Audio Denoising via Wavelet Transform

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ABSTRACT

This project uses wavelet filters in MATLAB to denoise audio signals that have artificial Gaussian noise. Different wavelet families, including Coiflet, Symlet, and Daubechies, were used and their performances were compared based on their denoising abilities. Double wavelet filtering was also demonstrated. The results showed that all the wavelets performed well, with cross-correlation values of over 95%.

INTRODUCTION

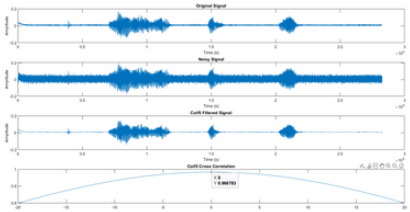
Noise is a common problem that can affect the quality of signals in various applications, including communication, data processing, and imaging. The main objective of this project is to remove noise from audio signals to improve their clarity. The researchers used MATLAB and various toolboxes, including the Wavelet, Communications, and Econometrics Toolbox, to denoise audio signals. The project focused on using wavelet transform due to its ability to represent signals in both the time and frequency domain, making signal analysis more efficient than Fourier Transform.

Coiflet, Daubechies, and Symlet wavelets are commonly used for signal processing tasks such as image compression, denoising, and feature extraction. For this project, Coiflet 5, Daubechies 9, and Symlet 2 will be the wavelets to be tested.

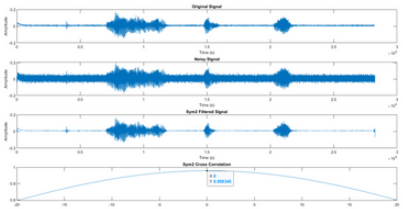
METHODOLOGY

The project only uses MATLAB software and requires three toolboxes to be installed: Communications, Econometric, and Wavelet. The Communications Toolbox is used for signal processing in communications applications, the Econometric Toolbox is used for cross correlation, and the Wavelet Toolbox is the most important as it provides tools for analyzing and processing signals using wavelet transforms. The Wavelet Toolbox is also used for image processing and feature extraction.
Three orthogonal wavelets are used: Coiflet5, Daubechies 9, and Symlet2. The program starts by importing an audio file and adding artificial white gaussian noise to it using the awgn() function. The wavelet packet decomposition of the signal is performed using the specified wavelet and decomposition level using the wpdec() function. The wpcoef() function extracts the detail coefficients which are then thresholded using the median() and wpbmpen() functions. The wpdencmp() function performs wavelet packet denoising, and the 's' option is used to shrink the detail coefficients larger than the threshold. The two-stage wavelet-based denoising on audio signals is applied using Symlet2, Daubechies9, and Coiflet5 wavelets. Lastly, cross-correlation techniques in MATLAB are used to compare the performances of different wavelet transforms.

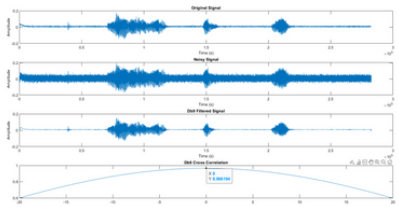
RESULTS



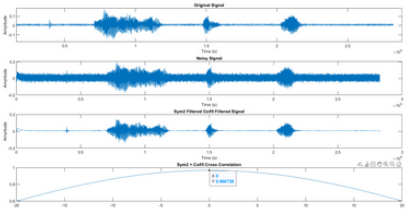
The cross correlation results between the Coiflet 5 Filtered Signal and the Original Signal is around 96.67% or 0.966783 to be exact.



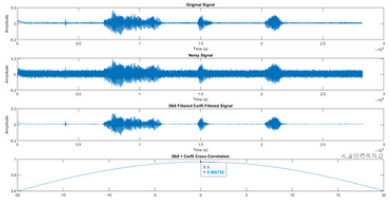
The cross correlation results between the Symlet 2 Filtered Signal and the Original Signal is around 95.83% or 0.958345 to be exact.



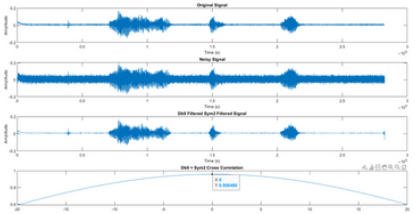
The cross correlation results between the Daubechies 9 Filtered Signal and the Original Signal is around 96.61% or 0.966194 to be exact.



The cross correlation results between the Symlet 2 Filtered Coiflet 5 Filtered Signal and the Original Signal is around 96.67% or 0.966726 to be exact.



The cross correlation results between the Daubechies 9 Filtered Coiflet 5 Filtered Signal and the Original Signal is around 96.67% or 0.966752 to be exact.



The cross correlation results between the Db9 Filtered Sym2 Filtered signal and the Original Signal is around 95.84% or 0.958408 to be exact.

DISCUSSION

The project demonstrated the effectiveness of various wavelet transforms in reducing Gaussian noise in signals. The cross-correlation graphs showed that the Coiflet 5 wavelet performed the best, with a cross-correlation result of 96.67%. The cross-correlation results of the two-stage wavelet-based denoising were still good, with all results above 95%.

The project concludes that single wavelet denoising performs better than the two-stage wavelet-based denoising. This is because adding another wavelet filter to the already denoised signal can alter or modify the signal itself, leading to over-filtering and loss of information. The second wavelet filter may suppress or amplify certain frequencies of the signal, leading to additional distortions and decreased overall signal quality.

CONCLUSION

This project investigates the use of MATLAB wavelets for denoising audio signals. Wavelets from the Coiflet, Symlet, and Daubechies families were compared for their denoising capabilities using cross-correlation to compare the denoised signals to the clean signal. The Coiflet 5 wavelet was found to be the best performing wavelet. The study also demonstrated the double wavelet filtering approach but showed that it does not always yield the best results and may alter the characteristics of the signal being filtered. Overall, the study provides insight into the performance of various wavelet families for denoising audio signals and demonstrates the effectiveness of wavelet filtering for this application.

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