recursive Watermarking Technique (RWT) on digital image content where multiple watermarks are embedded in the host image. In this technique, multi-segmentation was carried out. Embedding and extracting of watermark was performed in the Discrete Wavelet Transform (DWT) domain, after the image segmentation process. Besides that, reconstruction image stage was carried out to get the most robust watermark. These multiple watermarking processes in RWT have the capability to minimize the effect of the attacks. The robustness of RWT against attacks was tested against motion blur, Gaussian noise (1%, 5% and 10%), salt and pepper noise (0.02), cropped image, JPEG compression, intensity adjustment, sharpen and mosaic tile attacks. The results showed that RWT has a higher NC value which is equal to 1. At the same time, Gaussian blur, salt and pepper noise (0.05 and 0.1), and histogram equalization attacks gained an NC value of 0.99. These results imply that RWT is able to withstand the attacks successfully and performs better than the other known techniques.

ABSTRAK

Pada masa kini, perkongsian data dan pencarian maklumat adalah lebih mudah untuk dilaksanakan di atas talian dan ianya menyebabkan kandungan digital boleh didapati secara meluas dan mudah diakses. Walau bagaimanapun, ramai pengguna telah menyalahgunakan kandungan ini melalui cetak rompak dan amalan pemalsuan. Oleh itu keperluan untuk perlindungan hak cipta perlu diadakan dan ini boleh diperolehi dengan teknik tera air digital. Tera air digital yang teguh sepatutnya dapat menahan dari serangan sengaja dan tidak sengaja. Walaupun terdapat pelbagai cadangan teknik tera air yang telah dibangunakan tetapi ianya masih belum mencapai prestasi pertahanan terbaik terhadap serangan. Oleh itu, kajian ini mencadangkan teknik alternatif tera air yang dirujuk sebagai Teknik Rekursi Tera Air (RWT) untuk kandungan imej digital di mana beberapa tera air dibenamkan dalam imej hos. Dalam teknik ini, segmentasi berganda telah dijalankan. Pembenaman dan pengekstrakan tera air dilaksanakan di domain *Discrete Wavelet Transform* (DWT), ke dalam dan dari segmentasi imej. Selain itu, peringkat pembinaan semula imej dijalankan bagi mendapatkan tera air yang paling teguh. Proses tera air berganda yang dilaksanakan dalam RWT mempunyai keupayaan untuk mengurangkan kesan serangan. Keteguhan RWT terhadap serangan telah diuji terhadap serangan gerakan kabur, gangguan Gaussan (1%, 5% dan 10%), gangguan garam dan lada (0.02), imej timbul, mampatan JPEG, pelarasan kekuatan, mengasah dan jubin mozek. Hasil kajian menunjukkan bahawa RWT mempunyai nilai korelasi normal (NC) yang tinggi iaitu sama dengan 1. Pada masa yang sama, serangan Gaussan kabur, gangguan garam dan lada (0.05 dan 0.1), dan penyamaan histogram telah menghasilkan nilai NC 0.99. Keputusan ini menunjukkan bahawa RWT mampu menahan serangan dengan jayanya dan tahap ketahanan adalah lebih baik daripada teknik-teknik tera air lain yang diketahui.

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LIST OF ABBREVIATIONS

BMP	Bitmap image
CDMA	Code Division Multiple Access
CPU	Central Processing Unit
DCT	Discrete Cosine Transform
DFT	Discrete Fourier Transform
DWT	Discrete Wavelet Transform
GHz	Gigahertz
HH	High-High Sub-band
HL	High-Low Sub-band
HPF	High Pass Filter
HVS	Human Visual System
IDWT	Inverse Discrete Wavelet Transform
JPG/JPEG	Joint Photographic Expert Group
LH	Low-High Sub-band
LL	Low-Low Sub-band
LPF	Low Pass Filter
LSB	Least Significant Bit
MRA	Multi-Resolution Analysis
MRR	Multi-Resolution Representation
MSB	Most Significant Bit
MSE	Mean Square Error
NC	Normalization Correlation
PC	Personal Computer
PNG	Portable Networks Graphic
PSNR	Peak Signal to Noise Ratio

QSWT	Qualified Significant Wavelet Tree
RAM	Random Access Memory
RGB	Red Green Blue
RWT	Recursive Watermarking Technique
SH	Sub-Host
TIF/TIFF	Tagged Image File Format

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CHAPTER 1

INTRODUCTION

1.1 Overview

Internet is one of the most common technologies that have been used for various purposes, such as for sending, transferring and publishing data or information. In addition, with multimedia technology advancement, data can be presented in digital form. This in turn has created a situation where internet and multimedia technologies have become daily desires. Even though, the transition of the data from analog to digital is a brilliant idea, but the onset of this technology makes the data exposed to the threat. There are many types of threats such as duplication, manipulation, modification and distribution. All the threats would decrease the integrity and security of information. To improve the integrity and security of information, watermarking system is regarded as a reliable way whereby many efforts have been exerted by researchers in order to get fully acquainted with it. However, the requirements for the watermarking are significant to be discussed. Based on (Lee and Lee, 1999; Chen and Chen, 2009; Mohamed, 2009; Deng and Jiang, 2012; Shekhawat *et al.*, 2012) good watermark must fulfil the requirement as mentioned below:

i. Robustness: The ability to recover the watermark after performing various signal processing attacks on watermarked image.

