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RESEARCH ARTICLE

Digital Speech Watermarking Based on Linear Predictive Analysis and Singular Value Decomposition

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Abstract In this paper different digital audio watermarking techniques have been proposed. Currently, more attention is given to combination of Discrete Wavelet Transform (DWT) and Singular Value Decomposition (SVD) techniques for watermarking purpose. Available DWT–SVD audio watermarking techniques cannot be applied to speech signals efficiently. However, Linear Predictive Analysis (LPA) technique can model digital speech signals (20–30 ms) in more flexible and efficient ways than DWT. In this paper, a novel digital speech watermarking technique is proposed by applying both LPA and SVD. Quantization Index Modulation (QIM) is further applied to embed the watermark bits. The experimental results show that not only time and memory were reduced significantly as compared to different DWT–SVD audio watermarking techniques, but also the proposed technique was more robust and imperceptible for speech watermarking than other DWT–SVD audio watermarking techniques.

Keywords Digital speech watermarking · Digital audio watermarking · Linear predictive analysis · Singular value decomposition · Quantization index modulation

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1 Introduction

In recent decades, rapid growth of network and communication industries have allowed the ability of illegal digital media to be distributed in the digital world. Digital speech watermarking as a popular solution to protect copyrights has attracted a lot of interest from researchers. The manipulation of digital speech can make sounds undetectable by human hearing due to advances in speech synthesizing technology. Figure 1 shows how manipulating small parts of the speech signal scan change the meaning of whole utterances. Therefore, digital speech watermarking can be applied to speech streams in the digital world.

Digital watermarking is a process of embedding watermarks in original media such as video, audio and image so that their presence cannot be perceived. According to International Federation of the Phonographic Industry (IFPI), digital audio watermarking must have a few main characteristics [1]. The first is imperceptibility. The watermark should not be audible what measured by objective and subjective methods. Furthermore, its Signal to Noise Ratio (SNR) must be more than 20 dB. Another main characteristic is payload, i.e., the number of bits carried by an audio watermarked signal should be at least 20 bit per second (bps). The third main characteristic is, robustness, i.e., the watermark must be extracted under different signal processing attacks unless the quality of the watermarked signal has been significantly degraded. Another characteristic of watermark is fragile which is the opposite of robustness and it is used for authentication purposes [2]. Other characteristics include *security* (which is defined as watermark detection by an authorized person); *transparency* (which means no perceptible artifacts or loss of quality); *complexity* (which needs time for embedding and extraction especially in real-time system); *inevitability*