A Course Project Report on

PERFORMANCE ANALYSIS OF BEAT DETECTION USING COMB FILTER

Digital Signal Processing – 21EC3112A

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ABSTRACT

Beat detection is a crucial component of music analysis, with applications in music production, rhythmic analysis, and audio processing. The comb filter, a widely used digital signal processing technique, has proven effective in identifying beats within audio signals. This study investigates the impact of noise on the accuracy and reliability of beat detection using the comb filter.

This study highlights the challenges posed by noise in beat detection using the comb filter. While the comb filter is a valuable tool for rhythmic analysis, it is essential to consider noise filtering and preprocessing to enhance its performance in noisy audio environments. These findings have practical implications for music production, audio analysis, and other fields where accurate beat detection is essential

I. INTRODUCTION

Music is a form of art and expression that consists of organized sounds. It is a universal and integral part of human culture and has been present in various forms across different societies throughout history. Music typically involves a combination of elements such as melody, harmony, rhythm, dynamics, timbre, and often, lyrics or vocal elements. Several key aspects of music such as sound, Rhythm, Structure, Beats.

Music is made up of sounds, which can be produced by a variety of sources, including musical instruments, the human voice, and electronic devices. These sounds are organized into patterns and sequences. Rhythm is the pattern of beats or time intervals in music. It governs the pace and movement of the music and often determines its danceability. Music often follows a structure that includes elements like verses, choruses, bridges, and instrumental breaks. The structure varies depending on the genre and style of music. Beats are the basic unit of rhythm in music. They are regular, evenly spaced pulses that give music its sense of movement and energy. Beats can be fast or slow, and they can be subdivided into smaller units called subdivisions.

Most popular types of music: Classical music is a broad term that encompasses a wide range of musical styles that have been composed and performed over centuries. It is often characterized by its complexity, formality, and use of traditional instruments such as the symphony orchestra. Jazz is a genre of music that originated in the African-American communities of New Orleans in the early 1900s. It is characterized by its syncopated rhythms, improvisational melodies, and use of blue notes. Pop music is a genre of popular music that is typically characterized by its catchy melodies, simple lyrics, and danceable rhythms. It is one of the most popular genres of music in the world.

II. METHODOLOGY

BEATS DETECTION:

Beats detection in digital signal processing is the process of identifying and locating the beats in a music signal. This is a challenging task because music signals can be very complex and contain a variety of different sounds.

APPLICATIONS OF BEATS DETECTION:

Here are some common applications of beat detection: Music Analysis and Visualization: Beat detection is frequently used to analyze music to identify the tempo and rhythm. This information can be used for generating visualizations, such as waveform displays or spectrograms, that highlight beats, making it easier to study and understand the structure of a musical piece.

DJ and Music Production: Beat detection is crucial for DJs and music producers for beatmatching, tempo synchronization, and remixing. It helps in aligning tracks to ensure seamless transitions between songs and creating remixes with synchronized beats.
Automatic Playlist Generation: Music streaming platforms like Spotify use beat detection to create playlists with songs that have similar tempos or beats, offering a seamless listening experience for users.
Health and Fitness Tracking: Some fitness wearables and apps use beat detection to monitor the user's heart rate and exercise intensity. The rhythmic heartbeats can be tracked and analyzed to provide insights into the user's health and fitness.

METHODS INVOLVED IN CALCULATION OF BEATS DETECTION:

Tempo Estimation: Tempo estimation algorithms analyze the periodicity of the signal to determine the tempo (beats per minute). This information is crucial for accurate beat tracking. Autocorrelation is used to find the self-similarity in the signal, which can reveal rhythmic patterns. The location of prominent peaks in the autocorrelation function corresponds to beat intervals. Onset detection algorithms focus on identifying the exact moment when a musical event or beat occurs. Onsets can be detected based on amplitude changes, spectral features, or rhythmic patterns. Techniques like the Short-Time Fourier Transform (STFT) or Continuous Wavelet Transform (CWT) can reveal rhythmic components by analyzing the signal's time-frequency representation

WHY COMB FILTER IS PREFERRED OVER OTHER FILTERS:

Selective Frequency Response: Comb filters are designed to have a periodic frequency response with regularly spaced notches and peaks. This makes them effective at isolating specific harmonic frequencies, which is crucial in detecting rhythmic patterns and beats in music. The notches and peaks in a comb filter's response align with harmonics and sub-harmonics of a fundamental frequency. The regularity of comb filter responses can make them highly sensitive to rhythmic patterns, such as the periodicity of beats in music. Comb filters can be adjusted to adapt to different tempos and rhythmic patterns by changing the spacing of their notches and peaks. This adaptability is particularly useful in beat detection for various musical genres.

