ENHANCEMENT OF HUMAN VISION SENSITIVITY FEATURES FOR WATERMARKING PERFORMANCE USING WAVELET PACKET TRANSFORMATION

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To my beloved mother, father, wife and daughter

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ABSTRACT

Digital watermarking has grown extensively in the past few years. It embeds an invisible payload into digital content for the purpose of copyright protection, content authentication, forensic tracking and others. In some applications such as medical, military and law enforcement, even the imperceptible distortion introduced in the watermarking process is unacceptable. The important requirements are to make sure the embedding watermark is undetectable by the human eye, robust against common attack and capacity required for application. Most studies in the field of watermarking based on Human Vision Sensitivity (HVS) features only focus on embedding data into approximate coefficient and have not covered the best combination of the features. The purpose of this research is to determine the optimum region for embedding the watermark, and to enhance watermarking using HVS features. The enhancement approach of sensitivity watermarking is proposed in the process of embedding the watermarks while taking into consideration on maintaining the watermark from distortion. Before the embedding process, the host image is transformed using wavelet packet. The HVS features will try to identify the embedding region inside the coefficient block. In addition, this technique was based on testing 10 different percentages of coefficient regions. This approach exploits vision sensitivity features for embedding high rate payload data into a host image without distortion. Furthermore, the elimination of HVS features was tested to select the best combination of features in order to perform the watermark embedding. The results of this research show the highest embedding rate which is at 3.74 bpp with high imperceptibility rate at 37.1dB compared to others available schemes. The proposed scheme protects the watermark from destruction after attacks or a JPEG compression. It is also discovered that the middle percentages achieved high in capacity, robustness and visual quality. The HVS features also have a significant impact of increasing the performance of watermarking requirements especially on the capacity of embedded message bits.

ABSTRAK

Tera air digital telah berkembang secara meluas dalam beberapa tahun kebelakangan ini. Ia membenamkan sesuatu kandungan kepada kandungan digital bertujuan melindungi hak cipta, pengesahan kandungan, pengesanan forensik dan lain-lain. Di dalam sesetengah aplikasi seperti perubatan, tentera dan penguatkuasaan undang-undang, herotan yang tidak dapat dilihat adalah tidak boleh diterima sama sekali di dalam proses tera air. Syarat-syarat penting di dalam tera air digital adalah memastikan bahawa ia tidak dapat dikesan oleh mata kasar, teguh terhadap serangan lazim serta mengikut kapasiti yang dikehendaki oleh aplikasi. Berdasarkan ciri-ciri Kepekaan Penglihatan Manusia (HVS), sebahagian besar kajian yang dijalankan dalam bidang tera air hanya memberi tumpuan dalam membenamkan data dan bukan terhadap gabungan ciri-cirinya terbaik. Tujuan kajian ini adalah menentukan kawasan yang optimum untuk membenamkan tera air serta mempertingkatkan fungsinya menggunakan ciri-ciri HVS. Untuk mengekalkan tera air dari sebarang kecacatan, pendekatan meningkatkan kepekaan tera air dicadangkan supaya dilakukan ketika proses pembenaman. Sebelum proses pembenaman, imej hos diubah menggunakan paket gelombang**.** Berdasarkan kepada ciri-ciri HVS, ia akan cuba mengenal pasti kawasan pembenaman pada blok pekali. Teknik ini adalah berdasarkan ujian yang dijalankan terhadap 10 peratusan berbeza pada kawasan pekali. Pendekatan ini mengeksploitasikan ciri-ciri sensitiviti penglihatan dalam pembenaman data muatan pada kadar yang tinggi ke dalam imej hos tanpa sebarang herotan. Penghapusan ciri-ciri HVS telah diuji untuk memilih gabungan ciri-ciri yang terbaik untuk pembenaman tera air. Hasil kajian ini menyumbang kepada kadar tertinggi pembenaman iaitu pada 3.74 bpp dengan kadar tinggi yang ketara iaitu pada 37.1dB berbanding skim-skim lain. Skim yang dicadangkan melindungi tera air daripada kerosakan selepas serangan atau mampatan JPEG. Dalam pada itu, peratusan tengah juga didapati mencapai tahap tinggi dari segi kapasiti, keteguhan dan kualiti visual. Ciri-ciri HVS juga memberi kesan yang ketara kepada prestasi tera air terutamanya terhadap kapasiti bit pesanan yang dibenamkan..

