Perceptual Hash Techniques for Audio Copyright Protection in Decentralized Systems

GUIDED BY,

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Introduction

- Music piracy involves the illegal copying, distribution, and sale of copyrighted music without authorization from the rights holders, including artists and record labels.
- The issue has been prevalent since the digital age began, with significant events like the Napster controversy highlighting its impact on music distribution and consumption.
- Piracy leads to substantial revenue losses for artists and record labels, which can hinder their ability to produce new music and sustain their careers in a competitive market.
- Advances in technology have made it easier for individuals to share music illegally, complicating efforts to protect intellectual property rights within the industry.
- HADES leverages perceptual hashing and blockchain technology to combat unauthorized audio file sharing by identifying similar audio files even after alterations, checking hashes against a blockchain-stored database for potential infringements, securely storing files on decentralized platforms like Inter Planetary File Systems(IPFS), and ensuring tamper-proof records on the Ethereum blockchain. This innovative approach enhances transparency, security, and resilience against common audio processing attacks while protecting artists' rights in the digital era.

Problem Statement

Music piracy on decentralized platforms causes economic losses for artists, with traditional hashing inadequate for detecting subtly altered audio. Perceptual hashing offers a potential solution by identifying similar-sounding files but needs refinement. The challenge is alternating the perceptual hashing system that balances security, transparency, and decentralization for managing copyright infringements.

Objectives

- To develop a robust audio detection system using alternative perceptual hashing to identify copyright infringement.
- To design a secure and efficient framework for integrating these hash functions into peer-to-peer music platforms.

Outcomes

- Developing a robust audio detection system using alternative perceptual hashing to identify copyright infringement.
- Implementation of the proposed framework and evaluate its effectiveness in preventing unauthorized audio copies

Literature Survey - 1

PANAKO 2.0 - Updates For an Acoustic Fingerprinting System

Joren Six (2021) provided “Panako 2.0 - Updates for an acoustic fingerprinting system“

Methodology Used:

1. **Constant-Q Non-Stationary Gabor Transform**: This transform is used as a front-end for many Music Information Retrieval (MIR) tasks. It provides a finer frequency resolution at equal computational cost, allowing for more efficient spectral peak detection.

MJoren Six (2021). "Panako 2.0 - Updates for an acoustic fingerprinting system". Extended Abstracts for the LateBreaking Demo Session of the 22nd Int. Society for Music Information Retrieval Conf., Online, 2021..

Literature Survey – 1 Contd./..

2. **Near-Exact Hashing Technique**: This technique is used in combination with a persistent B-Tree to allow for some margin of error while maintaining reasonable query speeds. It enables the system to handle off-by-one errors and linear time-stretching/tempo modifications.

3. **Thresholded Matching Strategy**: A linear regression is used to filter true positive matches from false positives, allowing for some small margin in which matches are accepted.

Merits:

1. Improved Query Performance
2. Robustness to Modifications
3. Efficient Indexing and Querying
4. Open-Source and Freely Available

MJoren Six (2021). "Panako 2.0 - Updates for an acoustic fingerprinting system". Extended Abstracts for the LateBreaking Demo Session of the 22nd Int. Society for Music Information Retrieval Conf., Online, 2021..

Literature Survey – 1 Contd./..

Demerits:

1. Computational Complexity
2. Limited Evaluation
3. Trade-Offs
4. Potential for False Positives

Overall, Panako 2.0 appears to be a significant improvement over its predecessors, offering improved query performance, robustness to modifications, and efficient indexing and querying capabilities. However, its limitations and potential demerits should be carefully considered when applying the system to specific use cases.

MJoren Six (2021). "Panako 2.0 - Updates for an acoustic fingerprinting system". Extended Abstracts for the LateBreaking Demo Session of the 22nd Int. Society for Music Information Retrieval Conf., Online, 2021..

Literature Survey - 2

Accuracy comparisons of fingerprint based song recognition approaches using very high granularity

Salvatore Serrano(2023) provided "Accuracy comparisons of fingerprint based song recognition approaches using very high granularity"

Marco Scarpa(2023) offered help during "Accuracy comparisons of fingerprint based song recognition approaches using very high granularity"

In the paper "Accuracy comparisons of fingerprint based song recognition approaches using very high granularity" by Salvatore Serrano and Marco Scarpa, Panako is one of the five baseline algorithms used for comparison with the authors' new algorithm.The paper describes Panako as an open-source implementation of the Shazam like approach that uses the constellation algorithm.

Salvatore Serrano,Marco Scarpa "**Accuracy comparisons of fingerprint based song recognition approaches using very high granularity**", 21 March 2023.

Literature Survey -2 Contd./..

1. **Near-Exact Hashing Technique**: This technique is used in combination with a persistent B-Tree to allow for some margin of error while maintaining reasonable query speeds. It enables the system to handle off-by-one errors and linear time-stretching/tempo modifications.

2. **Thresholded Matching Strategy**: A linear regression is used to filter true positive matches from false positives, allowing for some small margin in which matches are accepted.

Salvatore Serrano,Marco Scarpa "**Accuracy comparisons of fingerprint based song recognition approaches using very high granularity**", 21 March 2023.

Literature Survey - 2 Contd./..

These results suggest that Panako performs relatively well for longer excerpts of audio, but struggles to accurately recognize very short excerpts. The authors' new algorithm, on the other hand, achieves high accuracy rates for all excerpt lengths, outperforming Panako and the other baseline algorithms.

Overall, the paper highlights the potential for improved accuracy in audio fingerprinting and song recognition, particularly for very short excerpts of audio, and suggests that the authors' new algorithm may be a promising alternative to existing algorithms such as Panako

Salvatore Serrano,Marco Scarpa "**Accuracy comparisons of fingerprint based song recognition approaches using very high granularity**", 21 March 2023.

