Watermarking Scheme with CS Encryption for Security and Piracy of Digital Audio Signals

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ABSTRACT
In this article, a watermarking scheme using Curvelet Transform with a combination of compressive sensing (CS) theory is proposed for the protection of a digital audio signal. The curvelet coefficients of the host audio signal are modified according to compressive sensing (CS) measurements of the watermarked data. The CS measurements of watermark data is generated using CS theory processes and sparse coefficients (wavelet coefficients of DCT coefficients). The proposed scheme can be employed for both audio and speech watermarking. The gray scale watermark image is inserted into the host digital audio signal when the proposed scheme is used for audio watermarking. The speech signal is inserted into the host digital audio signal when the proposed scheme is employed for speech watermarking. The experimental results show that proposed scheme performs better than the existing watermarking schemes in terms of perceptual transparency.

KEYWORDS
Audio Signal, Compressive Sensing (CS), Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT), Fast Discrete Curvelet Transform (FDCuT), Speech Signal, Watermarking

1. INTRODUCTION
The multimedia data such as images, videos, and audios are easily downloadable when transmitted over the internet. The duplication of this data is often possible without giving credits to the original creators. This situation creates the problem of owner authentication and protection. The watermarking technique provides one of the solutions for these issues. Many researchers have proposed various watermarking schemes for owner protection of data which is transferred over the non-secure communication channel.

The watermarking technique can be divided into various types such as image watermarking, video watermarking, audio watermarking, biometric watermarking, and medical watermarking (Langelaar et al., 2000; Jain and Uludag, 2003; Thanki and Kothari, 2016; Ashour and Dey, 2017; Borra et al., 2017; Borra and Swamy, 2013, 2012, 2011; Dey et al., 2017; Parah et al., 2017; Rajeswari et al., 2017). Most watermarking techniques are designed and analyzed for digital images and video protection. There are various types of watermarking techniques such spatial domain watermarking, transform domain watermarking and sparse domain watermarking (Langelaar et al., 2000; Sheikh and Baraniuk, 2007). The spatial domain watermarking has less secured against watermarking attack. While transform watermarking has more secured against watermarking attack but have less payload capacity. The sparse domain watermarking techniques are new watermarking techniques which were

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utilized Compressive Sensing (CS) theory (Donoho, 2006; Candes, 2006) with watermarking. This technique is mainly used data authentication and provided more payload capacity compared to other watermarking techniques.

There are various watermarking techniques are proposed by researchers for the security of audio data, image data, and speech data in last ten years. Here watermarking techniques which are related to proposed scheme are reviewed in two categories. In the first category, give information about watermarking techniques, where the audio signal was used as host medium and watermark data, can be an image. These are known as audio watermarking techniques. In the second category, give information about watermarking techniques where the speech signal was used as watermark data and host medium can be a digital image or audio signal. These are known as speech watermarking techniques.

1.1. Related Work to Audio Watermarking Scheme

The many watermarking techniques are designed in spatial and transform domain for audio signal protection (Cano et al., 2005; Kiah et al., 2011). In these techniques, the audio signal was used as host medium, and watermark data was embedded in it. Swanson (Swanson et al., 1998) has described an audio watermarking technique using perceptual masking for audio signal protection. In this technique, the author has divided the audio signal into the block and then calculates the frequency mask of the power spectrum of the audio signal block. The authors used noise signal as watermark data and calculated Fast Fourier Transform (FFT) of noise to get a signature. Then compute temporal mask using watermark data, and this temporal mask adds to the frequency mask of the power spectrum. Then apply IFFT to get a watermarked audio signal. This technique is robust against attacks and used for copyright protection.

Seok (Seok et al., 2002) has proposed a transform based watermarking technique using FFT and PN sequences for audio signal protection. The FFT coefficients of watermark data are modulated by PN sequences to generate watermark mask in this technique. This watermark mask was embedded into FFT coefficients of the host audio signal to get a watermarked audio signal. Kirovski (Kirovski and Malvar, 2003) has beautifully described direct sequence based spread spectrum watermarking techniques for audio signals. Wu (Wu et al., 2005) has proposed a watermarking technique using wavelet transform for audio signals. In this technique, first synchronization codes generated are with watermark data. Then these synchronization codes with hidden watermark data are embedded into low frequency wavelet coefficients of the host audio signal to generate watermarked audio signal. Wang and his research team (Wang and Zhao, 2006; Wang et al., 2009) have proposed a watermarking technique using Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT) for audio signals. In this technique, DCT coefficients of low-frequency wavelet coefficients are modified according to a bit of binary watermark image. This technique provides robustness against various watermarking attacks. El-Samie (Samie, 2009) has proposed singular value decomposition based watermarking technique for an audio signal in the spatial and transform domain. In this technique, singular value of the audio signal is modified by PN sequences according to watermark image bits. This technique is robust against various watermarking attacks. V. Bhat (Bhat et al., 2010) has proposed a hybrid watermarking technique using DWT and Singular Value Decomposition (SVD) for the audio signal. In this technique, singular value of low-frequency wavelet coefficients of host audio signal was modified according to watermark image bits.

W. Al-Nuaimy (Al-Nuaimy et al., 2011) has proposed SVD watermarking technique with chaotic encrypted images for audio signal protection. In this technique, watermark image is encrypted using a chaotic encryption method. Then the singular value of host audio signal is modified according to
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