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Improved-WHVS	-	Improved Watermarking Human Vision Sensitivity
BCR	-	Bit Correct Rate
BER	-	Bit Error Ratio
BP	-	Back propagation
CSF	-	Contrast Sensitivity Function
dB	-	The decibel
DCT	-	Discrete Cosine Transform
DFT	-	Discrete Fourier Transform
DWT	-	Discrete Wavelet Transform
FIS	-	Fuzzy Inference System
HVS	-	Human Vision Sensitivity
JND	-	just-noticeable difference
LSB	-	Last Significant Bit
MSE	-	Mean Square Error
NC	-	Normalized correlation
NVF	-	Noise Visibility Function
PN	-	Pseudorandom Noise
PSNR	-	Peak Signal-to-Noise Ratio
RBF	-	Radial Basis Function
ROI	-	Region of Interest
SSIM	-	Structural Similarity
SVD	-	Singular Value Decomposition
WPT	-	Wavelet Packet Transform

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CHAPTER 1

INTRODUCTION

1.1 Overview

Nowadays, networks become faster and easier due to the rapid growth of multimedia contents in a digital form, the speedy advancement of the internet technology and the magnitude increasing of internet users, the reproduction, stored, transmitted, manipulation and the distribution of digital multimedia (Lang et al., 2012). It also gives cultivate an extensive range of application in entertainment, education, medicine, the media, and the military, among other fields (Wu and Shih, 2009; Rawat and Raman, 2012b).

Due to the rapid growth of the Internet and the extensive evolution of digital technologies, the availability of digital multimedia content for example the images, audios and videos has sharply increased. As a result, digital multimedia data can be modified or tampered easily using a lot of image processing tools, whether it is malicious or not. Copying, editing and distributing the multimedia contents illegally have a direct and severe impact on the copyright owners as it is easy to be done. Therefore, content authentication and copyright protection for intellectual property are a very important issue (Rawat and Raman, 2012a).

In addition, digital watermarking has been considered an efficient method to ensure integrity and authenticity verification (El Hajji et al., 2012). Furthermore, the idea of using a digital watermark to detect and trace copyright violation has stimulated significant interests among engineers, scientists, lawyers, artists, and publishers, respect to compression, image-processing operations, and cryptographic attacks. It has become very active in recent years, and the developed techniques have grown and greatly improved (Wu and Shih, 2009).

Digital watermarking allows for the imperceptibly embed information (or digital signatures) in an original multimedia data. It has emerged as a widely approved approach for copyright protection and ownership identification (Tsai and Liu, 2011).

1.2 Background of the Research Problem

Since digital multimedia has become progressively advanced in the rapidly growing field of internet application, data security, including copyright protection and data integrity detection, it has become a huge concern. One of the keys to achieve information security is digital watermarking, which embeds hidden information or secret data in the image (Wu and Shih, 2007). This technology works as one of the suitable tools to identify the source, creator, owner, distributor, or authorized consumer of a document or images. It can also be used to detect if the document or image has been illegally distributed or modified (Wu and Shih, 2009).

On digital right management (DRM) systems, encryption and robust watermarking are two major schemes for applications in the digital encryption. For example, if one bit of the data has not been correctly received, all or parts of the received data cannot be decrypted, thus the contents become worthless (Huang et al., 2009a). In contrast to this, the robust watermarking, the watermarked contents and original media equivalent look similar or at least matching from a subjective point of view. Next, if there are parts that have been received incorrectly through the transmission, the received contents can be distinguished and as a result, maintaining the copyright (Wu and Shih, 2007; El Hajji et al., 2012).

One of the applications that mostly use watermarking is copyright protection. Classic digital copyright protection methods no longer satisfy the digital copyright protection needs (Wang and Niu, 2009). Therefore, it is necessary to manage and protect the copyright by using robust watermarking. The robust watermarking should survive any attacks against watermarked media. The issue of surviving against attacks need to be look upon to since it directly effects the copyright protection performance (Sudirman and Al-Jumeily, 2009).

In addition, copyright protection in digital watermarking technology is important. For example, it is important for watermarking to be applied on medical images. Medical image is one of the most important parts of patients' medical information. In medical images, the patients' data must be concealed in the images (Al-Qershi and Khoo, 2011). Thus, the capacity to hide should be high enough to adopt with the payload. (Kamstra and Heijmans, 2005). As a result, in addition to the robustness and imperceptibility, the capacity requirement should be taken into serious account.

