
**UNIVERSITI PUTRA MALAYSIA**

# *AN EFFICIENT METHOD FOR AUDIO WATERMARKING USING SWT AND MEAN VALUE QUANTIZATION*

**BAYDAA MOHAMMAD MUSHGIL**

# AN EFFICIENT METHOD FOR AUDIO WATERMARKING USING SWT AND MEAN VALUE QUANTIZATION

By

**BAYDAA MOHAMMAD MUSHGIL**

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Master of Science**

**November 2016**

**DEDICATION**

*To my parents, for their prayers and endless support*

*To my precious children, the joy of my life*

*To my beloved husband, for his everlasting love and support*

*To my brothers and sisters, for their love and encouragement*

*...with all love and gratitude...*

Abstract of thesis presented to the Senate of Universiti Putra Malaysiain fulfillment of the requirement for the degree of Master of Science

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**November 2016**

**Chairman : Associate Professor Wan Azizun Wan Adnan, PhD**
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Digital watermarking has been capturing the interests in programming society several decades ago due to the development of software and programming techniques that cause an increase in illegal use of digital files. In addition, with the widespread use of Internet which support sharing any digital files easily, this had simplified distribution of illegal digital files without the owner's permission. As the multimedia files; which include images, audio, and video clips; are prone to piracy, the multimedia industry and owner's of digital media are coping with this issue to protect their intellectual property. Furthermore, the multimedia digital market needs to find solutions for copyright protection.

A robust, imperceptible and high capacity algorithm is proposed by using the stationary wavelet transform and the quantization index modulation technique with new synchronization method.

The results obtained show high robustness towards signal processing and manipulating attacks specially the de-synchronization attacks such as jittering, cropping, and zero inserting attacks. In addition, the imperceptibility and capacity obtained are considered high with respect to signal to noise values. A subjective test with volunteer's listeners had been conducted for the proposed method. The findings show high imperceptibility with subject difference grade SDG of 4.76; meanwhile high payload capacity with mean value of 176.4 bps is achieved. Hence, based on these results, the proposed audio watermarking method outperforms most of the previous studies.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai Memenuhi keperluan untuk ijazah Doctor Falsafah

**KAEDAH PEMILIHAN EFISIEN UNTUK AUDIO *WATERMARKING*MENGGUNAKAN SWT DAN NILAI MIN PENGKUANTUMAN**

Oleh

**BAYDAA MOHAMMAD MUSHGIL**

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*Watermarking* digital telah membawa perhatian kepada masyarakat pengaturcaraan beberapa dekad yang lalu disebabkan oleh pembangunan teknik perisian dan pengaturcaraan yang menyebabkan peningkatan dalam penggunaan fail digital secara haram. Di samping itu, dengan penggunaan meluas Internet yang menyokong pengkongsian sebarang fail digital dengan mudah, ini telah memudahkan pengedaran fail digital haram tanpa kebenaran pemilik. Fail multimedia; termasuk imej, audio, dan klip video; terdedah kepada cetak rompak, industri multimedia dan pemilik media digital menangani isu ini untuk melindungi harta intelek mereka. Tambahan pula, pasaran digital multimedia perlu mencari penyelesaian untuk perlindungan hak cipta.

Di sebabkan oleh terdapat banyaknya fail audio dan peluang yang tinggi fail audio akan digunakan secara haram, kajian ini memberi tumpuan kepada pembangunan kaedah *watermarking* untuk perlindungan hak cipta audio. Algorithma yang mempunyai ciri ciri yang teguh, tidak kelihatan dan mempunyai kapasiti yang tinggi dicadangkan dengan menggunakan *stationary wavelet transform* dan teknik pemodulatan pengkuantuman indeks dengan kaedah penyegerakan baru.

Keputusan yang diperolehi menunjukkan keteguhan yang tinggi terhadap serangan pemprosesan isyarat dan memanipulasi terutama serangan *de-synchronization* seperti *jittering*, *cropping*, dan kemasukkan sifar. Di samping itu, *imperceptibility* dan kapasiti yang diperolehi dianggap tinggi dibanding dengan nilai isyarat kepada bunyi. Ujian subjektif dengan pendengar sukarelawan telah dijalankan untuk kaedah yang dicadangkan. Hasil kajian menunjukkan *imperceptibility* yang tinggi dengan perbezaan nilai SDG sebanyak 4.76; sementara nilai kapasiti muatan juga adalah tinggi dengan min 176.4 bps dicapai. Oleh itu, berdasarkan keputusan ini, kaedah *watermarking* audio yang dicadangkan melebihi prestasi kebanyakan kajian sebelumnya.

