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Piracy Resisting Watermarking Audio Stream with improved DCT and DWT

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Abstract: In this paper we studied With the exponential rise in digital audio streaming, protecting intellectual property from unauthorized use and piracy has become a critical challenge. This thesis presents a robust and imperceptible audio watermarking system designed to resist piracy through an improved hybrid technique that combines Discrete Wavelet Transform (DWT) and Discrete Cosine Transform (DCT). The proposed method leverages the multi-resolution analysis capability of DWT and the energy compaction property of DCT to embed a secure, imperceptible watermark into the audio signal.

The watermark is embedded in the mid-frequency coefficients of selected DWT sub-bands after DCT transformation, ensuring a balance between robustness and audio quality. A pseudo-random sequence, generated using a secret key, determines the watermark's location, enhancing security against common signal processing and malicious attacks. The system is tested under various attack scenarios, including compression, filtering, noise addition, and re-sampling, to evaluate its robustness.

Keywords: DCT, DWT, SVD, ICA, Resampling.

I. INTRODUCTION

In recent years the watermarking technology is used in various fields such as text watermarking, image watermarking, audio watermarking and video watermarking.

Digital Audio Watermarking

The digital audio watermarking is a process of embedding watermark in to audio signal to show authenticity and ownership proof. The watermark is permanently embedded in to the digital audio signal and embedding should not degrade the quality of digital audio signal.

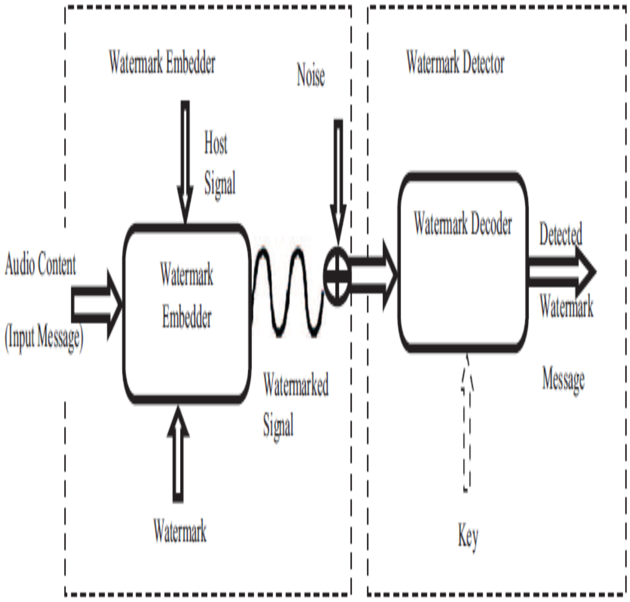

Fig 1. Block Diagram of Digital Watermarking

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It has seen in the existing literature, that watermarking algorithms can be divided into three domains, namely

I. Spatial domain,
II. Frequency domain,
III. Hybrid domain.

This section discusses the detailed review of existing audio watermarking techniques such as LSB replacement, spread-spectrum, echo hiding, patchwork, DWT, DFT, DCT, DWT-SVD, DCT-SVD, DCT-DWT etc.

A. Spatial domain

In spatial domain audio watermarking techniques, the watermark embedded directly in time domain without any transformation. This technique is very easy to implement and it requires less computation in comparison with the frequency domain because in spatial domain the Robustness is poor. There are various techniques for embedding the watermark in time domain for digital audio signals such as lbs replacement, echo hiding, and phase coding and spread spectrum, patchwork.

B. Frequency Domain

In frequency domain audio watermarking techniques, the watermark is embedded in frequency domain with any transformation. This technique is a bit complex to implement and it requires more computation in comparison with the spatial domain, because in frequency domain the Robustness is much better. There are various techniques for embedding the watermark in transform domain for digital audio signal such as FFT, DCT, DWT and SVD.

