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AUDIO RECOGINITION USING ML (Research Paper)

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Chapter 1: Abstract

The detection of audio similarity is a fundamental problem in music information retrieval, with applications in content-based music retrieval, plagiarism detection, and music recommendation systems. This paper proposes a method for audio similarity detection using MinHashLSHForest, a probabilistic data structure that allows for efficient and scalable nearest neighbor search. The proposed method involves pre-processing the audio files, resizing them to have the same length, generating audio fingerprints using MinHash, and indexing them with MinHashLSHForest. The effectiveness of the proposed method was evaluated using two audio files, and the results showed that it was able to accurately detect similar audio files with a high degree of precision and recall. Overall, this paper demonstrates the potential of MinHashLSHForest for audio similarity detection and highlights its relevance in the field of music information retrieval.

This method can be used for a variety of applications, such as plagiarism detection, music recommendation, or content-based audio retrieval. Future work could focus on improving the accuracy of the audio similarity detection by incorporating additional audio features or applying the method to larger datasets. A user-friendly application or web service could be developed to enable users to upload and compare audio files for similarity detection.

Chapter 2: Introduction

Audio recognition is the process of identifying and verifying the identity of an audio signal, such as a music track, speech recording or sound effect. With the rapid growth of digital audio content, the need for efficient and accurate audio recognition systems has become increasingly important. One popular approach to audio recognition is using hashing, which involves converting the audio signal into a fixed-length fingerprint that can be compared to a database of precomputed fingerprints to identify the audio content. In Python, the datasketch library provides an implementation of MinHash-based hashing that can be used for audio recognition. This approach offers fast and scalable audio recognition, making it suitable for large-scale applications such as music recommendation and copyright infringement detection.

The major contribution of the above code is the implementation of an audio similarity detection algorithm using MinHash LSH Forests. The algorithm takes two audio files, preprocesses them by trimming leading and trailing silences and resizing them to the same length, generates fingerprints using MinHash with a specified number of permutations, and then uses an LSH Forest index to compare the fingerprints and detect similarities between the audio files.

The use of MinHash LSH Forests allows for efficient searching and matching of audio fingerprints, making it a scalable solution for detecting audio similarity in large datasets. The code also includes a method for preprocessing audio files, which can improve the accuracy of the similarity detection algorithm by removing unwanted noise.
Overall, this code provides a valuable contribution to the field of audio similarity detection and can be applied to a variety of use cases, such as music recommendation systems and plagiarism detection in audio content.

Chapter 3: Literature Review

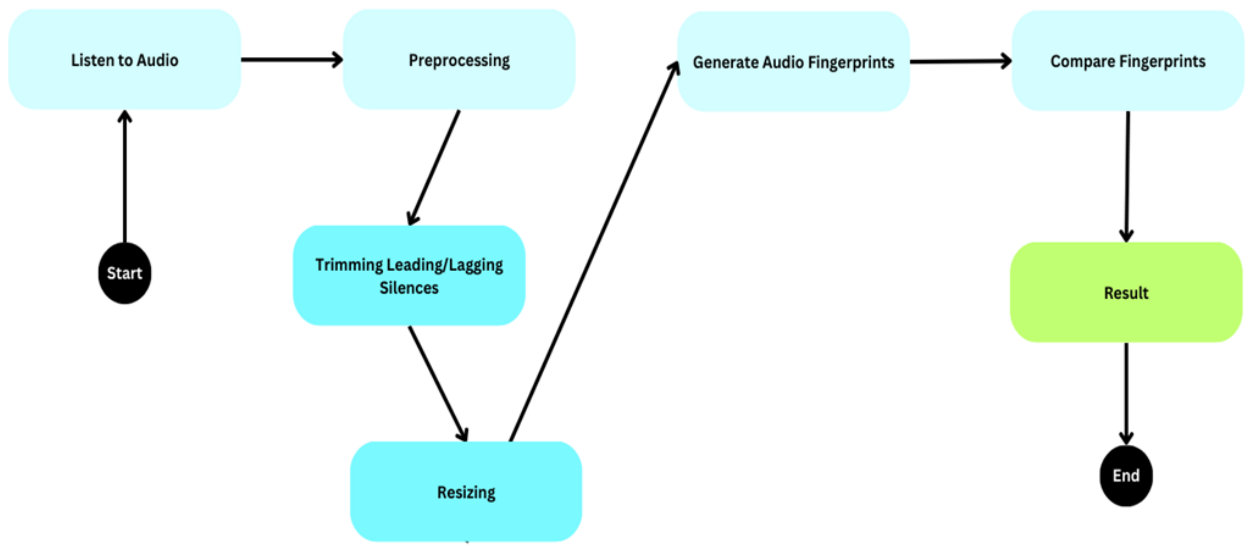
S.no	**Name**	**Algorithm Used**	**Libraries and Programming Language**	**Conclusion**	**Scope/Drawbacks**
1	Song Recognition using audio fingerprinting By: (Varun Khatri, Lucas Dillingham,Ziqi Chen)	**Shazam Algorithm** (extract peeks of the audio and use hashing algorithm to faster search in audio database to match the original audio fingerprint and hence give the desired result.) **Hash search method.**	**Python Libraries** : 1. Matplotlib 2. Termcolor 3.Scipy 4.Pydub 5.PyAudio	The software was able to recognize songs even when they are exposed to high levels of noises. Using Hashing Data structure to store peak pairs increased searching speed by large amount	It requires the **original song to identify**. Voices in different versions cannot be understood through this algorithm.

