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MATHEMATICAL MODEL OF SPECTRAL SUBTRACTION TECHNIQUE

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Abstract

In this paper we do the mathematical modeling of Spectral subtraction. Spectral subtraction is a traditional technique used in speech enhancement. Often the speech signals found in nature are corrupted by environmental noises. The common form of noises which corrupt the speech signal are additive white Gaussian noise, shot noise, pink noise etc. Our main aim is to remove these noises using Spectral subtraction. Spectral subtraction method removes noise in a very effective way. The application of this algorithm is used in this paper where we take bird noises in the tropical forest where there are unique birds like tropical birds their squeaking noises are corrupted with the environmental noises, like noise of river, trees and other existing noises. We remove these noises by applying this algorithm and extract the bird noise which helps in recognizing the type of the bird.

1. Motivation and Main Results

The spectral subtraction is an algorithm where a speech signal which is

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degraded by noise is taken and speech enhancement algorithm is applied to remove the noise. The spectral subtraction algorithm is historically one of the first algorithms proposed for noise reduction (Boll, 1979; Weiss et al., 1974), and is perhaps one of the most popular algorithms. It is based on a simple principle, first the speech signal is converted into frequency domain by applying Fast Fourier Trans from, noise spectrum from the noisy speech spectrum is estimated. The noise spectrum can be estimated and updated, during periods when the signal is absent. The enhanced signal is obtained by subtracting the noise spectrum from noisy speech signal spectrum to obtain clean speech signal and computing the inverse discrete Fourier transform of the estimated signal spectrum. The algorithm is computationally simple as it uses only fast Fourier transform and can be implemented in real time using a DSP processor.

Let $y(n) = x(n) + d(n)$ be the sampled noisy speech signal consisting of the clean signal $x(n)$ and the noise signal $d(n)$. Short-time Fourier transform of $y(n)$ is given in Equation (1).

$$Y(\omega_k) = X(\omega_k) + D(\omega_k) \tag{1}$$

Where and $\omega_k = 2\pi k/N$ and $k = 0, 1, 2, \ldots, N - 1$ where N is the frame length in samples.

$Y(\omega_k)$ can be expressed in terms of magnitude and phase as given in Equation (2)

$$Y(\omega_k) = |\, Y(\omega_k)\,| e^{j\theta_y}. \tag{2}$$

Where $|\, Y(\omega_k)\,|$ is the magnitude spectra and θ is the phase spectra of noisy speech signal.

Noise spectra in terms of magnitude and phase spectra is given in Equation (3)

$$D(\omega_k) = |\, D(\omega_k)\,| e^{j\phi_Y}. \tag{3}$$

The magnitude of noise spectrum $|\, D(\omega_k)\,|$ is unknown but is replaced by its average value or estimated noise $|\, D_e(\omega_k)\,|$ computed during non speech activity that is during non speech pauses. The noise phase is replaced by noisy speech phase θy that does not effect speech intelligibility. The clean speech signal is estimated by subtracting the noise spectrum from noisy speech spectrum as given in Equation (4).

$$X_e(\omega_k) = [| Y(\omega_k) | - | D(\omega_k) |] e^{j\theta_y} \tag{10}$$

Where $X_e(\omega_k)$ is the estimated clean speech signal. The estimation of clean speech magnitude spectra is given in equation (5)

$$X_e(\omega_k) = | Y(\omega_k) | - | D(\omega_k) | \tag{5}$$

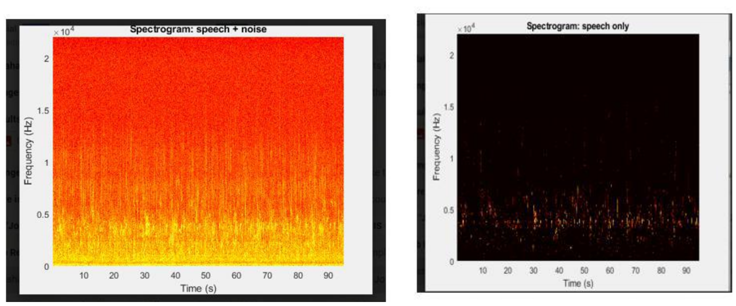
Similarly the estimation of clean speech Power spectrum is given in Equation (6)

$$X_e(\omega_k)^2 | Y(\omega_k)^2 |^2 - | D(\omega_k) |^2 \tag{6}$$

The enhanced speech signal is finally obtained by computing the inverse Fourier Transform of the estimated clean speech $| X_e(\omega) |$ for magnitude spectra.

Results

A tropical bird chirping signal was taken which was corrupted by noises surrounding in the forest and spectral subtraction method was applied to remove the background noise. The spectrogram results were found out before and after enhancement using MATLAB.



(a) (b)

Figure 1: Bird signal corrupted with noise in Frquency domain and enhanced signal.