ii. Readability: The mobility of the information in the watermark system ought to be pretty rapid, statistically organized, with a sufficient amount of data to define the ownership and sound copyright.

iii. Imperceptibility: The perceive quality of the image should not be degraded and does not introduce any perceptible artifacts into the original image by embedding process.

iv. Security: Only permitted users are allowed to access watermark data.

There are several approaches of increasing the watermarking technique which is adjusting the robustness and imperceptibility of the watermark.

1.2 Problem Background

Unfortunately, ICT technology has led to the unauthorized replication problem, when the usage of the internet had been misused by irresponsible persons for their own benefits or with intention of sabotage. These types of irresponsible persons are often referred as hackers; they will duplicate, manipulate and distribute secure data or information without permission of the owner. Misuses of this precious data through the internet without permission will directly breach the owner's copyright and the integrity of their data. With the advanced technology the images are difficult to distinguish from the original. This has a serious impact on copyright and data integrity. In order to overcome this issue, digital watermarking techniques have been proposed by many researchers. Image copyright protection is done by hiding appropriate information in the original image to declare rightful ownership. This mechanism is being provided by digital image watermarking. Any insertion and extraction of the copyright information which is referred as watermark in digital contents can be used to prove the ownership of the copyright holder (Lee and Jung, 2001; De Vleeschouwer *et al*., 2002; Santoso, 2004;

Brannock and Weeks, 2006; Furht and Kirovski, 2006; Lee *et al*., 2006; Gunjal and Manthalkar, 2010; Gupta and Jain, 2010; Gunjal and Mali, 2011; Hui *et al.*, 2011; Khalili, 2011; Saaid *et al.*, 2011; Deng and Jiang, 2012; Shekhawat *et al.*, 2012).

The digital watermarking technology proposed methods are still an ongoing research as there are various techniques that can be implemented to increase the strength of the watermark and thus in turn the security of the digital media. Watermarking technology can be implemented in two different domains which are spatial and frequency. In the spatial domain, the watermark is inserted by directly modifying the pixel values of the host image. These spatial domains are simple and easy to implement, but they are not robust against attacks (Shih, 2008). In the frequency domain, the watermark is inserted in the coefficients of the Discrete Cosine Transform (DCT), Discrete Fourier Transform (DFT), or Discrete Wavelet Transform (DWT). The frequency domain schemes are more complicated, but they are more robust and resistant to various attacks (Furht and Kirovski, 2006; Shih, 2008). The advantages of frequency transform domain have led many researchers to propose several techniques using it. The most popular technique in this domain is DWT. The advantages of using DWT are minimal amounts of visual degradation, highly resistant to compression and noise, and also have high imperceptibly.

The robustness is one of the requirements for good watermark. Robustness refers to the ability to recover the watermark after performing various signal processing attacks on watermarked image. It is another issue in watermarking, whereby an embedding process should not introduce any perceptible artifacts into original image and should not degrade the perceive quality of image. The degree of watermarking robustness differs from one signal processing to another. To get robustness watermark, Mintzer and Braudaway (1999) once asked: *If one watermark is good, are more better?* From the statement, it can be concluded that the robustness of watermark do not rely on one watermark only, it can be more than one watermark. It means multiple watermarks are better choices than one watermark. According to Xioa and Wang (2006), multiple watermarking is an

embranchment of digital watermarking, which has many desirable characteristic that common singular watermarking does not have, such as robustness to union attacks. There are several multiple techniques that had been proposed by another researcher. However, each of the proposed techniques had its own limitations or problems. Based on Mintzer and Braudaway (1999), Sheppard *et al.* (2001) and, Raval and Rege (2003), the existing multiple watermarking algorithms can be divided into three classes: re-watermarking, segmented watermarking and composite watermarking. Meanwhile, Toa and Eskicioglu (2004) embedded multiple watermarking using LL and HH sub-bands in single and second level DWT. Even though, the algorithm is robust against JPEG compression, blurring and Gaussian noise, the result for intensity adjustment and histogram equalization are below 0.75.