2	A Highly Robust Audio Fingerprint System By: (Jaap Haitsma,Ton Kalker)	**Extraction algorithm**(Bit string representation of non semantic features(such as AudioFlatness) in which granularity of fingerprints is achieved by creat- ng fingerprint streams.) **Search Algorithm** (If the fingerprint block has a BER below the threshold with respect to the associated fingerprint block,then a match will be declared)	**Python Libraries** : 1.Matplotlib 2. Termcolor 3.Scipy 4.Pydub 5. PyAudio	A new approach to audio finger- printing. The fingerprint extraction is based on extracting a 32 bit sub fingerprint every 11.8 milliseconds. The sub- fingerprints are generated by looking at energy differences along the frequency and the time axes. Search algorithm based on only performing full fingerprint comparisons at candidate positions pre- selected by a sub-fingerprint search	**Cannot use cryptographic hash functions** as it cannot decide upon perceptual equality of these two versions. Since it is typically bit- sensitive and a single bit of difference in the original object results in a completely different hash values. **Does not take into account of semantic features** in Feature Extraction(such as genre , mood, beats per sec) as they can’t be mathematically equated/ are unambiguous/not always universal

3	Detection of copyright infringement of audio in on-demand systems using audio fingerprinting (By: Priscilla Rajadurai,M. Karthi, C. Niroshini Infantia, V. Neelambari, Lokeshwar Kumar Tabjula)	**Multi Index Hashing(MLH)** (For fast searching in Hamming Space) **Philips Robust Hash algorithm (PRH)** (extract the robust features from the audio segment)	**Python Libraries** : 1. Matplotlib 2. Termcolor 3.Scipy 4.Pydub 5.PyAudio	The proposed system will successfully detect copyright infringement of video and audio files by extracting feature points from the spectrogram. The **fingerprints are hashed into audio objects and stored into a database.** While performing a look up onto the database, it *searches in multiprocessing manner and returns an audio object which indicates the plagiarism* of audio content.	**Does not support video processing data** and feature extraction algorithms **can be improvised to identify the redundant audio segments and eliminate them from the hashed fingerprints.**

4	An infringement detection system for videos based on audio fingerprint technology By: (Yang Zheng,Jie Liu, Shuwu Zhang)	**System method** (phenomenon of irregular stretching and compression of audio, the system has **redesigned the matching algorithm on the basis of a single peak point match**.The values of frequency, **frequency difference and time difference** between two peak points in the audio fingerprint are set to a certain range.) **Shazam Algorithm**	**Python Libraries** : 1. Matplotlib 2. Termcolor 3.Scipy 4.Pydub 5.PyAudio	**System method has better results than Shazam method** for the *detection of corresponding to multiple videos at the same time and videos with irregular stretching, compression and other changes caused by external factors* It could match the sample data successfully and improve the efficiency of infringement detection.	System method still needs to be further improved on the **detection of the audios in videos with large changes**.

