1 Introduction

In modern signal processing applications, noise reduction is a critical task to enhance the quality of audio signals. This document provides a detailed analysis of three advanced filtering techniques: Wiener Filtering, Spectral Subtraction, and Wavelet Denoising. Each method is applied to an audio file with the denoising process visualized through several plots:

1. Time Domain Plot
2. Frequency Domain Plot
3. Effective Gain Plot
4. (For Wavelet Denoising) Wavelet Coefficient Plot

2 Overview of the Processing Pipeline

The noise reduction process involves:

- Acquiring and pre-processing the audio.
- Applying a noise reduction technique.
- Visualizing the results via time domain, frequency domain, and gain plots.

3 Visualization of Filtering Performance

3.1 Time Domain Analysis

Figure 1 shows the time domain representation of the original and denoised signals.

3.2 Frequency Domain Analysis

Figure 2 displays the magnitude spectra (in dB) for both the original and denoised signals, computed via the FFT.

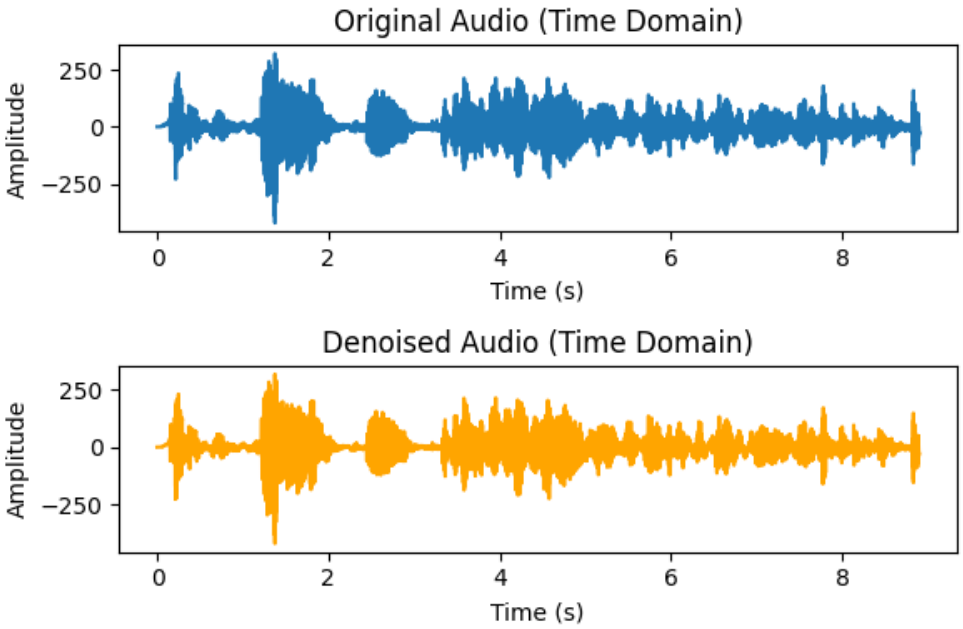

Figure 1: Time Domain Plot: Upper panel displays the original audio signal, and the lower panel shows the denoised audio.

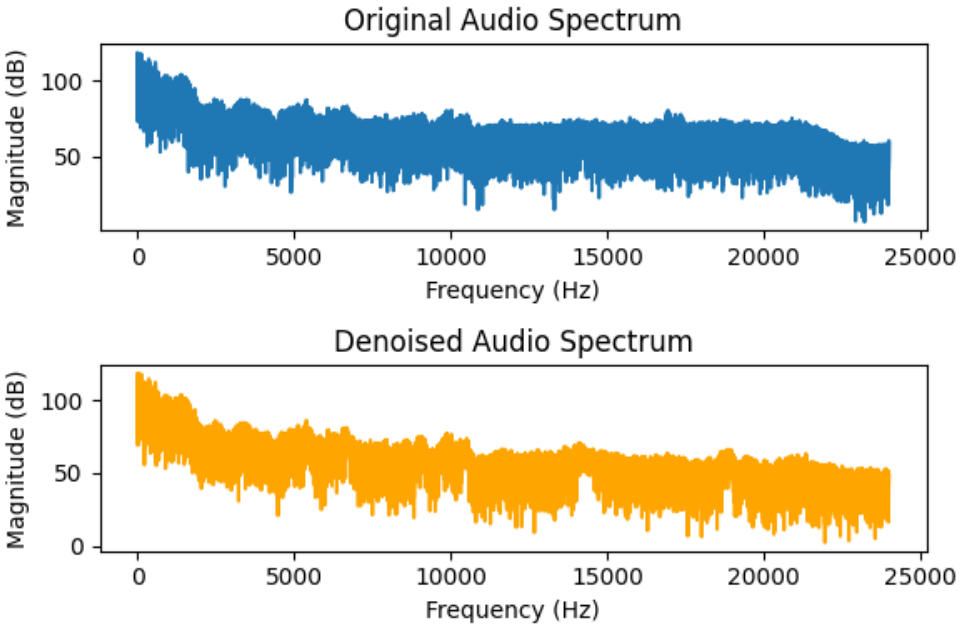

Figure 2: Frequency Domain Plot: Comparison of spectral magnitudes before and after denoising.