Literature Survey -3

Olaf: a lightweight, portable audio search system

Joren Six,(2023) provided "Olaf: a lightweight, portable audio search system"

Methodology Used:

- **Spectral Peaks Fingerprinting**: Combines two or three spectral peaks for effective audio matching.
- **C Programming Language**: Core functionality in C for portability and simplicity, with a Ruby script for file handling and transcoding.
- **Modular Design**: Uses opaque structs and different database implementations for flexibility

Joren Six (2023). "Olaf: a lightweight, portable audio search system". Journal of Open Source Software, 8(87), 5459. https://doi.org/10.21105/joss.05459

Literature Survey -3 Contd./..

Merits:

1. **Portability and Lightweight**: Suitable for devices from microcontrollers to browsers due to low memory usage.
2. **High Performance**: Efficient algorithms and libraries ensure fast performance.
3. **Versatility**: Supports applications like digital music archive management and audio synchronization.
4. **Accessibility**: Provides a scalable, freely-available implementation of audio fingerprinting.

Joren Six (2023). "Olaf: a lightweight, portable audio search system". Journal of Open Source Software, 8(87), 5459. https://doi.org/10.21105/joss.05459

Literature Survey -3 Contd./..

Demerits:

1. **Complexity of C**: Developing bug-free code is challenging.
2. **Limited Input Validation**: Relies on Ruby script for input validation, posing potential risks.
3. **False Positives**: Two-peak fingerprints may lead to false positives in larger datasets; three-peak fingerprints might miss shorter or distorted queries.

Joren Six (2023). "Olaf: a lightweight, portable audio search system". Journal of Open Source Software, 8(87), 5459. https://doi.org/10.21105/joss.05459

Literature Survey -4

A Decentralized Music Copyright Operation Management System Based On Blockchain Technology

Yanghuan Li,(2020) provided “A Decentralized Music Copyright Operation Management System Based On Blockchain Technology”

Jinhui Wei,(2020) offered help during“A Decentralized Music Copyright Operation Management System Based On Blockchain Technology”

Qingzhen Xu,(2020) offered help during“A Decentralized Music Copyright Operation Management System Based On Blockchain Technology”

Chengying He,(2020) offered help during“A Decentralized Music Copyright Operation Management System Based On Blockchain Technology”

"A Decentralized Music Copyright Operation Management System Based On Blockchain Technology" by Yanghuan Li et al.(2020)

Literature Survey -4 Contd./..

Merits:

1.**Decentralization**: No central authority, ensuring a transparent and secure system.
2.**Enhanced Copyright Protection**: Utilizes blockchain's shared ledger and smart contracts to safeguard copyrights and prevent infringement.
3.**Interest Coordination**: Aligns the interests of creators, copyright owners, operators, and users, ensuring mutual benefits.
4.**Improved User Experience**: Offers users more choices and better experiences by enabling music rights purchases and services across platforms via Ethereum.

"A Decentralized Music Copyright Operation Management System Based On Blockchain Technology" by Yanghuan Li et al.(2020)

Literature Survey -4 Contd./..

Demerits:

1.**Complexity**: The system is based on Blockchain technology, which can be complex to understand and implement.

2. **Scalability**: The system may face scalability issues as the number of users and transactions increases.

3.**Security**: While the system is secure, there is always a risk of hacking or other security breaches.

4.**Regulatory issues**: The system may face regulatory issues in different countries as copyright laws vary headings only

"A Decentralized Music Copyright Operation Management System Based On Blockchain Technology" by Yanghuan Li et al.(2020)

Literature Survey -5

Analysis of Perceptual Hashing Algorithms in Image Manipulation Detection

Priyanka Samanta,(2021) provided "Analysis of Perceptual Hashing Algorithms in Image Manipulation **Detection"**

Shweta Jain,(2021) , helped during "Analysis of Perceptual Hashing Algorithms in Image Manipulation Detection"

"Analysis of Perceptual Hashing Algorithms in Image Manipulation Detection" are Priyanka Samanta and Shweta Jain.

Literature Survey -5 Contd./..

Methodology used:

1. **Image Pre-processing**: This step prepares the input image for feature extraction by reducing data size and processing time. Techniques such as resizing, color transformation, normalization, filtration, and histogram equalization are employed.
2. **Feature Extraction**: The paper discusses various techniques for extracting perceptual features from images, including:

- Frequency domain transformations (e.g., Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT)).
- Dimensionality reduction techniques (e.g., Principal Component Analysis (PCA), Non-Negative Matrix Factorization (NMF), Singular Value Decomposition (SVD)).

"Analysis of Perceptual Hashing Algorithms in Image Manipulation Detection" are Priyanka Samanta and Shweta Jain.

Literature Survey -5 Contd./..

Merits:

- **Robustness to Minor Modifications**: Perceptual hashing algorithms are designed to remain stable under minor content-preserving modifications, making them useful for applications like duplicate detection and reverse image search.
- **Performance Analysis**: The paper provides a comprehensive performance analysis of various perceptual hashing algorithms against datasets of manipulated images, identifying strengths and weaknesses.

"Analysis of Perceptual Hashing Algorithms in Image Manipulation Detection" are Priyanka Samanta and Shweta Jain.

Literature Survey -5 Contd./..

Demerits:

Limited Effectiveness in Content Changing Manipulations: The results indicate that existing perceptual hashing algorithms show less than ideal performance in distinguishing maliciously manipulated images from legitimate ones, particularly in detecting content-changing manipulations.

Dependence on Pre-processing: The effectiveness of the algorithms can be influenced by the pre-processing steps, which may not be uniformly applicable across different datasets

"Analysis of Perceptual Hashing Algorithms in Image Manipulation Detection" are Priyanka Samanta and Shweta Jain.

Literature Survey -6

Shallow and deep feature fusion for digital audio tampering detection

The research article titled "Shallow and deep feature fusion for digital audio tampering detection" is authored by Zhifeng Wang(2022), Yao Yang(2022), Chunyan Zeng(2022), Shuai Kong(2022), Shixiong Feng(2022), and Nan Zhao(2022).