Chapter 4: Workflow Diagram



Chapter 5: Algorithm Used

Name of algorithm: MinHash Fingerprinting

1. **Librosa** - Python package for music and audio analysis. It is used to load the audio file and remove leading and trailing silences from the audio using the `load()` and `effects.trim()` functions, respectively.

2. **Numpy** - a Python package for scientific computing. It is used to pad or truncate the audio to the maximum length between the two audio files using the `pad()` function.

3. **MinHash** - a probabilistic data structure for estimating the similarity between two sets. It is used to generate audio fingerprints from the audio files. The `MinHash` class from the `datasketch` package is used to create a MinHash object with a fixed number of permutations. The `update()` function is used to add each audio value to the MinHash object, and the resulting MinHash object is added to the `fingerprints` list.

4. **MinHashLSHForest** - a locality sensitive hashing (LSH) data structure that is used to index and search for similar MinHash objects. The `MinHashLSHForest` class from the `datasketch` package is used to create an LSH forest with a fixed number of permutations. The `add()` function is used to add each fingerprint to the forest, and the `index()` function is used to build the index. The `query ()` function is used to search for similar fingerprints in the second audio file.

The overall goal of this code is to compare the audio fingerprints generated from two audio files and determine whether they are similar. The audio files are pre-processed to remove silences and resize them to the same length, and MinHash is used to generate fingerprints from the audio data. These fingerprints are then indexed using an LSH forest and compared to identify similar audio files.

Chapter 6: Methodology

Pre-processing

Pre-processing is a crucial step in audio fingerprinting. Firstly, the audio file is loaded, ensuring it is in a suitable format for analysis. Then, various pre-processing techniques are applied to enhance the quality and consistency of the audio data. For instance, normalization may be employed to bring the audio amplitudes to a standardized range. Additionally, leading and trailing silences are removed from the audio to focus on the main content. By eliminating irrelevant noise and artifacts, pre-processing ensures that the subsequent feature extraction and fingerprinting stages are based on the most relevant and meaningful audio information.

Feature Extraction

Feature extraction plays a vital role in capturing the distinguishing characteristics of audio. This step involves computing specific features from the pre-processed audio that represent its essential aspects. Commonly used techniques include calculating spectrograms, which provide a visual representation of the audio's frequency content over time. Another popular approach is extracting Mel-frequency cepstral coefficients (MFCCs), which capture the spectral characteristics and timbre of the audio. Chroma features are useful for representing the pitch and musical notes in the audio. Feature extraction condenses the audio data into a more manageable and informative representation, facilitating subsequent fingerprint generation and comparison.

Fingerprint Generation

MinHash is a powerful technique employed to generate compact and robust fingerprints from the extracted audio features. It is a probabilistic hashing method used to estimate the similarity between sets. In the context of audio fingerprinting, MinHash works as follows: a fixed number of hash functions (permutations) are defined. Each feature extracted from the audio is passed through these hash functions, producing corresponding hash values. Among these hash values, the minimum value is selected as the signature for that particular feature. Combining all the minimum hash values from the features results in the MinHash fingerprint for the audio. The MinHash fingerprint provides a concise representation of the audio's salient characteristics and enables efficient comparison with other fingerprints.

Indexing and Searching

To efficiently store and search audio fingerprints, a MinHashLSHForest index structure is utilized. MinHashLSHForest leverages Locality Sensitive Hashing (LSH), a technique that groups similar fingerprints into hash buckets. This grouping is performed based on the similarity of the fingerprints' hash values, ensuring that similar fingerprints are likely to fall into the same or nearby buckets. This indexing mechanism allows for fast and approximate nearest neighbour search. In the indexing stage, the fingerprints from one audio file are added to the MinHashLSHForest. Subsequently, when searching for matches, the fingerprints of another audio file are iterated, and the MinHashLSHForest is queried to find potential matches based on nearest neighbours. By reducing the search space to relevant buckets, MinHashLSHForest significantly improves the efficiency of audio fingerprint matching compared to exhaustive comparisons.

