Robustness and Imperceptibility Improvement of Transform Domain Digital Audio Watermarking using Neural Networks

न्यूरल नेटवर्क की सहायता से फ्रीक्वेंसी डोमेन डिजिटल ऑडियो वाटरमार्किंग की मजबूती और अगोचरता में सुधार।

A Thesis

Submitted for the Award of the Ph.D. degree of

PACIFIC ACADEMY OF HIGHER EDUCATION AND RESEARCH UNIVERSITY

By

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2024

DECLARATION

I, **PATIL ABHIJIT JAYPRAKASH,** S/o **SHRI PATIL JAYPRAKASH SHANTARAM** resident of B-302, Shree Mahavir C.H.S., Sector No. 5A, New Panvel (East), Panvel Raigad - 410206, Maharashtra, India, hereby declare that the research work incorporated in the present thesis entitled **"Robustness and Imperceptibility Improvement of Transform Domain Digital Audio Watermarking using Neural Networks"** is my own work and is original. This work (in-part or in full) has not been submitted to any University for the award of a Degree or a Diploma. I have properly acknowledged the material collected from secondary sources wherever required. I solely own the responsibility for the originality of the entire content.

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ABSTRACT

This research introduces an advanced digital audio watermarking system designed to bolster the security of digital data, specifically focusing on ownership and copyright protection. Conventional audio watermarking methods often encounter limitations and reliability issues against various attacks. To address these challenges, a novel approach is proposed, leveraging deep learning and integrating the Discrete Wavelet Transform (DWT) with an optimized deep Convolutional neural network (DCNN). The primary contribution lies in the DCNN's adeptness in selecting optimal embedding locations, a critical factor for robust watermarking. Through hyper parameter tuning and search location optimization, classifier errors are minimized. Experimental results showcase superior performance, with the proposed model achieving a Bit Error Rate (BER) of 0.082, Mean Square Error (MSE) of 0.099, and Signal-to-noise ratio (SNR) of 45.363. This model surpasses the existing watermarking models and underscores the effectiveness of neural network architectures, particularly the DCNN, in optimizing watermark embedding and extraction with minimal bit error. The research also explores various hybrid and innovative techniques in digital audio watermarking, highlighting the utility of neural networks in advancing the field. The discussion encompasses classical and modern approaches incorporating machine learning, deep learning, bio-inspired algorithms, and cryptographic methods to enhance watermarking efficiency and security. The research provides insights into the challenges and opportunities in achieving robustness, imperceptibility, and security in digital audio watermarking, ultimately showcasing the applicability of neural network architectures in this domain.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

DWT	:	Discrete Wavelet Transform
DCNN	:	Deep Convolutional Neural Network
BER	:	Error Rate
MSE	:	Mean Square Error
SNR	:	Signal-To-Noise Ratio
DL	:	Deep Learning
HAS	:	Human Auditory System
LSB	:	Least Significant Bit
DFT	:	Discrete Fourier Transform
DCT	:	Discrete Cosine Transform
SVD	:	Singular Value Decomposition
QIM	:	Quantization Index Modulation
SLOA	:	Search Location Optimization Algorithm
DWT	:	Discrete Wavelet Transform
FRT	:	Fractional Fourier Transform
IWT	:	Integer Wavelet Transform
FPP	:	False Positive Problem
KNN	:	K-Nearest Neighbor
SVM	:	Support Vector Machine
FFT	:	Fast Fourier Transform
DTCWT	:	Dual-Tree Complex Wavelet Transforms
STFT	:	Sort-Time Fourier Transform
RFPS	:	Robust Feature Point Scheme Algorithm

AES	:	Advanced Encryption Standard
AVNM	:	Adaptive Vector Norm Modulation
GA	:	Genetic Algorithm
MME	:	Meet-In-The-Middle Embedding
PSHT	:	Parametric Slant-Hadamard Transform
HD	:	Hessenberg Decomposition
PEAQ	:	Perceptual Evaluation Of The Audio Quality
BPNN	:	Back Propagation Neural Network
FCNN	:	Fully Connected Neural Network
LGG	:	Lower-Grade Glioma
HH	:	High-High
HL	:	High-Low
LH	:	Low-High
LL	:	Low-Low
RNNs	:	Recurrent Neural Networks
HMS	:	Human Mental Search
HSO	:	Hybrid Swarm Optimization
PAR	:	Pitch Adjusting Rate
ODG	:	Objective Difference Grade
MSE	:	Mean Square Error
BER	:	Bit Error Rate
SNR	:	Signal-To-Noise Ratio