Methodology used:

1. **Feature Extraction**: The audio signal is band-pass filtered to isolate the ENF component. The discrete Fourier transform (DFT) is applied to obtain phase features, while the Hilbert transform is used to derive instantaneous frequency features.
2. **Shallow Features**: The mean value of the variations in the ENF phase and frequenc is calculated as shallow features, which reflect discontinuities in the audio.

"Shallow and deep feature fusion for digital audio tampering detection" by Zhifeng Wang, Yao Yang, Chunyan Zeng, Shuai Kong, Shixiong Feng, and Nan Zhao, EURASIP Journal on Advances in Signal Processing in 2022.

Literature Survey -6 Contd./..

3.Deep Features: A convolutional neural network (CNN) is employed to extract local details from the ENF phase and frequency feature matrices. Additionally, fitting coefficients are obtained through curve fitting to provide global information.
4.Feature Fusion: The shallow and deep features are fused using an attention mechanism, which assigns different weights to the features based on their significance in classification.
5.Classification: A deep neural network (DNN) classifier is used to classify the audio as tampered or authentic based on the fused features

"Shallow and deep feature fusion for digital audio tampering detection" by Zhifeng Wang, Yao Yang, Chunyan Zeng, Shuai Kong, Shixiong Feng, and Nan Zhao, EURASIP Journal on Advances in Signal Processing in 2022.

Literature Survey -6 Contd./..

Merits:

Improved Detection Accuracy: The proposed method achieves higher accuracy and F1-scores compared to state-of-the-art methods, as demonstrated in experiments
Generalization Ability: The methodology shows good generalization performance across different datasets, indicating robustness .
Complementarity of Features: By combining shallow and deep features, the method leverages the strengths of both, enhancing the overall feature representation .

"Shallow and deep feature fusion for digital audio tampering detection" by Zhifeng Wang, Yao Yang, Chunyan Zeng, Shuai Kong, Shixiong Feng, and Nan Zhao, EURASIP Journal on Advances in Signal Processing in 2022.

Literature Survey -6 Contd./..

Demerits:

- **Complexity**: The methodology involves multiple steps, including feature extraction, fitting, and fusion, which may increase computational complexity and processing time .

- **Dependence on Data Quality**: The effectiveness of the method may be influenced by the quality and characteristics of the audio data used for training and testing.

"Shallow and deep feature fusion for digital audio tampering detection" by Zhifeng Wang, Yao Yang, Chunyan Zeng, Shuai Kong, Shixiong Feng, and Nan Zhao, EURASIP Journal on Advances in Signal Processing in 2022.

Literature Survey -7

Analysing the performance of the OLAF framework in the context of identifying music in movies

Casper W.R. Hildebrand(2021) provided"Analysing the performance of the OLAF framework in the context of identifying music in movies" , with supervisors Dr. Cynthia C.S. Liem and Dr. Jaehun Kim.

Methodology used:

The methodology used in the research involves setting up a benchmark to evaluate the performance of the OLAF framework in identifying music in movies, which includes defining metrics for robustness, reliability, and search speed, generating query data from various sound categories, and performing tests on both synthesized and real movie data.

Casper W.R. Hildebrand, "Analysing the performance of the OLAF framework in the context of identifying music in movies", Delft University of Technology, Netherlands, 27th June 2021.

Literature Survey -7 Contd./..

Merits:

The OLAF framework demonstrated robust performance in identifying music even in layered audio scenarios, achieving satisfactory recall and precision scores across various noise categories.

Demerits:

The framework struggled with pitch-shifted and tempo-altered audio, leading to lower recall and precision in those cases, and the parameter setup used may not be optimal for all use cases

Casper W.R. Hildebrand, "Analysing the performance of the OLAF framework in the context of identifying music in movies", Delft University of Technology, Netherlands, 27th June 2021.

Literature Survey -8

Signal Processing: Image Communication

Xiaofeng Wang,Xiaorui Zhou,Qian Zhang,Bingchao Xu,Jianru Xue(2020) provided"Signal Processing: Image Communication".

Methodology used:

The proposed methodology involves an image alignment process followed by hybrid feature extraction using global and local Zernike moments combined with DCT-based statistical features to generate a perceptual image hash for content authentication.

"Image alignment based perceptual image hash for content authentication" by Xiaofeng Wang, Xiaorui Zhou, Qian Zhang, Bingchao Xu, and Jianru Xue,September 20, 2020

Literature Survey -8 Contd./..

Merits:

The method exhibits broad-spectrum robustness, effectively tolerating content-preserving manipulations and geometric distortions while providing satisfactory tampering localization accuracy

Demerits:

The complexity of the image alignment and feature extraction processes may increase computational burden, and there may be challenges in achieving optimal performance across all types of manipulations

"Image alignment based perceptual image hash for content authentication" by Xiaofeng Wang, Xiaorui Zhou, Qian Zhang, Bingchao Xu, and Jianru Xue,September 20, 2020

Literature Survey -9

A secured distributed detection system based on IPFS and blockchain for industrial image and video data security

Randhir Kumar, Rakesh Tripathi, Ningrinla Marchang, Gautam Srivastava, Thippa Reddy Gadekallu, and Neal N. Xiong(2021) provided"A secured distributed detection system based on IPFS and blockchain for industrial image and video data security".

Methodology used:

The proposed methodology employs an IPFS-based decentralized peer to-peer image and video sharing platform integrated with blockchain technology and perceptual hashing (pHash) for copyright infringement detection

"A secured distributed detection system based on IPFS and blockchain for industrial image and video data security" by Randhir Kumar, Rakesh Tripathi, Ningrinla Marchang, Gautam Srivastava, Thippa Reddy Gadekallu, and Neal N. Xiong2021

Literature Survey -9 Contd./..