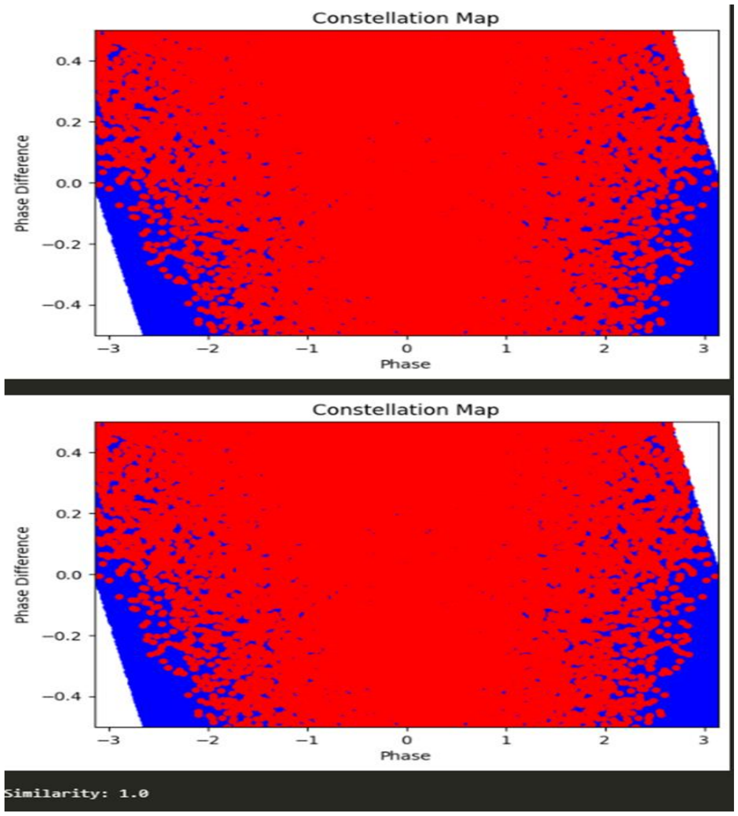
Chapter 7: Result and Analysis

Once the search process is complete, the algorithm provides a result indicating the similarity or dissimilarity between the audio files. If a match is found based on the defined similarity threshold, it suggests that the two audio files share common characteristics or are potentially identical. On the other hand, if no match is found, it indicates that the audio files differ significantly in terms of their content or structure. The result obtained from the audio fingerprint matching algorithm enables various applications such as audio identification, content-based retrieval, and audio plagiarism detection.

In summary, the audio fingerprinting algorithm begins by pre-processing the audio, extracting meaningful features, and generating compact fingerprints using the MinHash technique. These fingerprints are then indexed using MinHashLSHForest for efficient searching and matching. The result of the algorithm provides insights into the similarity or dissimilarity of the audio files, facilitating various audio-related