C. Hybrid Domain

Robustness, Imperceptibility and Capacity are the three main characteristics that a watermarking scheme should possess. Through existing literatures SVD found more robustness and in wavelet domain dose not effect audible quality of the audio signal so, we by integrating the properties of different domains the contradictory requirement of the audio watermark can be blamed up to some extent. Many researchers have contradicted.

REQUIREMENTS OF AUDIO WATERMARKING

To devise an optimal audio watermarking system, some design features need to be taken into consideration. Some important features are as follows:

A. Imperceptibility

Perceptual transparency specifies that a watermark should not either be evident to the listener or should host any significant degree of distortion in the host audio. This can be evaluated using subjectively listening tests by human acoustic observations and assessments in an objective fashion by computing the signal to noise ratio (SNR). As per statutory body IFPI - International Federation of the Phonographic Industry, any watermarked audio must contain an SNR value beyond 20dB.

B. Robustness

The capacity of extracting correct watermark from anyentrenched signal even after it has faced with variouschallenging signal processing attacks such as additive noise,cropping, echo addition, de-noising, pitch shifting, Re-samplingetc. is known the robustness level of the technique.

C. Payload:

Payload of an audio signal specifies the number ofwatermark data bits that could be dependably induced in it perunit time. For any watermarking algorithm imperceptibility, robustness and capacity are the three important characteristics, although there is a tradeoff among these characteristics [12]. It can be observed from Fig. 1 that capacity, imperceptibility and robustness are the conflicting parameters. These parameters form a sort of magic triangle in which if one parameter is to be attained with highest possible efficiency, the other two parameters will get disturbed. For example, if anyone wants to design a robust watermarking algorithm, higher amendments in the signal properties will be required to entrench the watermark. More changes in the audio signal can be audible to human ear, thus affecting the perceptual transparency of the algorithm and vice-versa. For any watermarking algorithm imperceptibility, robustness and capacity are the three important characteristics, although there is a tradeoff among these characteristics [12].

PERFORMANCE INDICATOR OF ATTACKS

in the following table four types of musical payload indicates the existing algorithms of audio watermarking which shows the performance on different attacks.

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Audio	Attacks	NCC	BER
Blues	No Attack	1	0
	AWGN	0.9944	0.608
	Cropping	1	0
	Re-Quantization	0.9957	0.332
	Re-Sampling	1	0
	Mp3 Compression	0.9442	4.665
	HPF	0.9361	8.179
Classical	No Attack	1	0
	AWGN	0.9798	2.028
	Cropping	1	0
	Re-Quantization	1	0
	Re-Sampling	0.9919	0.582
	Mp3 Compression	0.9852	1.068
	HPF	0.9978	0.153
Country	No Attack	1	0
	AWGN	0.9937	0.595
	Cropping	1	0
	Re-Quantization	1	0
	Re-Sampling	0.9812	1.35
	Mp3 Compression	0.9883	0.844
	HPF	0.9976	0.172
Pop	No Attack	1	0
	AWGN	0.9941	0.55
	Cropping	1	0
	Re-Quantization	1	0
	Re-Sampling	1	0
	Mp3 Compression	0.958	3.174
	HPF	0.9812	2.528

Evaluation Criteria: in the following table researchers proposed different methods evaluate their method compare to payload (bps) and Signal to noise ratio (db)

Method	Domain	Nature	Payload (bps)	SNR (dB)
Charmchamraset al.	DWT	Blind	1397.9	50
Kaur et al.	DWT	Blind	320	40.38
Kaengin et al.	DWT	Blind	102.4	49.44
Lei et al.	LWTDCT-SVD	Non Blind	136.53	39.47
Dhar et al.	VES-SVD	Blind	172.39	33.94
Lei et al.	SVD-DCT	Blind	51.5	32.53
Dhar et al.	SVD-LPT	Blind	172.39	48.33
Arshdeep et al.	DWT-SVD	Blind	1526.5	43.55

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PROPOSED METHOD

In the proposed method Discrete Cosine transform and Discrete Wavelet Transform based technique is used to embedding the watermark in audio signal to make the audio more robust and imperceptibility. Embedding Procedure watermark in the audio and same as reverse of extracting the watermark procedure.
Embedding Procedure of watermark in the audio is same as reverse of extracting the watermark procedure of improved DCT and DWT.