Merits:

The framework ensures availability, immutability, transparency, and protection of copyright for multimedia objects while allowing each peer to verify copyright details through a distributed ledger

Demerits:

The existing centralized storage mechanisms in copyright techniques increase the chances of security and privacy threats, and somtraditional hashing techniques may fail to detect minor modifications in multimedia content

"A secured distributed detection system based on IPFS and blockchain for industrial image and video data security" by Randhir Kumar, Rakesh Tripathi, Ningrinla Marchang, Gautam Srivastava, Thippa Reddy Gadekallu, and Neal N. Xiong2021

Literature Survey -10

Hamming distributions of popular perceptual hashing techniques

"Hamming distributions of popular perceptual hashing techniques," by Sean McKeown and William J. Buchanan(2023)

Methodology used:

he study employs a million-image scale evaluation of various perceptual hashing algorithms, analyzing their Hamming distance distributions against different image modifications

"Hamming distributions of popular perceptual hashing techniques" by Sean McKeown and William J. Buchanan, March 2023

Literature Survey -10 Contd./..

Merits:

The approach provides a comprehensive understanding of the robustness and performance of perceptual hashing techniques in detecting content-preserving modifications

Demerits:

The reliance on a specific dataset and the controlled nature of image modifications may limit the generalizability of the findings to real-world scenarios

"Hamming distributions of popular perceptual hashing techniques" by Sean McKeown and William J. Buchanan, March 2023

Literature Survey - # Contd./..

Consolidation of the literatures:

S.No.	Author(s) & Year	Methodology used	Limitations
1	Yanghuan Li, Jinhui Wei, Junbin Yuan, Qingzhen Xu, and Chengying He & 2020	Blockchain Technology	Complexibility, Scalability, Security, Regulatory issues:
2	Xiaofeng Wang, Xiaorui Zhou, Qian Zhang, Bingchao Xu, Jianru Xue &2020	image alignment process followed by hybrid feature extraction using global and local Zernike moments combined with DCT-based statistical features	Optimal performance
3	Joren Six (2021)	Constant-Q Non-Stationary Gabor Transform, Near-Exact Hashing Technique,Thresholded Matching Strategy	Computational Complexity, Limited Evaluation, Trade-Offs, Potential for False Positives
4	Shweta Jain, Priyanka Samanta	Image Pre-processing, Feature Extraction	Limited Effectiveness in Content Changing Manipulations, Depenence on Pre-processing

Literature Survey - # Contd./..

Consolidation of the literatures:

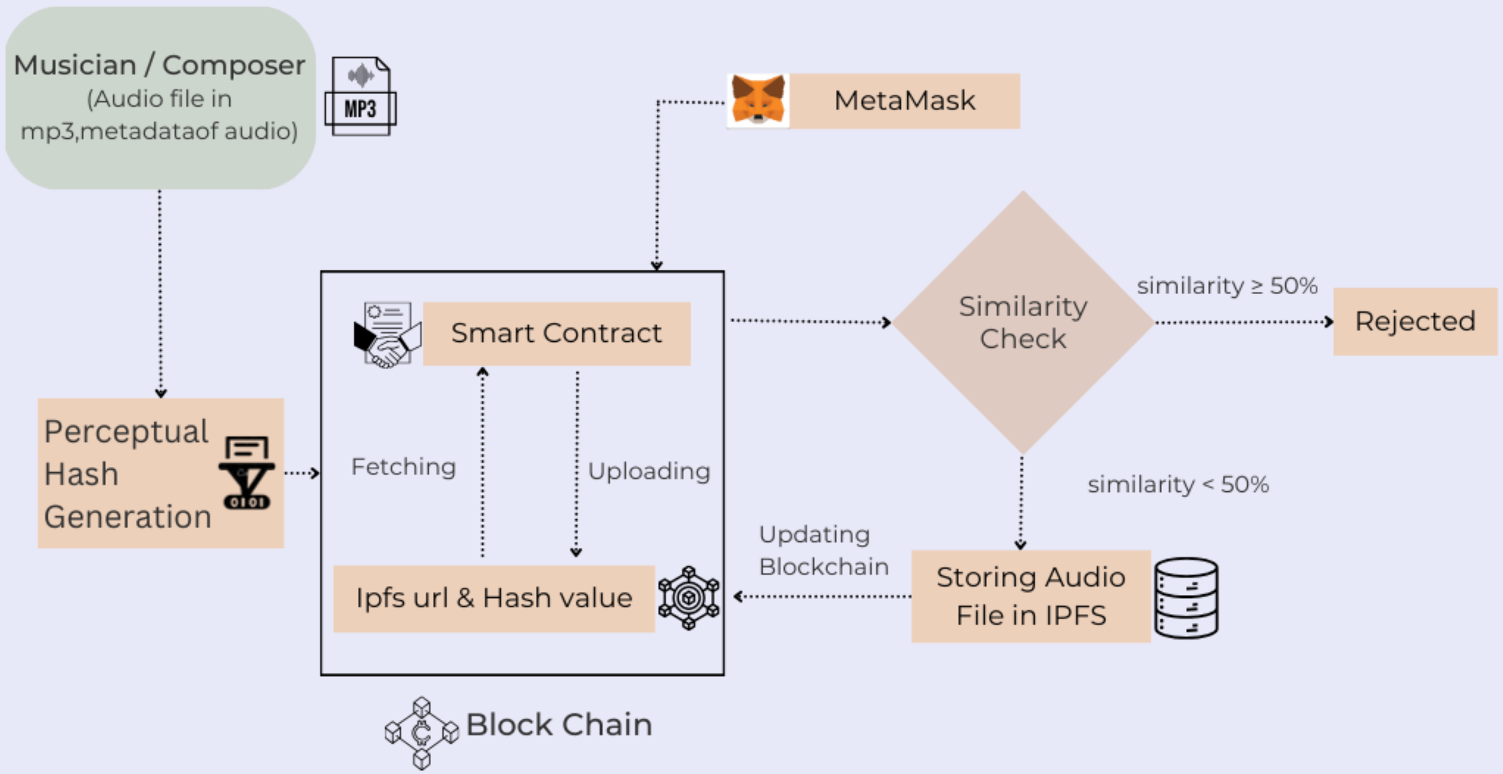
S.No.	Author(s) & Year	Methodology used	Limitations
5	Randhir Kumar, Rakesh Tripathi, Ningrinla Marchang, Gautam Srivastava, Thippa Reddy Gadekallu, and Neal N. Xiong	IPFS-based decentralized peer-to-peer image and video sharing platform integrated with blockchain technology and perceptual hashing (pHash) for copyright infringement detection	The existing centralized storage mechanisms in copyright techniques increase the chances of security and privacy threats, and some traditional hashing techniques may fail to detect minor modifications in multimedia content
6	Casper W.R. Hildebrand,Dr. Cynthia C.S. Liem and Dr. Jaehun Kim	a benchmark to evaluate the performance of the OLAF framework	The framework struggled with pitch-shifted and tempo-altered audio, leading to lower recall and precision in those cases, and the parameter setup used may not be optimal for all use cases

Literature Survey - # Contd./..