Figure 1 shows a bird signal which was corrupted by river noise was taken and Spectral subtraction algorithm was applied to it and the noise was eliminated. Figure 1 (b) shows the spectrogram of extracted clean speech signal. Figure 2 shows corrupted signal and enhanced signal in time domain. Figure 3 and Figure 4 shows another signal corrupted with noise in frequency and time Doman.

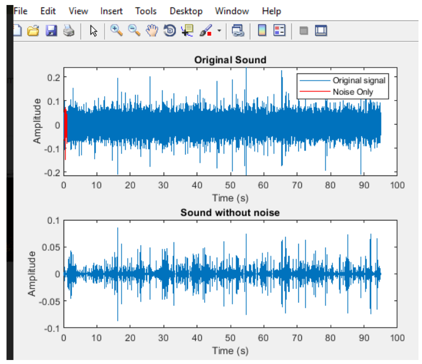


Figure 2. Spectrogram of extracted audio signal.

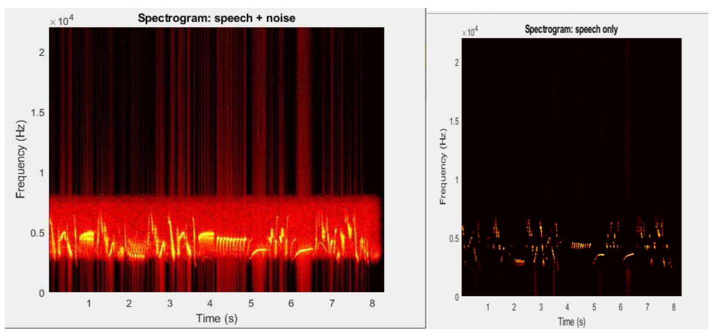


Figure 2. Original audio signal with noise and enhanced signal.

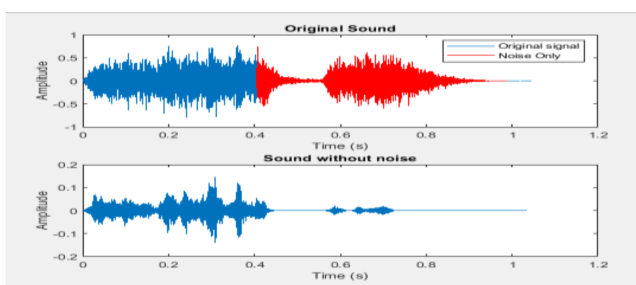


Figure 3. Spectrogram of second sample of bird signal and spectrogram of enhanced signal.

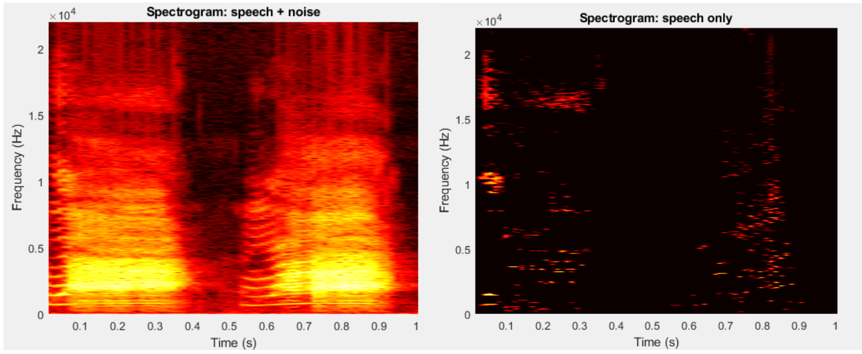
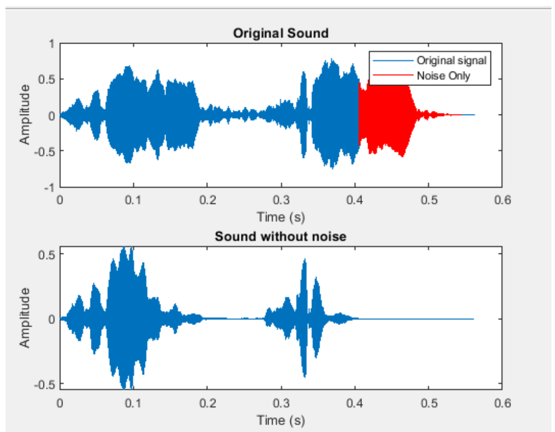


Figure 4. Noisy signal and enhanced signal in time domain.

The third sample of speech of a little bird species which was corrupted by noise was taken and spectral subtraction was applied and clean speech spectrum was obtained. This is a very rare species of bird which can be detected on this basis.



The time domain analysis of speech signal of little bird species which was Corrupted by noise was taken spectral subtraction was applied.

Conclusion

This spectral subtraction technique can be further implemented to find SNR the speech samples and a geometrical approach to it can also be done. In this way many unknown bird and animals can also be detected. Which is very helpful for the forest conservation.

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