It is generally agreed that there are three parameters or requirements of watermark; the quality of watermarked contents (imperceptibility), the ability to survive of extracted watermark after intentional or unintentional attacks (robustness), and the number of bits embedded (capacity). Figure 1.1 shows these parameters are conflicting with each other. Therefore, the performance is determined by these three parameters combined together then the trade-off must be searched (Huang et al., 2009b; Pan et al., 2009)

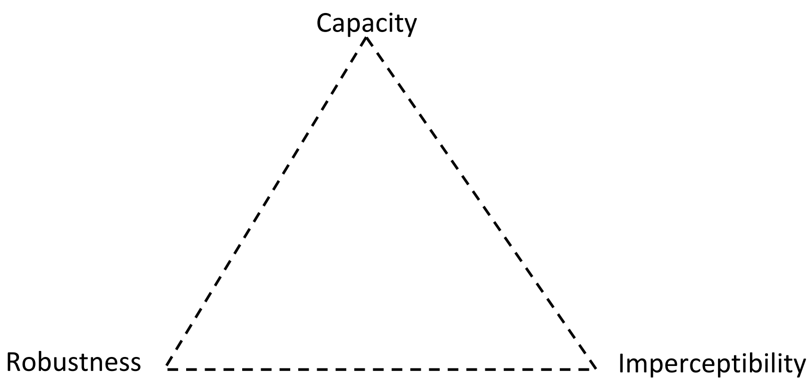

Figure 1.1 The relationship between imperceptibility, robustness and capacity (Huang and Wu, 2009)

Furthermore, the complexity of the relationship between these three watermarking requirements can be explained by giving examples as following: if the hidden watermark data is embedded into the least significant bit or higher, then frequency coefficient would slightly changed the image quality thus achieve imperceptibility. However, it would reduce the robustness since the watermarked image may experience filtering might result the hidden watermark to vanish. In the other hand, if embedding bits occurred into lower frequency coefficient, it would increase the robustness.

However, this would forfeit the imperceptibility (Phadikar and Maity, 2010; Huang et al., 2009b). In addition, if the capacity is determined; then embedding into higher frequency coefficients will meet the goal for imperceptibility. On the contrary, embedding into lower frequency coefficients will meet the goal for robustness (Hsiang-Cheh Huang, 2008). This is due to the low frequency coefficient to have more energy than high frequency coefficients while high frequency coefficients contain details of the image that makes it difficult for changes and weak against attacks.

For a well-designed watermark, it is necessary to take the human visual system into consideration (Doerr and Dugelay, 2003; Fang et al., 2011). The human visual system can make final evaluations of the quality of the processed and displayed images. Thus maintain the image quality and at the same time increase the probability of watermark detection after embedding the watermark (Li et al., 2013).

The human visual system provides a visual threshold based on the vision sensitivity characteristics and the image features itself. The human vision sensitivity model provides solutions for the trade-off problem between the watermarking requirements (Li et al., 2013). Digital watermarking utilizes Human Vision Sensitivity model to manage the embedding intensity and position of the watermark, while ensuring the optimal performance of watermarking (Li et al., 2012; 2013).

The most classic visual models are Watson's visual model in DCT domain (Watson et al., 1997) and Barni’s visual model in wavelet domain (Barni et al., 2001). Many image watermarking algorithms usually utilize visual models using human vision system (HVS) to increase the transparency and robustness (Ling and Lu, 2003; Zhenyu and Ngan, 2008; Bei and Yan, 2007; HU and ZHU, 2009). In contrast, these watermarking researches only partially use the results of the human visual system studies (Fang et al., 2011). According to Chi-Ming et al. (2008), research have designed an optimized watermarking scheme with two watermarking requirements; imperceptibility and robustness. This is while assuming the capacity needs to be fixed. This is because if the capacity is inconsistent, the watermarking algorithm design becomes much more complicated.

The capacity of watermarking is not included in the human visual system to improve the watermarking scheme. As mentioned by Fang and Chen (2009), one of the functions of the human vision system (HVS) is building a watermarking algorithm that has the ability to select the appropriate region to embed watermark information by the highest possible bit rate as well as the highest possible intensity that might give chance to achieve a good watermarking technique by enhancing the performance of requirements.

On the other hand, the human visual system model is applied in frequency domain and that gives an advantage than the other domains. Based on the HVS, the embedding process performs on the approximation coefficient or detail coefficient or both of them. However, most of the studies that used HVS model only used approximation coefficient for embedding data because they assumed the approximation coefficient contain important information than detail coefficient, (Foriš and Levický (2007); Motwani and Harris Jr (2009); Agarwal and Mishra (2010); Reddy and Varadarajan (2010)). But as according to (Ghannam and Abou-Chadi (2008)) that assumption is not true for a lot of signals. Approximation coefficient especially at the DWT is too small to contain enough information, while detail coefficients covered the large space in the image (Gui and Hong, 2005).