Consolidation of the literatures:

S.No.	Author(s) & Year	Methodology used	Limitations
7	Zhifeng Wang,Yao Yang, Chunyan Zeng,Shuai Kong, Shixiong Feng, and Nan Zhao. (2022)	Feature Extraction, Shallow Features, Deep Features, Feature Fusion, Classification	Complexity, Dependence on Data Quality
8	Joren Six,(2023)	Spectral Peaks Fingerprinting,C Programming Language, Modular Design	Complexity of C,Limited Input Validation,False Positives
9	Salvatore Serrano,Marco Scarpa(2023)	Panako	
10	Sean McKeown and William J. Buchanan(2023)	perceptual hashing algorithms, Hamming distance distributions	The reliance on a specific dataset and the controlled nature of image modifications may limit the generalizability of the findings to real-world scenarios

SYSTEM DESIGN



MODULES DESCRIPTION

1. Perceptual Hashing:

- **Panako:** An open-source audio fingerprinting tool designed for robust and efficient audio matching. Unlike Chromaprint, Panako utilizes a different hashing mechanism based on spectral peaks and time-frequency representations to identify audio segments. It is capable of handling noise, time-stretching, and pitch variations.
- **Process:** Panako's fingerprinting method is adapted to work similarly by capturing distinctive audio features while remaining resilient to minor modifications.

Steps:

1. Resample the audio to a standard rate and convert it to mono, then normalize the volume.
2. Use Short-Time Fourier Transform (STFT) to convert the audio into a spectrogram showing frequency and amplitude over time.
3. Extract key audio features such as dominant frequencies and temporal patterns, using techniques like MFCC.

MODULES DESCRIPTION

4. Apply thresholding to the features, turning them into binary values (1's and 0's) for simplification.

5. Combine the binary values into a unique hash that represents the audio content.

6. Compare the generated hashes between audio files, with smaller differences indicating similarity for copyright detection.

MODULES DESCRIPTION

2. Similarity Check:

- **OLAF Algorithm:** The OLAF algorithm is used for comparing the fingerprint of a new audio file with existing ones in the system. Unlike traditional peak-based methods, Panako utilizes a wavelet-based approach to extract time-frequency landmarks, making it resilient to pitch shifts, speed changes, and noise. It converts audio into fingerprints and searches for matches using locality-sensitive hashing (LSH). If the difference between fingerprints exceeds a 50% threshold, the audio is flagged for copyright infringement.
- **Hash Comparison with Blockchain:** The generated perceptual hash is compared with existing hashes stored on the blockchain. Since the blockchain holds previously registered audio files’ hashes, this step ensures that the uploaded audio is compared against all known records in a decentralized, immutable manner.

MODULES DESCRIPTION

- **Process:** This process determines whether to accept or reject an audio file by comparing its perceptual hash (PHash) to a list of previously stored audio hashes using Hamming distance. The hash of the current audio is generated and compared character-by-character with each stored hash. The similarity percentage is calculated based on the number of differing characters. If any hash comparison shows a similarity of 50% or more, the audio is rejected as too similar to an existing file. If no such similarity is found, the audio is uploaded to the decentralized IPFS storage system for further use.

MODULES DESCRIPTION

3. Storing the audio file in IPFS:

- **Inter Planetary File System (IPFS):** The decentralized storage system is used to store audio files off-chain. The IPFS URI (Uniform Resource Identifier) is saved on the blockchain as a reference to the stored file.
- **Blockchain (Ethereum):** A smart contract is used to manage the copyright protection mechanism. Once an audio file passes the similarity check, its IPFS URI and hash are stored on the Ethereum blockchain to ensure immutability, transparency, and availability.
- **Process:** The process connects to IPFS, a decentralized storage system, by calling `ipfs.start()`. Once connected, the audio file is added to IPFS using `ipfs.add(audiofile)`, which returns a unique URI (Uniform Resource Identifier) for the stored file. This URI is then stored in the smart contract as `hades.laudio`. Additionally, the current audio file's perceptual hash (`h1`) is appended to the list of hashes (`hades.PHashList`) for future comparisons. After these operations are completed, the IPFS connection is closed with `ipfs.stop()`, ensuring the system is ready for further transactions or processes.

EVALUATION METRICS

Audio Modification Attacks:

- Several signal-processing attacks were simulated to test the robustness of the perceptual hash:
  - Low-Pass Filter (LPF): Used to filter out high frequencies in audio.
  - Noise Addition: Adds varying levels of noise to the audio until a specific signal-to-noise ratio (SNR) is achieved.
  - Time Scale Modification: Adjusts the tempo of the audio without changing the pitch.
  - Pitch Shifting: Alters the pitch while maintaining the same tempo and duration.

MP3 and AAC Compression: Compresses the audio file at different bitrates to test if the hash can still detect the original audio.

