DIGITAL SIGNAL PROCESSING

ACTIVE NOISE CANCELLATION

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1. Introduction

Active noise cancellation (ANC) is a transformative technology that effectively reduces or eliminates unwanted ambient sounds by generating anti-noise signals that destructively interfere with the original noise. By capturing ambient noise with a microphone and generating anti-noise signals with opposite phases, ANC systems cancel out unwanted sounds, creating a quieter and more comfortable environment. Widely utilized in aviation, automotive, consumer electronics, and industrial settings, ANC enhances passenger comfort in aircraft cabins, mitigates road and engine noise in vehicles, and provides users with clearer audio experiences in headphones and earbuds. Overall, ANC technology offers a versatile solution for combating noise pollution and improving audio quality across various applications and industries.

2. Audio Signal Characteristics

Audio signal characteristics play a critical role in the effectiveness of active noise cancellation (ANC) systems. These characteristics include frequency spectrum, amplitude, phase, and temporal properties. The frequency spectrum of the audio signal determines the range of frequencies that the ANC system needs to address. Different types of noise have distinct frequency profiles, and the ANC system must be capable of attenuating noise across these frequencies. The amplitude of the audio signal indicates its intensity, which influences the level of noise that needs to be cancelled. Additionally, the phase of the audio signal is crucial for generating anti-noise signals that can effectively cancel out the original noise through destructive interference. Temporal properties, such as transient events or dynamic changes in noise levels, require adaptive ANC algorithms to continuously adjust the cancellation signal in real-time.

2.1 Perceptual Features :

Intensity :

Loudness is closely related to the physical intensity or power of a sound wave, measured in decibels (dB). However, the relationship between physical intensity and perceived loudness is not linear; instead, it follows a logarithmic scale. This means that doubling the physical intensity does not necessarily result in a perceived doubling of loudness.

Frequency dependence :

Human hearing is more sensitive to certain frequencies than others. As a result, the perceived loudness of a sound can vary depending on its frequency content. Sounds in the mid-frequency range (around 1 to 4 kHz) are typically perceived as louder than low or high-frequency sounds at the same intensity level.

3. Audio Processing Techniques

Audio processing techniques play a vital role in the effectiveness of active noise cancellation (ANC) systems, enabling them to accurately detect and cancel out unwanted ambient sounds while preserving the desired audio content

3.1 Adaptive Filtering

Adaptive filtering algorithms continuously analyze the characteristics of the ambient noise and adapt the ANC system's response in real-time to cancel out the noise effectively. These algorithms adjust parameters such as filter coefficients and attenuation levels based on the changing noise environment, ensuring optimal noise reduction performance.

3.2 Digital Signal Processing(DSP)

DSP techniques are utilized to manipulate audio signals digitally, allowing for precise control over filtering, equalization, and signal modulation. ANC systems often employ DSP algorithms to process both the input and cancellation signals, applying filters and modifications to achieve the desired noise reduction while maintaining audio fidelity.

3.3 Echo Cancellation

In scenarios where echo or reverberation is present, echo cancellation techniques are employed to remove the echo component from the audio signals before applying noise cancellation. These techniques utilize adaptive filtering and signal modeling to estimate and cancel out the echo, ensuring clear and intelligible audio communication.

3.4 Frequency Domain Processing

ANC systems commonly operate in the frequency domain, where the incoming audio signals are analyzed and processed in terms of their frequency components. Techniques such as Fourier analysis, spectral subtraction, and adaptive filtering are applied to identify and attenuate specific frequency bands corresponding to the ambient noise, thereby achieving effective noise cancellation.

4 . Algorithm of the Code

4.1 Initialize the parameters :

- ‘Fs1’ : Sampling Frequency
- ‘Fs2’ : Sampling Frequency
- ‘y1’ :reading the noise signal
- ‘y2’ :reading the other noise signal
- ‘noise’: adjusting the noise level as needed
- ‘y2_noisy’ :adding noise to the audio file
- ‘combinedaudioFFT’:Combine the audio files
- ‘NoisereducedaudioFFT’:noise is reduced here.

4.2 Reading MP3 file :

- Reading both the MP3 files and storing them into two variables.

4.3 Adding noise :

- Add noise to one of the file.