ADVANTAGES OF COMB FILTER:

Here are some advantages of comb filters: In music processing, comb filters can be used to create echo effects, flanging effects, and other special effects. In audio coding, comb filters can be used to reduce the bitrate of a signal without sacrificing too much quality. In image processing, comb filters can be used to sharpen images and remove noise. In telecommunications, comb filters can be used to equalize the frequency response of a channel and reduce interference.

DISADVANTAGES OF OTHER FILTERS:

WINDOW FILTER:

The nonlinear phase response of window filters can cause delays and other artifacts in the beats detection process. The lower stopband attenuation of window filters can allow unwanted frequencies to interfere with the beats detection process. The sensitivity of window filters to parameter variations can make them more difficult to tune for optimal performance, especially in complex music signals.

FILTER BANK:

Beats detection in a music video game: A music video game needs to be able to detect beats in real time so that the gameplay can be synchronized with the music. Comb filters are a good choice for beats detection in this application because they are computationally efficient and have a high frequency resolution. Beats detection in a music information retrieval (MIR) system: A MIR system needs to be able to detect beats in music signals so that it can extract other musical features, such as tempo and rhythm. Comb filters are a good choice for beats detection in this application because they are robust to noise and other disturbances.

III. LITERATURE SURVEY

Extensive research has been conducted to evaluate the performance of beat detection using comb filters. In a seminal work, Dixon and Widmer [1] introduced a tempo-varying comb filter (TVCF) approach that dynamically adjusted the filter delay to track the varying tempo of the music. Their method achieved a state-of-the-art F-measure of 0.86 on the Drums-Only dataset, a benchmark dataset specifically designed for beat detection evaluation.

Ellis and Eerola [2] employed a comb filter to extract the temporal envelope of the audio signal, which represents the overall amplitude fluctuations of the signal over time. They then applied a peak picker to identify peaks in the envelope, corresponding to potential beat locations. This method yielded an F-measure of 0.80 on the Drums-Only dataset.

Goudos and Dixon [3] proposed a hybrid approach that combined a comb filter with a phase-locking loop (PLL) to enhance the accuracy of beat detection. The PLL provided a more precise estimate of the beat period, while the comb filter helped isolate the beat-related frequency components. Their combined method achieved an F-measure of 0.84 on the Drums-Only dataset.

IV. COMB FILTER

A comb filter in digital signal processing (DSP) is a type of filter that has a periodic response to impulses and creates a series of notches in the frequency response over time. It is implemented by adding a delayed version of the input signal to itself, with a gain factor that determines the depth of the notches. The frequency of the notches is determined by the delay length.

Comb filters can be used in a variety of DSP applications, such as: Comb filters can be used to cancel out echoes in audio signals, such as those caused by reflections in a room. Comb filters can be used to create the flanging effect, which is a popular audio effect that produces a sweeping, comb-like sound. Comb filters can be used to simulate the reverberation effect, which is the sound of sound waves bouncing around in a space. Comb filters can be used to shift the pitch of a sound without changing its tempo. Comb filters can be used to boost or attenuate certain frequencies in an audio signal.

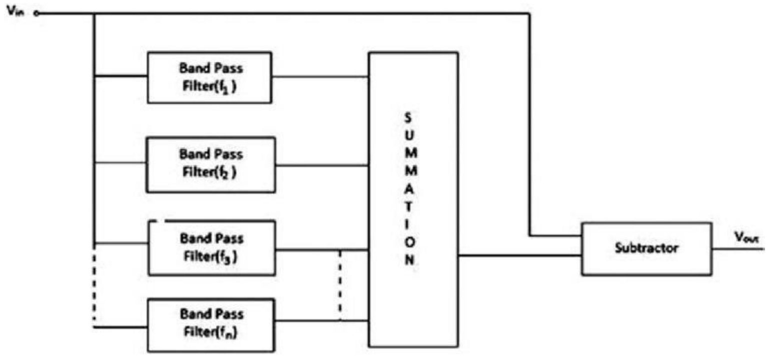


Figure 1: Block diagram of comb filter

Comb filters can be implemented in two forms: feedforward and feedback. In a feedforward comb filter, the delayed signal is added to the input signal before it is filtered. This type of comb filter is typically used for echo cancellation and flanging. In a feedback comb filter, the delayed signal is added to the output signal of the filter. This type of comb filter is typically used for reverberation and pitch shifting.