EVALUATION METRICS

- **Robustness:**

$$\mathrm{FNR} = \frac{\mathrm{FN}}{\mathrm{TP} + \mathrm{FN}}$$

FN = False Negatives (incorrectly missed matches)
TP = True Positives (correctly identified matches)

EVALUATION METRICS

- **Reliability:**

$$FPR = \frac{FP}{FP + TN}$$

FP = False Positives (incorrect results)
TN = True Negatives (correctly identified as not matching)

EVALUATION METRICS

- **Fingerprint Size:** No specific formula is provided, but this is generally calculated as the amount of storage space required for each fingerprint, typically expressed in bytes or kilobytes per fingerprint
- **Granularity:** A Granularity is expressed in terms of time, usually as the minimum duration of audio (in seconds) required for a positive match.

Granularity (G)=Minimum duration of audio needed for a positive match (in seconds)

- **Search Speed and Scalability:** This is often measured using performance metrics like Time Complexity or actual search time. While no specific formula is provided for search speed, the general form is:

Search Time (T)=f(n)

Where n is the number of fingerprints in the database, and f(n) is the time complexity of the search algorithm (often logarithmic or linear).

ALGORITHMS USED

1. OLAF Similarity Algorithm :

```
while i ≤ length(audioList) do
h2 ← audioPHashList[i];
minLen ← min(length(h1),length(h2));
similar ← FALSE;
distance ← 0;
k ← 1;
while k ≤ minLen do
if h1[k] ≠ h2[k] then
distance ← distance + 1;
else
continue;
end
k ← k + 1
end
i ← i + 1;
percentage[i] ← (distance×100)÷minLen;
end
j ← 1;
while j ≤ length(percentage) do
if percentage[j] ≥ 50% then
similar ← TRUE;
reject the audio;
else
continue;
end
j ← j + 1;
end
```

ALGORITHMS USED

2. Storing Audio File in IPFS Algorithm:

```
//Connecting to the IPFS Storage//;
ipfs.start();
//Adding Audio File to IPFS and Its URI to Smart Contract//;
hades.Iaudio ← ipfs.add(audiofile);
hades.PHashList ← [hades.PHashList, h1];
//Close the IPFS connection//;
 ipfs.stop();
```

Working Environment

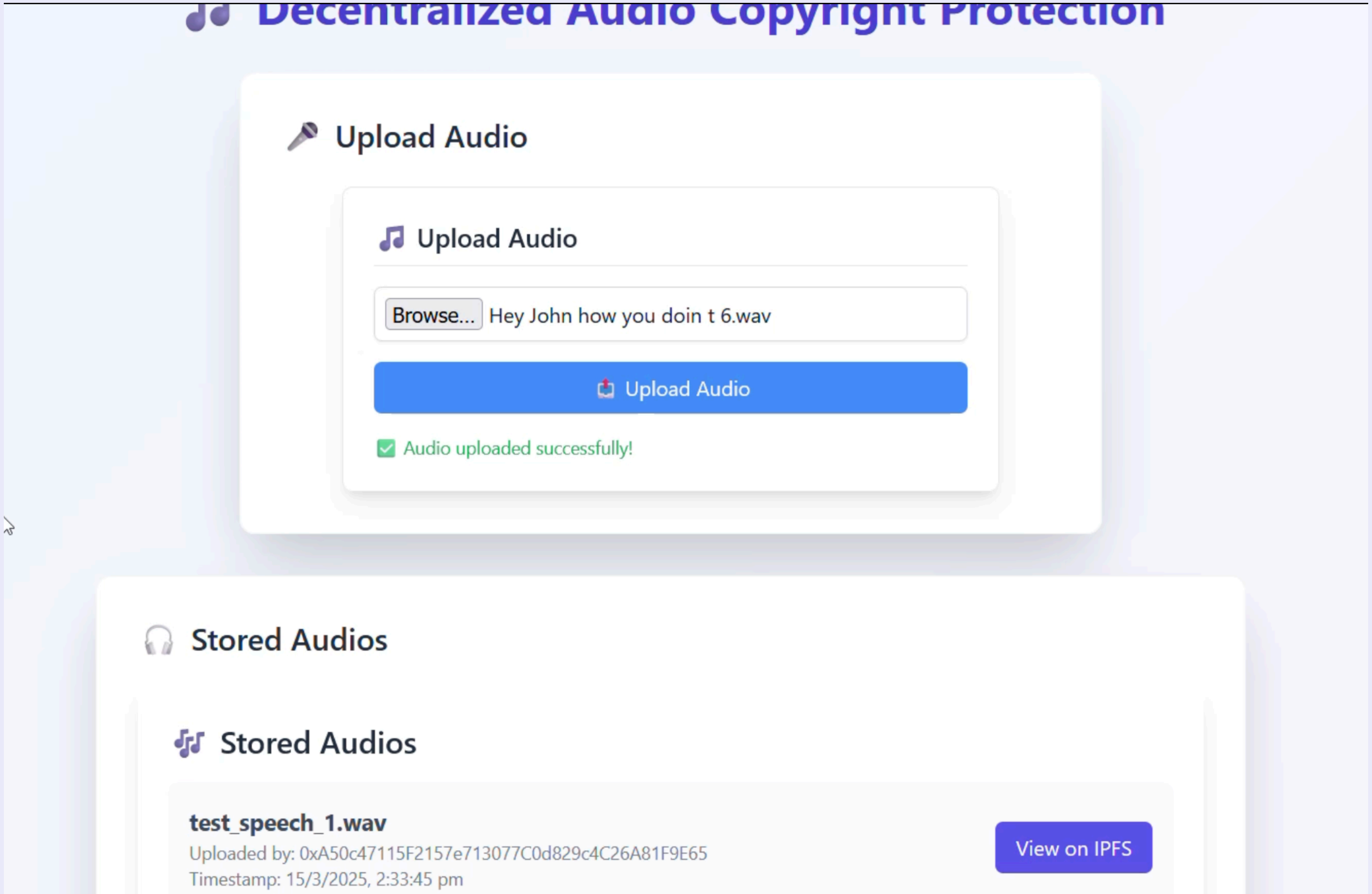
- Ganache
- Metamask
- Truffle
- Panako and Olaf
- Solidity
- React JS
- IPFS Desktop
- Node
- Gradle