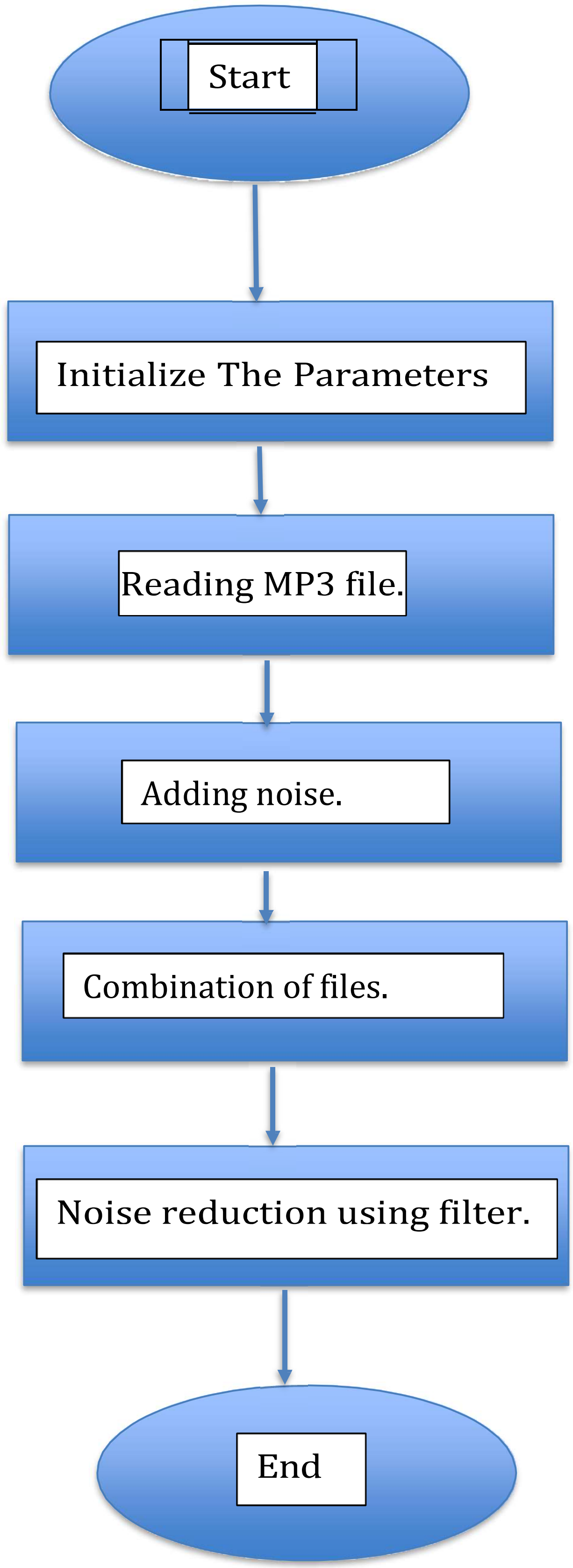
4.4 Combination of two files :

- Combine the noisy as well as the other mp3 file and form a variable called as combined audio.

4.5 Apply noise reduction using weiner filter

- Calculate the FFT ('fft') of the combined audio.
- Now use the weiner filter to represent the noise reduced audio in fft format.
- Finally take ifft and plot the noise reduced audio.

