Audio Watermark

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A Comprehensive Foundation Using MATLAB

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Preface

Audio watermarking is a technique providing a promising solution to copyrights protection for digital audio and multimedia products. Using this technique, hidden information called *watermark* containing copyrights information is imperceptibly embedded into the audio track of a host media. This watermark may be extracted later on from a suspected media to verify the authenticity. To function as an effective tool to enforce ownership rights, the audio watermarking scheme must satisfy the imperceptibility, robustness, security, data payload, and computational complexity requirements. Throughout this book we will be illustrating in a practical way the commonly used and novel approaches of audio watermarking for copyrights protection. We will also introduce our recently developed methods for objectively predicting the perceptual quality of the watermarked audio signals.

This book is directed towards students, researchers, engineers, multimedia practitioners, and academics who are interested in multimedia authentication and audio pirating control. The theoretical descriptions of the watermarking techniques are augmented by MATLAB implementations to ease understanding of the watermarking principles. A GUI demonstration program for watermarking embedding and extraction under different attacks is also provided to quickly surf through the different aspects of the watermarking attributes.

Book Motivations and Objectives

Motivated by the booming of the digital media applications, plenty of research has been conducted to investigate the methods of audio watermarking for copyrights protection. However, clear and easy to follow information about the audio watermarking subject are still not widely available and scattered among many publications. Currently, it is hard to find an easy pathway to develop research in this field. One main reason to this difficulty is that most of the works are bounded by IP or patent constraints. On the implementation side it is still hard to find or write the implementation programs for the known audio watermarking techniques

to see how the algorithms work. This book is introduced to establish a shortcut to get into this interesting field with minimal efforts. The commonly known techniques are well explained and supplemented with MATLAB codes to get a clear idea about how each technique performs. In addition, the reader can reproduce the functional figures of the book with provided MATLAB scripts written specifically for this purpose.

From the robustness and security perspectives, the commonly used audio watermarking techniques have limitations on the resistance to various attacks (especially desynchronization attacks) and/or security against unauthorized detection. Thus, in this book we develop new robust and secure audio watermark algorithm; it is well explained and implemented in MATLAB environment. This algorithm can embed unperceivable, robust, blind, and secure watermarks into digital audio files for the purpose of copyrights protection. In the developed algorithm, additional requirements such as data payload and computational complexity are also taken into account and detailed.

Apart from the improvement of audio watermarking algorithms, another landmark of this book is the exploration of benchmarking approaches to evaluate different algorithms in a fair and objective manner. For the application in copyrights protection, audio watermarking schemes are mainly evaluated in terms of imperceptibility, robustness, and security. In particular, the extent of imperceptibility is graded by perceptual quality assessment, which mostly involves a laborious process of subjective judgment. To facilitate the implementation of automatic perceptual measurement, we explore a new method for reliably predicting the perceptual quality of the watermarked audio signals. A comprehensive evaluation technique is illustrated to let the readers know how to pinpoint the strengths and weaknesses of each technique. The evaluation techniques are supported with tested MATLAB codes.

Furthermore to what we have just stated that this book extensively illustrates several commonly used audio watermarking algorithms for copyrights protection along with the improvement of benchmarking approaches, we may pinpoint the following new contributions of the current book:

- We introduce a spread spectrum based audio watermarking algorithm for copyrights protection, which involves Psychoacoustic Model 1, multiple scrambling, adaptive synchronization, frequency alignment, and coded-image watermark. In comparison with other existing audio watermarking schemes [1–10], the proposed scheme achieves a better compromise between imperceptibility, robustness, and data payload.
- We design a performance evaluation which consists of perceptual quality assessment, robustness test, security analysis, estimations of data payload, and computational complexity. The presented performance evaluation can serve as one comprehensive benchmarking of audio watermarking algorithms.
- We portray objective quality measures adopted in speech processing for perceptual quality evaluation of audio watermarking. Compared to traditional perception modelling, objective quality measures provide a faster and more

efficient method of evaluating the watermarked audio signals relative to host audio signals.
- We analyze methods for implementing psychoacoustic models in the MPEG standard, with the goal of achieving inaudible watermarks at a lower computational cost. With the same level of minimum masking threshold, Psychoacoustic Model 1 requires less computation time than Psychoacoustic Model 2.
- We identify the imperceptibility, robustness, and security characteristics of audio watermarking algorithms and further use them as attacks in the process of multiple watermarking.
- We propose the use of variable frame length to make the investigated cepstrum domain watermarking, wavelet domain watermarking, and echo hiding robust against time-scale modification.

Organization of the Book

The chapters in this book are organized as follows.

Chapter 1 provides an overview of digital watermarking technology and then opens a discussion on audio watermarking for copyrights protection.

Chapter 2 describes the principles of psychoacoustics, including the anatomy of the auditory system, perception of sound, and the phenomenon of auditory masking. Then two psychoacoustic models in the MPEG-1 standard, i.e., Psychoacoustic Model 1 and 2, are investigated. Through comparisons of the masking effect and the computational cost, the minimum masking threshold from Psychoacoustic Model 1 is chosen to be used for amplitude shaping of the watermark signal in Chap. 4.

Chapter 3 begins with the implementation specifications for perceptual quality assessment and the basic robustness test used in this chapter. Then it describes and evaluates several algorithms for audio watermarking, such as least significant bit modification, phase coding, spread spectrum watermarking, cepstrum domain watermarking, wavelet domain watermarking, echo hiding, and histogram-based watermarking. In the meantime, possible enhancements are exploited to improve the capabilities of some algorithms.

Chapter 4 presents a spread spectrum based audio watermarking algorithm for copyrights protection, which uses Psychoacoustic Model 1, multiple scrambling, adaptive synchronization, frequency alignment, and coded-image watermark. The basic idea is to embed the watermark by amplitude modulation on the time–frequency domain of the host audio signal and then detect the watermark by normalized correlation between the watermarked signal and corresponding secret keys.

In Chap. 5, the performance of the proposed audio watermarking algorithm is evaluated in terms of imperceptibility, robustness, security, data payload, and computational complexity. The evaluation starts with perceptual quality assessment, which consists of the subjective listening test (including the MUSHRA test and SDG rating) and the objective evaluation test (including the ODG by PEAQ and

the SNR value). Then, the basic robustness test and the advanced robustness test (including a test with StirMark for Audio, a test under collusion, and a test under multiple watermarking) are carried out. In addition, a security analysis is followed by estimations of data payload and computational complexity. At the end of this chapter, a comparison between the proposed scheme and other reported systems is also presented.

Chapter 6 presents an investigation of objective quality measures for perceptual quality evaluation in the context of different audio watermarking techniques. The definitions of selected objective quality measures are described. In the experiments, two types of Pearson correlation analysis are conducted to evaluate the performance of these measures for predicting the perceptual quality of the watermarked audio signals.

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