INPUT

- Audio file along with metadata

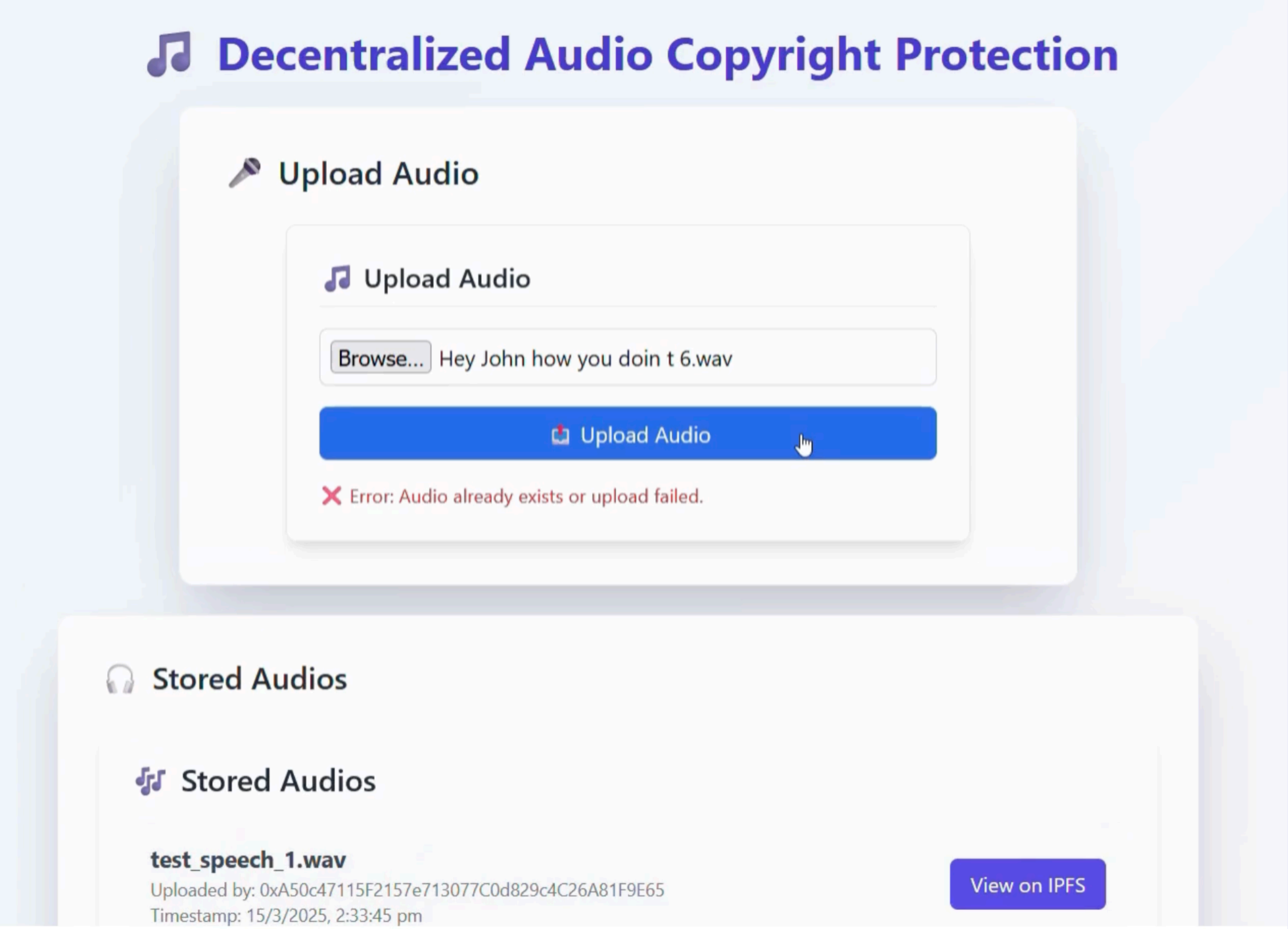
OUTPUT

Audio Upload Successful :