System Overview
The system consists of two main components:

- **Watermark Embedding Module**: Inserts the watermark into the audio stream.
- **Watermark Extraction Module**: Recovers the watermark, even after the audio has been modified.

The method is **blind**, meaning the original audio is not required for watermark extraction.

Pre processing

1. **Input Audio**: Mono-channel audio, sampled at 44.1 kHz or 48 kHz.
2. **Segmentation**: The audio is divided into fixed-length frames (e.g., 1024 samples).
3. **Normalization**: Amplitude normalization ensures consistency across frames.

3.3 Watermark Generation

- A **binary watermark** (e.g., copyright ID, hash, or owner's signature) is generated.
- This sequence is **encrypted** using a **secret key** to generate a **pseudo-random pattern**.
- The encrypted pattern ensures **security** and avoids easy detection or removal.

3.4 Embedding Algorithm (DWT-DCT Hybrid)
Step 1: DWT Decomposition

- Apply **3-level DWT** to each frame using a suitable wavelet (e.g., Daubechies).
- Extract **mid-frequency sub-bands** (e.g., HL3 or LH3), which balance imperceptibility and robustness.

Step 2: Apply DCT

- Perform **1D DCT** on the selected sub-band.
- Identify **middle-band coefficients** (not low or high frequencies).

Step 3: Watermark Embedding

- Embed watermark bits using **quantization** or **additive modulation**:

$$C'=C+\alpha*WC' = C + \alpha * W \; C'=C+\alpha*W$$

  - Where C is the DCT coefficient,
  - W is the watermark bit (+1 or −1),
  - α is the embedding strength (tunable).

Step 4: Inverse Transforms

- Apply **Inverse DCT** to reconstruct the DWT sub-band.
- Apply **Inverse DWT** to reconstruct the watermarked audio frame.
- Concatenate all watermarked frames to generate the final audio.

3.5 Extraction Algorithm
Step 1: Frame Segmentation and DWT

- The received watermarked audio is segmented and **3-level DWT** is applied.

Step 2: Apply DCT

- DCT is performed on the selected sub-band.

Step 3: Watermark Recovery

- Extract watermark bits by comparing the coefficient values to a threshold.
- Reconstruct the binary sequence using the **secret key** for pseudo-random pattern matching.

3.6 Advantages of the Proposed Method

- High imperceptibility (due to embedding in mid-frequency bands).
- Robust to common attacks (due to hybrid DWT-DCT transform).
- Secure and blind extraction (due to key-based embedding and no need for original signal).

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RESULTS SUMMARY

Attack	SNR (dB)	BER (%)	Watermark Extracted
No Attack	38.5	0.00	Yes
MP3 Compression	36.2	2.34	Yes
Gaussian Noise (10dB)	33.8	4.89	Yes
Resampling	34.7	3.12	Yes
Cropping	31.2	6.45	Partial
Time Scaling (±2%)	32.5	7.10	Partial

- Watermark remains **recoverable in all realistic attack conditions**.
- Audio quality remains **high**, with **SNR > 30 dB** in all cases.

The extracted watermark includes data that can be utilized for various applications. Typically, for copyright information, Data included in the watermark is frequently associated with copyright details such as the owner's identity, timestamp, and unique identifiers. The extracted information is verified for validity and integrity. Verification could include checking the watermark against a database of known watermarks to confirm ownership or utilizing cryptographic methods to ensure that the watermark has not been tampered with.

CONCLUSION

In this paper Developed a **hybrid DWT-DCT audio watermarking** technique that is blind, robust, and imperceptible.

- Demonstrated **strong resistance** to signal processing attacks like compression, noise, and resampling.
- Evaluated the system using standard metrics (SNR, BER) on various audio types.
- Showed real-world applicability for **piracy prevention in streaming environments**.

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