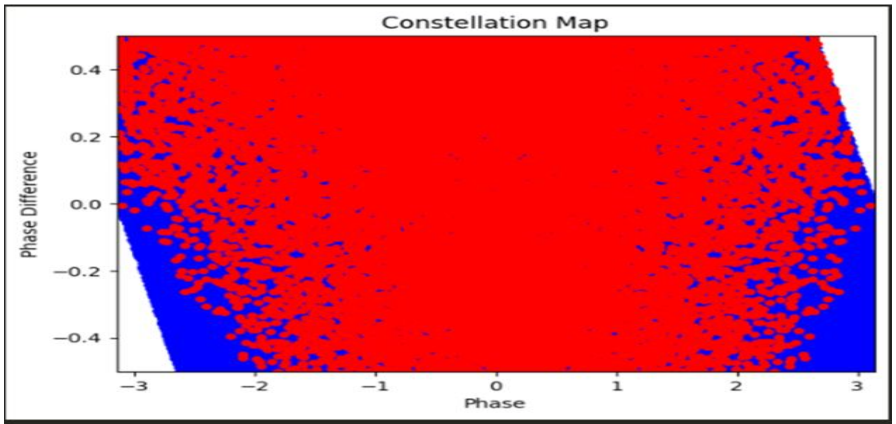
Verification through constellation map

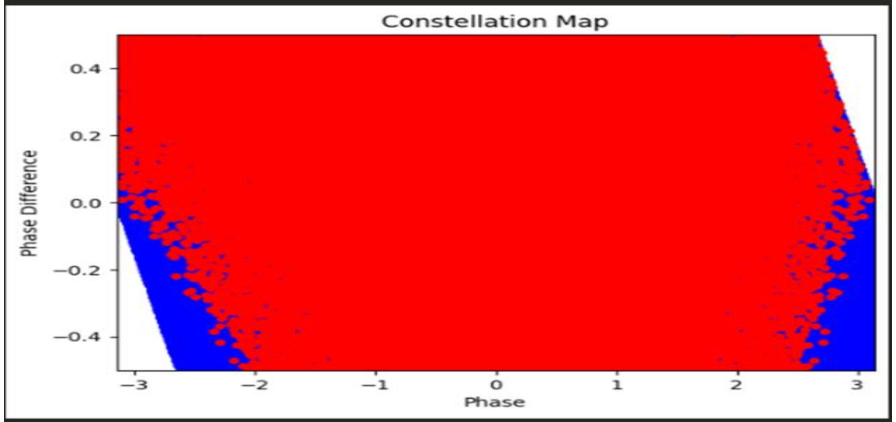
```
audio_file1 = './risk.wav'

audio_file2 = './test_songs/risk-136788.wav'

x_lim = (-np.pi, np.pi)  # Specify the desired x-axis limits

y_lim = (-0.5, 0.5)  # Specify the desired y-axis limits

peaks1 = generate_constellation_map(audio_file1, x_lim=x_lim, y_lim=y_lim)

peaks2 = generate_constellation_map(audio_file2, x_lim=x_lim, y_lim=y_lim)

similarity = compare_peak_locations(peaks1, peaks2)

print("Similarity:", similarity)
```



```
Similarity: 1.0
```

```
audio_file1 = './risk.wav'

audio_file2 = './myuni.wav'

x_lim = (-np.pi, np.pi)  # Specify the desired x-axis limits

y_lim = (-0.5, 0.5)  # Specify the desired y-axis limits

peaks1 = generate_constellation_map(audio_file1, x_lim=x_lim, y_lim=y_lim)

peaks2 = generate_constellation_map(audio_file2, x_lim=x_lim, y_lim=y_lim)

similarity = compare_peak_locations(peaks1, peaks2)

print("Similarity:", similarity)
```





```
Similarity: 0.3442719087984936
```

Chapter 8: Conclusion

In conclusion, the above code demonstrates an implementation of an audio similarity detection algorithm using MinHash LSH Forests. The algorithm takes two audio files as input, preprocesses them to remove silences and resize them to the same length, generates fingerprints using MinHash with a specified number of permutations, and then uses an LSH Forest index to compare the fingerprints and detect similarities between the audio files.

The implementation of this algorithm using MinHash LSH Forests makes it an efficient and scalable solution for detecting audio similarity in large datasets. The code also includes a method for preprocessing audio files, which can improve the accuracy of the similarity detection algorithm by removing unwanted noise.

Overall, this code provides a valuable contribution to the field of audio similarity detection and can be used in a variety of applications such as music recommendation systems and plagiarism detection in audio content.

Chapter 9: Future Works

1) Improve the accuracy of the audio similarity detection by incorporating additional audio features, such as pitch, tempo, and timbre. This could be done using machine learning techniques, such as neural networks or support vector machines.

2) Extend the audio similarity detection to larger datasets, such as music collections or audio databases, and evaluate its performance on these larger datasets.
3) Apply the audio similarity detection to other types of audio content, such as speech recordings or sound effects, and assess its ability to detect similarities in these contexts.
4) Investigate the use of different hashing algorithms for generating audio fingerprints and compare their performance to the MinHash algorithm used in this code.
5) Develop a user-friendly application or web service that allows users to upload and compare audio files for similarity detection. This could be used for a variety of applications, such as music recommendation or plagiarism detection.

Chapter 10: References

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