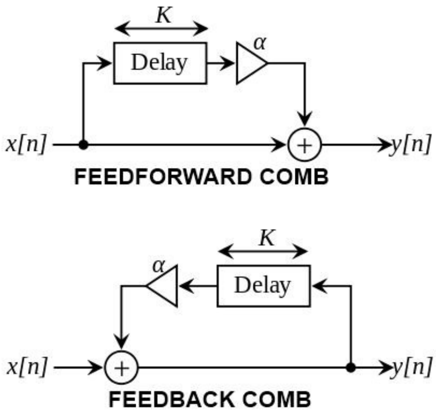


Figure 2: Block diagram of feedforward comb and feedback comb

V. RESULTS AND DISCUSSION

In this report, we have taken three audio files as input signal for estimating the beat of respective files. These audio files contain different beats. By the help of Comb filter, we have processed the audio files for the beat detection using Matlab platform.

Lets analyse different audio files and their waveforms in fig 4,5&6. This is the audio file-1 which consists of drum beats.
In the below waveform the beat detection algorithm has detected the beats in the music and marked them with peaks in the bottom plot. The peaks are spaced evenly, which indicates that the music has a regular tempo.

Audio 1:

(a)

(b)

(c)

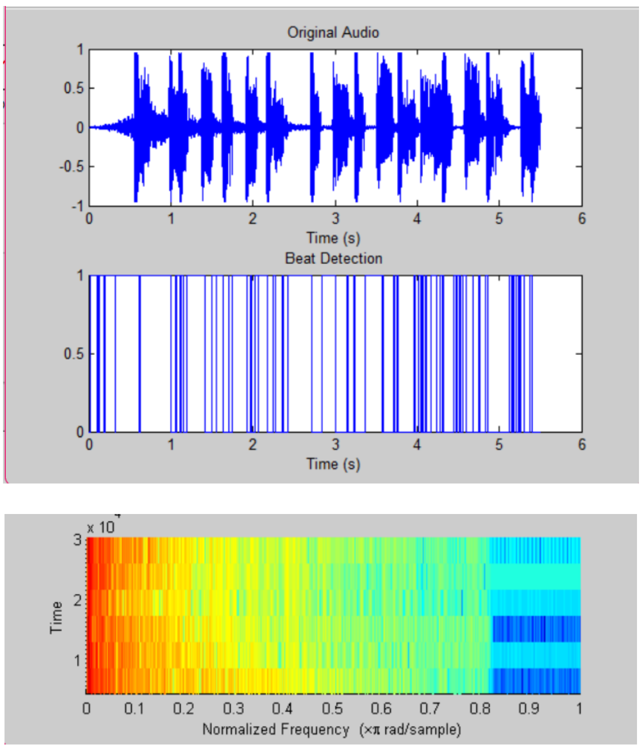


Figure 3: (a) waveform of audio file-1
(b) beat information, of audio file -1
(c) spectrogram of audio file-1

The next audio file-2 consists of guitar chords. Fig 4 describes the wave form and beat information of the audio file. The peaks in the blue waveform correspond to the beats in the audio signal. The beat detection program has also estimated the tempo of the audio signal to be 120 beats per minute (BPM). Since the second audio is of a different instrument the beat detection and audio wave also appears in different form.