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I certify that a Thesis Examination Committee has met on 8 November 2016 to conduct the final examination of Baydaa Mohammad Mushgil on his thesis entitled "An Efficient Method for Audio Watermarking using SWT and Mean Value Quantization" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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**TABLE OF CONTENTS**

## LIST OF TABLES

## LIST OF FIGURES

## LIST OF ABBREVIATIONS

| | |
|---|---|
| SWT | Stationary Wavelet Transform |
| SDG | Subjective Difference Grade |
| HAS | Human Auditory System |
| HVS | Human Visual System |
| DCT | Discrete Cosine Transform |
| DFT | Discrete Fourier Transform |
| SVD | Singular Value Decomposition |
| BER | Bit Error Rate |
| DWT | Discrete Wavelet Transform |
| LWT | Lifting Wavelet Transform |
| SS | Spread Spectrum |
| PN | Pseudo Noise |
| QIM | Quantization Index Modulation |
| RSVD | Reduced Singular Value Decomposition |
| SNR | Signal-to-Noise Ratio |
| $E_{r.m.s}$ | Root Mean Square Value Energy |
| BSC | Beginning Synchronization Code |
| ESC | Ending Synchronization Code |

# CHAPTER 1

# INTRODUCTION

## 1.1 Background

Nowadays, Internet has become the main stream to share ideas and thoughts through various software applications. Tools such as email and file sharing as well as social media applications, e.g. Facebook and Instagram, are widely used today. While Internet easily and inexpensively supports sharing any digital content such as image, audio, and video; this had simplified the illegal use and distribution of digital files without the ownership permission. Moreover, the wide spread of computers and gadgets usage in addition to high speed internet and the growth of peer to peer file sharing techniques allow easy sharing of digital media saved in individual device using special software such as e-Donkey and Kazaa [1]. As the multimedia files may prone to piracy, multimedia industry and ownerships of digital media are coping with this issue to protect their intellectual property. Hence, the multimedia digital market needs to find an effective solution for copyright protection.

The digital media industry tried to keep high product margins by adding encryption software that restricts duplication and playback as digital rights management. However all these arrangements to stop file sharing failed. Moreover, technology developers, scholars and customers think that this is a wasted effort by the industry to resist change and suppress creativity [1].

Copyrights focus on protecting the owners' rights and intellectual property from piracy. Trends today focus towards ways to protect the owner rights technologies that secure their digital products from being illegally used, distributed authority claimed or plagiarized. Watermarking copyright marks into digital media could be the most suitable solution for this problem [2]. Watermarking techniques hide information in the digital contents about the owner and the date of production. This hidden information can be extracted to claim the ownership and copyright of the digital content. However, hidden data security against attackers using watermarking techniques needs continuous improvements as the attacks types are becoming more challenging with available advanced software tools [3, 4].

Generally, audio watermarking is considered more challenging compared to image and video watermarking. Inserting watermarks to digital audio files is more complex technique when compared with image and video techniques. This is due to the fact that the sensitivity of human auditory is more than the human visual system [5]. Hence, the invisibility for images is easier to achieve than the inaudibility. In addition, the size of hidden information data that can be embedded robustly and inaudibly in an audio file is much lower than visual media. This is because the audio files are representedby far less samples per time interval.

As the requirements to develop efficient solutions for copyrights protection for digital audio and multimedia products is urgently needed, the audio watermarking is considered a promising technique. Hence, this research focuses on improving audio watermarking technique for copyright protection.

## 1.2 Digital Watermarking

Digital transmission had become the significant trend of the century due to the ease of producing, distributing and transmitting. However, the lack of unauthorized access protection is considered main issue. Digital watermarking techniques are suggested to embed data in digital content for the protection reasons [2].

Digital watermarking is a mechanism of hiding digital data (bit stream) covertly in a cover signal such as an image, audio, video, text data or even software data. It is usually used to identify copyright owner or for purposes of authentication. The embedded data is called watermarking data; while the signal used to hide the data is called carrier, cover, or host signal. The hiding process is called watermarking. The embedded stream is to carry an evidence marker to indicate the owner of the content, information of the receiver side, and/or the date of creating the file. When an illegal copy is discovered, extracting hidden data can prove property or authentication of the content.

Media owners are looking for techniques that guarantee protection of their rights, securing their content from piracy, unauthorized usage, and enable the chasing and conviction of illegal media distributors. Watermarking copyrights information could be the most important technique to protect the intellectual property for digital media. Watermarking data indicates the ownership and date of distributing the file content and extracting it when an illegal copy is discovered. Watermarking is not used for copyright protection only, there are many goals watermarking can achieve and it is already used. For instances: authentication, source detection, secret communication, networks security, and so on.

Proving the authentication of a digital file watermarks could be utilized to check whether the digital file have been tampered or forged. Additionally, it could be used to define type of attacks that used to manipulate the file. Moreover, it might help to recover the original data by giving clues to the attack type and giving a chance to reverse it [2].

For source detection, a marker is embedded into a digital file at each point of distribution. When a copy of the work is found, then the watermark may be extracted from the copy and then the source that cause the illegal distribution is known. The source of illegally copied movies can be detected using watermarking techniques. Actually, watermarking techniques have reportedly used for this case.

Another idea is covert or secret communication or data using watermarking. It is used frequently by military and security applications. Protection of this communication must be guaranteed. Digital watermarking can be used to secure the transformed data [2]. Covert communication using digital watermarking is more secure compared to cryptography.