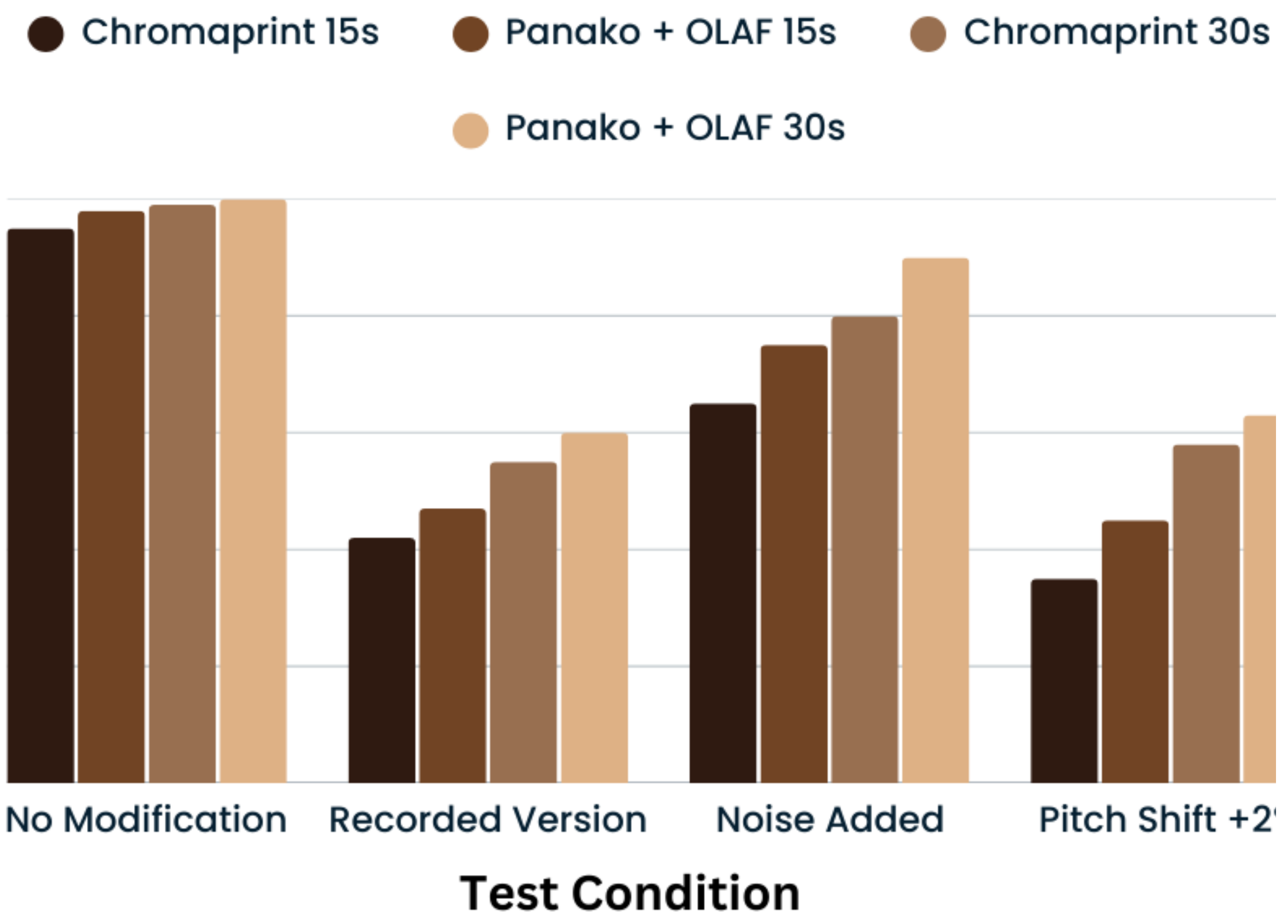
OUTPUT

Audio Upload Failed :



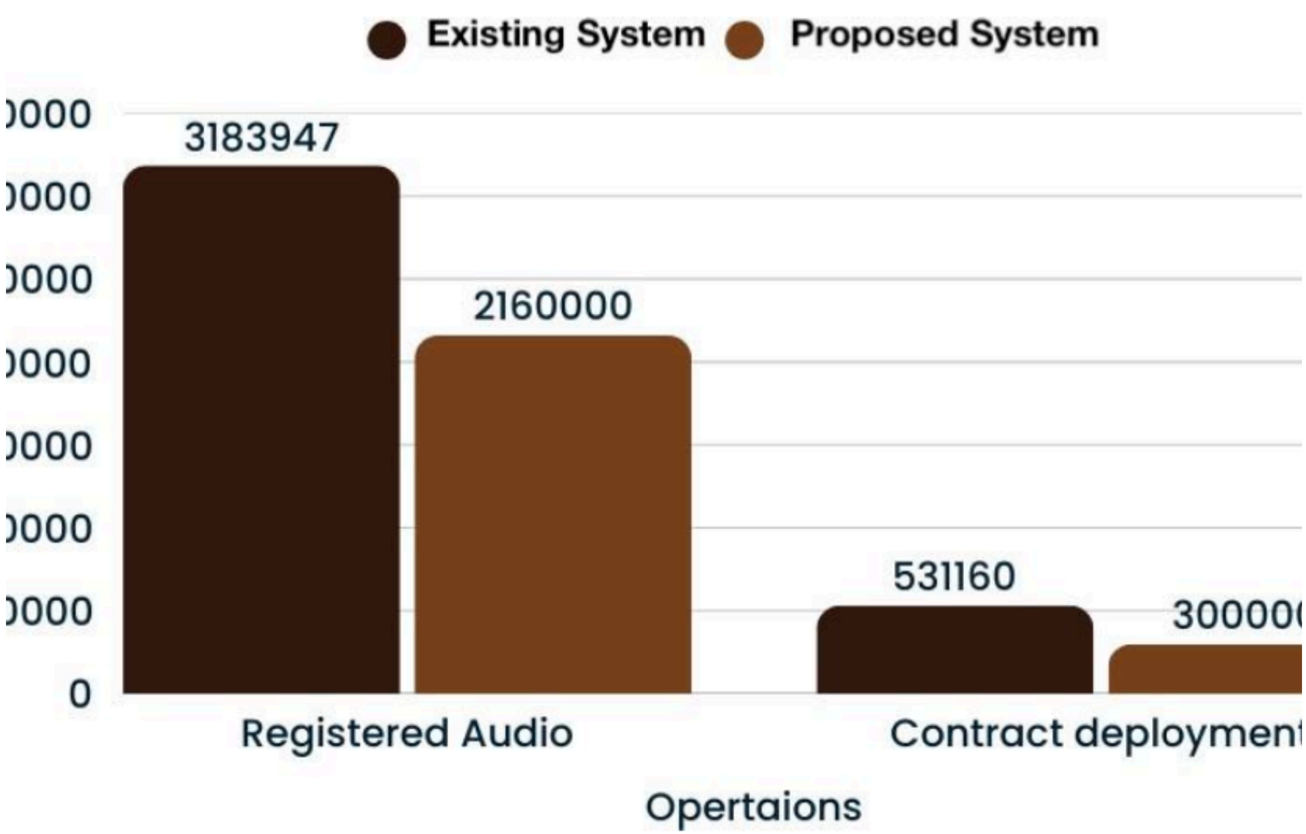
EXPERIMENTAL RESULTS

Similarity comparison:



EXPERIMENTAL RESULTS

Gas comparison:



MODULES COMPLETED

- Perceptual Hash Generation
- Blockchain Integration
- Hash Comparison
- IPFS Storage

SOCIAL IMPACT

- Protection of Artist’s Rights
- Encouragement of Creative Expression
- Reduction of Piracy
- Empowerment of Music Communities

ECONOMIC ASPECTS

- Increased Revenue for Artists
- Growth of the Music Industry
- Job Creation
- Investment in Technology
- Reduction of Legal Costs

REFERENCES

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