3.3 Effective Gain Plot

The effective gain plot (Figure 3) shows the frequency-dependent gain introduced by the filtering process, computed as:

$$\text{Gain (dB)} = 20 \log_{10} \left(\frac{|\text{FFT}_{\text{denoised}}|}{|\text{FFT}_{\text{original}}| + \epsilon} \right),$$

where ϵ is a small constant.

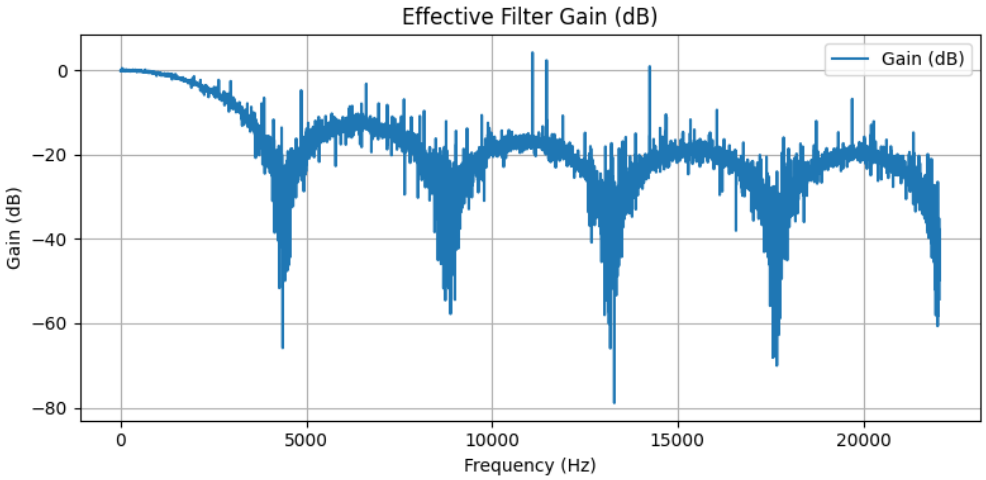

Figure 3: Effective Gain Plot: The gain (in dB) across frequencies, indicating the filter's attenuation characteristics.

3.4 Wavelet Coefficient Analysis (Wavelet Denoising Only)

For wavelet denoising, Figure 4 compares the detail coefficients before and after thresholding, illustrating the denoising effect in the wavelet domain.

4 Conclusion

This document has presented three advanced noise reduction techniques along with their visualizations. The time and frequency domain plots, effective gain plot, and (if applicable) the wavelet coefficient plot provide a comprehensive analysis of the denoising performance. These visualizations help in assessing the performance of each filtering method in practical applications.

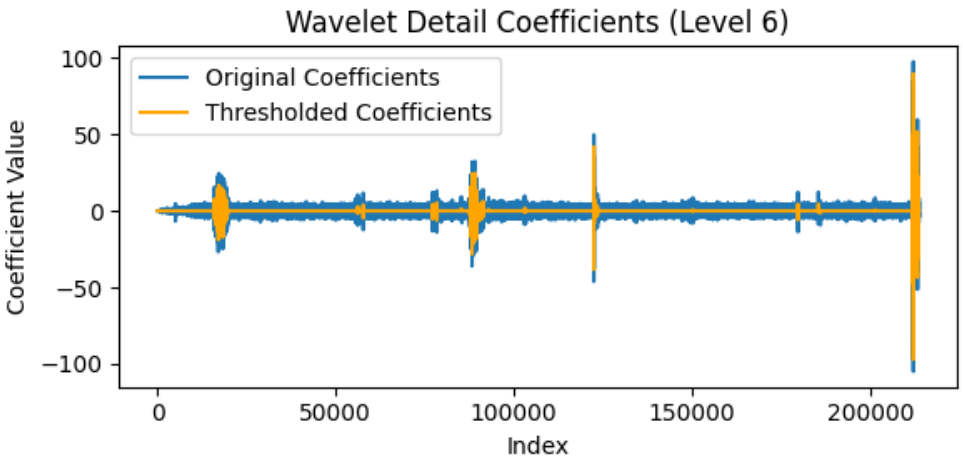

Figure 4: Wavelet Coefficient Plot: Original versus thresholded detail coefficients (last level) of the wavelet decomposition.