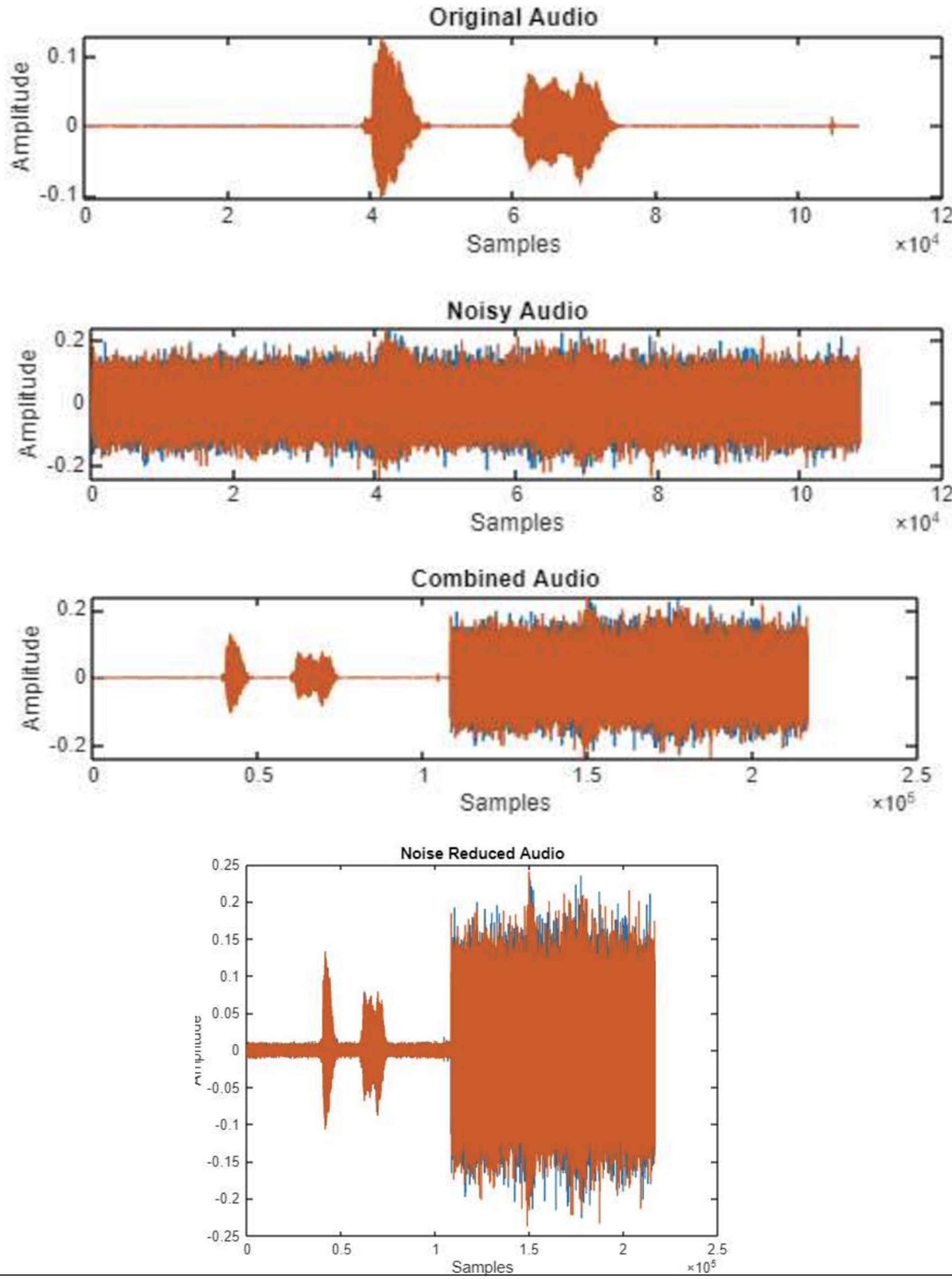
Flowchart


Start
Initialize The Parameters
Reading MP3 file.
Adding noise.
Combination of files.
Noise reduction using filter.
End

5. Matlab Code

```
% Read the MP3 files
[y1, Fs1] = audioread('audio1.mp3');
[y2, Fs2] = audioread('audio1.mp3'); % Assuming both files are the same

% Add noise to the second audio file
noise = 0.05 * randn(size(y2)); % Adjust the noise level as needed
y2_noisy = y2 + noise;

% Combine the audio files
combinedAudio = [y1; y2_noisy];

% Apply noise reduction using the Wiener filter
% Note: The Wiener filter requires the signal to be in the frequency domain.
% We'll use the FFT to convert the combined audio to the frequency domain.
combinedAudioFFT = fft(combinedAudio);
noiseReducedAudioFFT = wiener2(combinedAudioFFT);
noiseReducedAudio = real(ifft(noiseReducedAudioFFT));

% Write the processed audio to a new MP3 file
audiowrite('combined_noise_reduced.mp3', noiseReducedAudio, Fs1);

% Generate waveforms
% Plot the original audio waveform
figure;
subplot(3,1,1);
plot(y1);
title('Original Audio');
xlabel('Samples');
ylabel('Amplitude');

 % Plot the noisy audio waveform
 figure;
 subplot(3,1,2);
 plot(y2_noisy);
 title('Noisy Audio');
 xlabel('Samples');
 ylabel('Amplitude');
```

6. Experimental Results



7. Conclusion

In conclusion, active noise cancellation (ANC) stands as a transformative technology offering significant benefits in various domains by effectively reducing or eliminating unwanted ambient sounds. By employing advanced audio processing techniques such as adaptive filtering, digital signal processing, and frequency domain processing, ANC systems can accurately detect and cancel out noise while preserving desired audio content. This enables ANC to enhance comfort, safety, and audio quality in environments such as aviation, automotive, consumer electronics, and industrial settings. As ANC continues to evolve with advancements in signal processing algorithms and psychoacoustic modeling, it holds immense potential for further improvements in noise reduction performance and user experience, making it a valuable tool for creating quieter and more enjoyable environments.