# Chapter 13
# Conclusion and Future Trends

## 13.1 CONCLUSION OF THE BOOK

In this book, we introduced the advanced techniques and models for signal processing, perceptual coding and watermarking of digital, however with more emphasis on watermarking technologies. The beginning chapter briefly explains the human auditory system (HAS) and psychoacoustics followed by the introduction of digital watermarking in Chapter 2. New applications of digital watermarking are presented in Chapter 3 and background and literature review of selected watermarking techniques are presented in Chapter 4. Because of the dominant popularity of spread spectrum used in digital watermarking, Chapter 5 through Chapter 7 demonstrated this technology in great detail including the principles of spread spectrum, the survey of current audio watermarking schemes based on spread spectrum and several techniques to improve traditional spread spectrum detection.

Starting from Chapter 8 to the end of the book, we explain in great detail our major contributions to a better digital audio watermarking solution, including a novel discrete wavelet packet transform (DWPT) based psychoacoustic model and

DOI: 10.4018/978-1-61520-925-5.ch013

a synchronization method, which are the most fundamental and important keys for a successful digital audio watermarking system.

Due to the great sensitive property of the human auditory system (HAS) compared to the human visual system (HVS), embedding watermarks into audio signal is much more challenging than inserting watermarks into image or video signals. To make the embedding process transparent and provide enjoyable high quality watermarked audio to the listeners, a psychoacoustic model is indispensable to most of the digital audio watermarking systems.

The psychoacoustic model is a stereotype used to exploit the properties of HAS discovered from state-of-the-art results in psychoacoustics research. Such model takes advantage of the so called masking phenomena, which include frequency and temporal masking, to find out the spaces in the audio signal spectrum that fall below the masking thresholds and can be removed without introducing perceptible distortion. Those spaces can be used to embed watermarks for audio watermarking applications or to tolerate increased quantization noise in perceptual audio coding.

Unlike Fourier transform-based psychoacoustic models, which linearly divide the audio spectrum into different frequency sub bands, our proposed psychoacoustic model takes the advantage of the flexibility of the DWPT and decomposes the audio spectrum in the way that the sub bands distribution closely mimics the critical bands. This psychoacoustic model finds more spaces under the masking thresholds compared to the Fourier transform based psychoacoustic model, thus providing possible better robustness for watermarking applications by tolerating higher energy watermarks embedded imperceptibly. Meanwhile, the proposed psychoacoustic model is also attractive for perceptual audio coding by allowing more quantization noise introduced into the audio coding process, thus achieving a lower coding rate, resulting a smaller coded audio file.

Based on the new psychoacoustic model, we propose a high perceptual quality audio coder which proves performs better than MP3 audio codec.

We also incorporate the new proposed psychoacoustic model into a spread spectrum based audio watermarking system, which enables transparent watermarking embedding and provides reasonable robustness against normal signal processing and attacks. Later in Chapter 11, a more advanced watermarking system was further developed by embedding watermarks into the entire audio spectrum, whether audible or inaudible. This novel system carefully tunes the watermark strength according to the masking thresholds derived from the proposed psychoacoustic model, thus avoiding introducing annoying audible distortion into the watermarked audio. Since the watermarks are spread into the whole audio spectrum, it is very hard if not impossible for the opponents to remove the watermarks without severely degrading the audio quality. The enhanced system shows better robustness, offering faster decoding