1.3 Problem Statement

Although several researches have been done on digital watermarking using the human visual system, but there are still several issues that have not been addressed yet. The human visual system is applied through Human Vision Sensitivity (HVS) or Just Noticeable Distortion (JND). The main issue has been focused on the conflict between imperceptibility, robustness and capacity embedding, which are the three watermarking requirements. In the digital watermarking, many researchers try to improve the imperceptibility and robustness, while assuming that the capacity to be constant. The second issue is about the human vision sensitivity features that should be used to evaluate the embedding process. The HVS features are employed to improve the watermarking performance especially on imperceptibility by exploring the region for embedding data according to the human eye sensitivity. It is then to determine the region whether it is less or high sensitive towards modifying. There are some common features used by researchers in the field of watermarking such as the brightness, texture, edge, contrast, entropy and frequency. It is presented in the HVS model in different studies with different combination. It is mean to improve the embedding process but the inability to emphasize what is the best combination of those features would result in its performance and the requirement for watermarking. Furthermore, the computing features do not give clear definitions of the feature itself. It is due to researchers that used local characteristic of the features as the definition while others used the intensity of pixels or coefficients as the definition. After a transformation, embedding coefficient in HVS will then be divided into two frequencies; low frequency (approximation) coefficient and high frequency (detail) coefficient. Most of the researchers deal with approximation coefficient or detail coefficient separately and received promising results in the field of imperceptibility and robustness, while both coefficients are given the largest space in the transformed image. The approximation coefficient should give better imperceptibility and more robustness.

1.4 Research Question

These are some questions that the current researcher tries to answer which are:

I. What is the best human vision sensitivity features combination that can improve the watermarking performance?

II. How can we employ the Human vision sensitivity to develop a new watermarking scheme to achieve better results of the watermarking requirements?

III. How to increase the number of bits that can be embedded in the host image?

IV. How can we get the optimal solution to reach better imperceptibility and more robustness?

1.5 Research Objective

The following objectives were attempted to be achieved in this study:

I. To determine the best HVS features combination that affects performance of watermarking technique.
II. To enhance a watermarking scheme based on the Human Vision Sensitivity, in order to achieve better imperceptibility and more robustness, simultaneously.
III. To increase the rate of capacity of embedded bits number in host image.

1.6 Research Scope

The scope of watermarking project is presented as below:

i. The study was delimited to the embedding and extracting process of watermarking. There were also only three watermarking requirements (imperceptibility, Robustness and Capacity) used to evaluate and target the enhancement of watermarking.

ii. The study involved some of the human vision sensitivity features that usually used in watermarking enhancement (brightness, frequency, texture, edge and contrast). In addition, wavelet packet transform used to transform the host image to transformation domain

iii. The host images with size 256x256 will be in grayscale format.

iv. The proposed scheme is implemented using a MATLAB program to illustrate the main idea involved in watermarking scheme.

1.7 Signification of study

The outcomes of this research would greatly contribute to watermarking technology. The present research has the following contributions:

i. Finding out the best combination of the human visual system in order to get the best results
ii. Enhance a watermarking approach based on the human vision sensitivity model which finds the best robustness against watermarking attacks while keeping the image quality.
iii. Improving the embedding capacity by identifying the best regions in order to embed a high embedding capacity using the Human Vision Sensitivity feature in both approximation and detail coefficients.

1.8 Thesis Organization

This thesis is presented in 6 chapters as follows:

Chapter 1: This chapter introduces the problem area and objective to be achieved.

Chapter 2: Literature review explains the digital watermarking fundamentals, various applications and characteristics of watermarking. It also explains and compares the embedding domains of watermarking, the Human Vision Sensitivity models depends on the watermarking are discussed in detail.

Chapter 3: The methodology used for applying the proposed method is presented. First it discusses the research phases (planning, analysis design and implementation). The proposed method are explained by starting from transforming the host image, watermarking generator, choosing the embedding coefficients, features elimination and enhanced WHVS. Finally, the testing and evaluating the proposed method are presented.

Chapter 4: It presents the enhanced WHVS design. It also shows the process from choosing the coefficient blocks, embedding process based on the proposed scheme and extracting process.

Chapter 5: Chapter 5 discusses results of the research on watermarking techniques based on human vision sensitivity (HVS) features. The embedding and extracting of watermarking is applied using the proposed method and results obtained are presented. The findings are clearly presented and explained according to watermarking requirements, analysis and discussions in order to get the answer to the research problem.

Chapter 6: It introduces review and summarizes the dissertation research. It identifies the main methods used and discusses their implications in the research. Next, the contributions of this research are discussed as well as the recommendation and future works.

1.9 Summary

This chapter provides an overview on the digital watermarking. In this chapter the background problems were discussed as well as the objectives and research questions.

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