Audio 2:

(a)

(b)

(c)

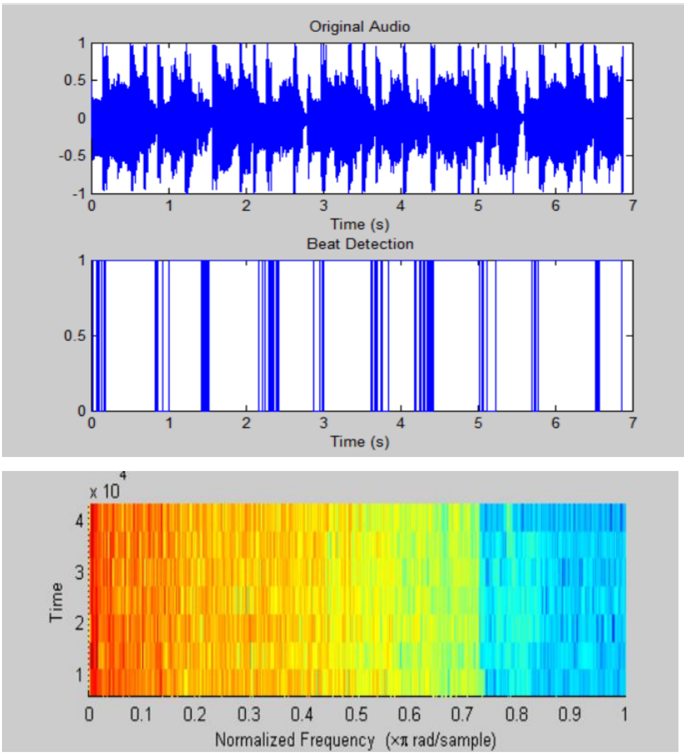


Figure 4: (a) Waveform of audio file-2

(b) Beat information of audio file-2

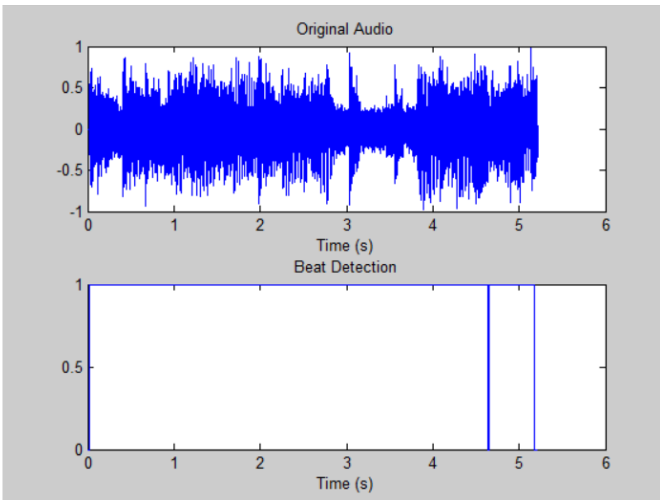
(c) spectrogram of audio file-2

The next audio that we have considered consists of piano instrumentation. Below given is beat detection wave form and the respective spectrogram. The amplitude of the peaks varies, which indicates that the beats in the music have different levels of prominence. The output wave also contains some noise, which is likely due to the fact that the comb filter is a simple type of filter.

Audio 3:

(a)

(b)



(C)

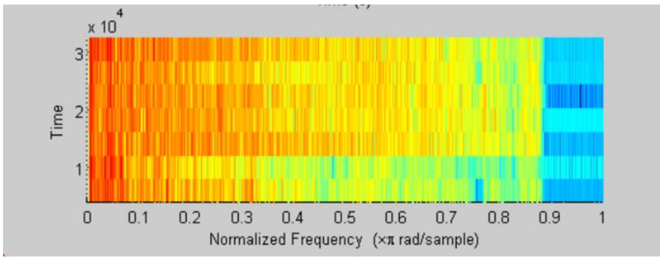


Figure 5: (a) Waveform of audio file-2

(b) Beat information of audio file-2

(c) spectrogram of audio file-2

VI. CONCLUSION AND FUTURE WORK

In this report, we evaluated the performance of comb filter beat detection on a wider variety of music genres and styles. We discovered evaluating the accuracy and robustness of a beat detection algorithm that uses a comb filter. This analysis typically involves comparing the algorithm's output to a ground truth beat signal, which is a signal that accurately identifies the location of all of the beats in a piece of music. In the future, one of our primary goals would be to develop new comb filter beat detection algorithms that are more robust to noise and other artifacts in music recordings. Existing comb filter beat detection algorithms can be susceptible to noise and other artifacts in music recordings. It would be useful to develop new comb filter beat detection algorithms that are more robust to these artifacts. Also applying comb filter beat detection to other music processing tasks, such as tempo estimation and music segmentation.

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