Xioa and Wang (2006) proposed a new method of multiple watermarking based on spread spectrum which has a good performance in validity and capacity. It uses three different types of watermark. The limitation of the method is the number of the watermark signal which can be embedded depends on the dimension of the projection vectors. A novel watermarking scheme using code division multiple access (CDMA) modulation was proposed by Chen and Chen (2009). DWT domain is being used to embed three different types of watermark. According to Li and Wang (2009) Bandelet was introduced by Mallat and Pennec, is a multiscale geometric analysis arithmetic to overcome the weakness of wavelet in high-dimensional data. These researchers proposed a novel multiple watermarking algorithm based on the second generation of bandelet transform. Two watermarks with different size are embedded into different frequencies of the image. The experimental results demonstrate that the watermarking algorithm has good performance both in invisibility and robustness. But certain attacks like cutting image totally make the extracted watermark worst.

Mnati (2010) proposed a multiple watermark image that embedded into the segmented blue part of the RGB host image using horizontal and vertical sub-band of Discrete Wavelet Transform (DWT). Performance in terms of robustness and

transparency of the watermarking scheme is obtained by embedding the maximum strength watermark while maintaining the perceptual lossless quality of the watermarked color image. The extracted watermarks are transparent and robust under common attacks. But, the Normalization Correlation (NC) value of cropping attack for this technique is 0.51 which is below of the acceptable value which is 0.75. It shows that each proposed technique has its own limitations and problems. From all the proposed technique mentioned, it shows that embedding multiple watermarks are better than one watermark.

1.3 Problem Statement

Several researchers have proposed digital image watermarking using Discrete Wavelet Transform (DWT), but the work of each one is distinct in terms of scopes and applications. The problem is how to embed a watermark in an image, which in a way can improve the robustness of the watermark. Most of work focus on capability of robustness and imperceptibility watermark. To find suitable locations for embedding watermark that can produce a robust watermark is one ways to improve robustness. Robust watermark must withstand from all attack that attempt to destroy it such as compression and noise.

From the previous studies, it can be found that efficient techniques must not only be effective but should also be affordable and simple to implement. By such, anyone who needs copyright protection can just use the techniques without hurdling over technical complexities. This is because high technology is not an added value unless it is user friendly. Thus, this study aims to provide an effective and yet simple and fast technique of copyright protection through the usage of recursive embedding. Recursive embedding is the process of embedding multiple identical watermarks in one image.

The hypothesis of this study can be stated as:

Recursive embedding watermarking can provide robust watermark against blurring, noise addition, cropped image, JPEG compression, intensity adjustment, histogram equalization, sharpen and mosaic tile.

1.4 Research Questions

The answers to the research questions outline the solution to the problem definition. The following research questions have been formulated:

i. How to calculate the sub-host images?

ii. Which pair of sub-band is providing better region?

iii. How to embed the watermark?

iv. How to extract the watermark?

v. Can extracted watermark withstand the attacks?

1.5 Research Aim

The aim of the research is to develop recursive watermarking using Code Division Multiple Access (CDMA) scheme in Discrete Wavelet Transform (DWT) domain to produce robust watermarks.

1.6 Research Objectives

Objectives served as a guide for the research in carrying out the fieldworks. There are three objectives identified in this research work, which are:

i. To formulate segmentation technique for recursive watermark embedding.

ii. To design recursive watermarking technique by implementing a CDMA scheme in Discrete Wavelet Transform (DWT) domain.

iii. To test the performance of recursive watermarking technique.

1.7 Research Scope

The scopes of this research are defined as follows:

i. Host image is grayscale image with size 512×512 pixels.

ii. Watermark image is black and white indexed image with size 128×128 pixels.

iii. All images are in .bmp format and dyadic squares size.

iv. Invisible watermark would employed.

1.8 Research Significance

This study discusses watermarking techniques for copyright protection. Watermarking technique was done to produce the robust watermark. Robust watermark was needed to overcome the issue of integrity and security information. The use of this technique was to deviate people from distributing, manipulating, modify or duplicating important information. Watermark also can be used to prove the ownership of the information. The information of watermark is created by a user. This study was also useful for future studies where it can be further enhanced with more security protections.

1.9 Organization of the Thesis

Chapter 1 describes briefly about the overview of the research and understanding of the research‘s problem background. It also includes the research‘s aim, scopes and objectives. Chapter 2 discusses about digital watermark, copyright protection, domain-based, watermarking technique, CDMA scheme, attacks and others. The methodology of this research and its executions of tasks are explained in detail in Chapter 3. It comprises of techniques, phases and stages that are systematically arranged whereby when executed, the objectives are successfully achieved. Both hardware and software specification requirements were discussed here.

Chapter 4 contains an explanation regarding the design and implementation of this study. Comparisons of sub-band are made to determine the best sub-band that offers the best region. These comparisons assist in making correct decision during designing and development of the proposed technique. The design of the proposed technique is also explained to give deeper understanding on how it works and how mathematical formulations are derived.

Chapter 5 explains the results of tests conducted on the proposed technique. These results are analyzed to determine the robustness capability of the proposed technique. The discussion is also done to conclude the proposed technique. Finally, Chapter 6 reviews and summarizes the whole studied. Future works are also recommended for further research.

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