In cryptography; when the original data is encrypted, only the secret key can be used to decrypt the data to obtain the original one. When the attackers have enough time, they have the possibility to decrypt the data as they are aware of the existence of such important data. However, in digital watermarking techniques; there is no way for attackers to assure that secret information is existing there or not [3].

Some sensors in wireless networks used to monitor the changes of physical phenomena in the enclose environments. This sensor networks help to surveillance of military and monitoring health of old people. The security of those networks is an important issue. Some watermarking methods are used to achieve security of monitoring networks [4].

Generally, the watermarking system can be described according to its embedding and extracting algorithm characteristics. These characteristics might be all or some of them required to achieve the watermarking system. This is depending on the application area [2]. Imperceptibility, robustness and capacity of embedded data are considered as efficiency factors of any watermarking algorithm [5]. Achieving higher results in these three factors are still hot topic in watermarking algorithms.

The embedded signal should not degrade the host signal and the quality of the file should be kept high. In other words, the user should not feel any change in the signal, this feature is called imperceptibility. The first most important method to measure the imperceptibility is calculating the Signal to Noise Ratio (SNR) [6,7]. The SNR should be high enough to make the hidden data imperceptible.Even though the characteristics are not all important in all application**,**the imperceptibility should be guaranteed in most of the cases. The second method is the subjective test;especially for audio watermarking. In audio watermarking, five grades are defined to evaluate the watermarked digital file based on a group of volunteers. The result is the mean value of their evaluation using a method called Subjective Difference Grade (SDG) measure [8, 9].

The embedded signal should survive intentional and non-intentional attacks. This reflects the degree of robustness of algorithm. Robustness is an important characteristic especially for copyright hiding marker. This is because the illegal users try to remove the copyright mark intentionally. Examples of attacks on audio watermarking may include many types of signal manipulating (e.g., noise addition), processing (e.g., re-quantization and re-sampling), coding (e.g., Moving Picture Experts Group compression (MPEG)), and de-synchronization attacks (e.g., random samples cropping, jittering and zero inserting). These attacks cause displacement and mightily threat the existence of the watermark [5].

On the other hand, the capacity or payload of the watermarking algorithm is defined as the number of bits that can be embedded in the scheme without causing any noticeable distortion to the content. The capacity is not the major concern in most of the watermarking applications. However, the capacity could be more important in audio applications because some kind of attacks may trimandcut the file into small clips in order to be used as phone ring tune.

It is obvious now that the digital distribution of music is unavoidable. The great increase of audio files over the Internet in last few decades made music industry extremely worried about these developments. While they perceive specific prospected advantages to digital distribution of music, they need protect their intellectual property eagerly. Every system adopted eventually must equipoise the interests of the industry, artists, and consumers [10].

The audio watermarking system for copyrights protection must cover the following main requirements: imperceptibility for high quality of the audio file, robustness against different attacks, and accepted-level of security to prevent unauthorized detection. Payload capacity and the computational complexity are important issues as well [11,12].

### 1.3 Problem Statement

As it has been mentioned before, there is wide availability and high chances of audio files to be illegally used. There is great need to develop a way for digital file owners to protect their intellectual property. Watermarking copyright mark is one of the proposed solutions.

In any watermarking system, the efficiency of the system is defined by three conflicting parameters namely imperceptibility, robustness and capacity. Until now, the need for an efficient system to survive the de-synchronization attacks with high data payload is still not fully satisfied [13,14]. The available audio watermarking systems lack the efficiency features in terms of acceptable trade off between robustness, imperceptibility and capacity. If one of these evaluation factors is achieved in these works, the others are not given the required performance for audio watermarking. Thus, an efficient audio watermarking algorithm that considers all these factors is needed to fulfill the multimedia market requirements.

An algorithm that can embed a high payload secret data into an audio signal without degrading the quality of the signal is proposed. The embedded data also should be able to be recovered after the signal being attacked. The proposed algorithm should cope with common attacks such amplitude scaling, echo addition, re-quantization and noise addition. The de-synchronization attacks will also considered. The computational complexity will be taken into account while efficiency factors are kept acceptable when developing the new watermarking algorithm.

## 1.4 Aims and Objectives

The aim of this study is to design and implement an efficient audio watermarking algorithm by covering following objectives:

1. To design a method that can embed data imperceptibly in audio files.
2. To develop an algorithm for hiding relatively high payload in audio files.
3. The proposed scheme should be able to survive common attacks, such as resampling, noise addition and amplitude scaling, as well as the de-synchronization attacks like jittering, cropping and zero inserting attacks.

## 1.5 Thesis Organization

After a short introduction, the rest of this thesis is organized as follows. Chapter 2 reviews the audio watermarking scheme followed by its applications. The classification of audio watermarking is also described. Then, the most relevant work related to audio watermarking is presented and critically analyzed. Chapter 3 illustrates the design and implementation of the proposed embedding and extracting algorithm for efficient audio watermarking approach. Afterward, the evaluation methods of the proposed approach for efficiency factors are presented. The details and description of experimental results of the proposed approach are given in Chapters 4. Finally, in Chapter 5, conclusions drawn from our results are discussed and suggestions for future work are explained.

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