REPORT

on

Analysis of Spectrograms Using Different Windowing Techniques

Submitted as part of Speech Understanding Programming Assignment 1

by

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Chapter - 1

Spectrogram and Windowing Techniques

1.1 Introduction

In this assignment, the UrbanSound8k dataset is used to explore various windowing techniques for generating spectrograms using the Short-Time Fourier Transform (STFT). Three windowing techniques were implemented:

- Hann Window
- Hamming Window
- Rectangular Window

For this analysis, a sample is considered from each class of each of the folds of the dataset. The resulting spectrograms for each window type are visually compared and analyzed for their frequency resolution and spectral leakage characteristics.

1.2 Visualisation of spectrogram

The dataset contains 8732 labeled sound excerpts ($\leq 4s$) of urban sounds from 10 classes: air_conditioner, car_horn, children_playing, dog_bark, drilling, engine_idling, gun_shot, jackhammer, siren, and street_music. There are 10 folds in the dataset. A sample from each of the class of each of the folds were considered for visualising the spectorgrams with Hanning, Hamming and Rectangular window implemented respectively. The samples and their spectrograms for Fold 1 are given in Fig 1.1:

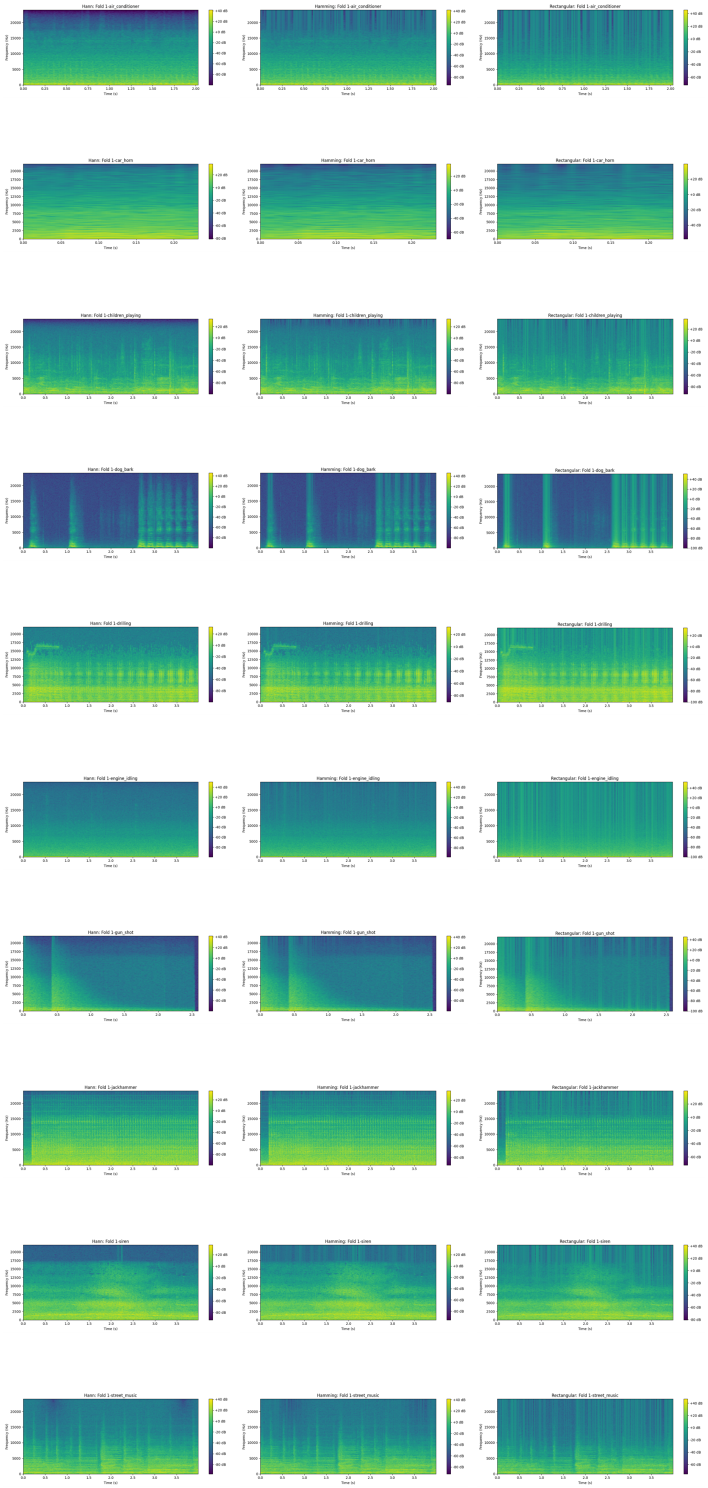

Figure 1.1: Spectrograms

1.3 Windowing Techniques and Spectrogram Analysis

1.3.1 Rectangular Window

- **Visual Characteristics:** The spectrogram generated with the rectangular window shows sharper transitions between frequencies. The frequency peaks are more pronounced but exhibit wider spikes, which suggests poor frequency resolution and significant spectral leakage.
- **Analysis:** The rectangular window is equivalent to no windowing at all, as it does not taper the signal at the boundaries. This leads to spectral leakage, where frequency components spread out. While the rectangular window offers the best frequency resolution due to the full length of the signal being used, this comes at the cost of increased leakage and reduced temporal resolution.

1.3.2 Hanning Window

- **Visual Characteristics:** The spectrogram with the Hanning window has smoother frequency transitions. The peaks are less sharp compared to the rectangular window, but still exhibit a clear structure. The frequency components are more localized with reduced leakage around the spectral lines.
- **Analysis:** The Hanning window reduces spectral leakage by tapering the signal smoothly at the edges. However, it causes a slight loss in frequency resolution, as the usable length of the signal is reduced due to the tapering at the boundaries. The trade-off is better temporal resolution at the expense of some frequency accuracy.

1.3.3 Hamming Window

- **Visual Characteristics:** The spectrogram with the Hamming window is similar to the Hanning window, with smoother transitions and reduced leakage. However, the peaks appear slightly sharper, and the transitions between frequency components are less smooth compared to the Hanning window.
- **Analysis:** The Hamming window is similar to the Hanning window, but with a slightly different tapering shape, making it less smooth. It also reduces spectral leakage, though it may produce slightly more

leakage than the Hanning window due to its different shaping. The frequency components in the spectrogram are slightly wider than with the Hanning window, but still less so compared to the rectangular window.

1.4 Correctness of Windowing Techniques

1.4.1 Rectangular Window

The rectangular window provides the best frequency resolution, but it comes with a significant drawback: spectral leakage. Since it does not taper the edges of the signal, frequency components spread into adjacent frequencies, leading to a less clear and more spread-out spectrogram. Therefore, while frequency resolution is optimal, the trade-off is higher leakage and a reduction in the clarity of the spectrogram.

1.4.2 Hanning and Hamming Windows

Both the Hanning and Hamming windows address the issue of spectral leakage by tapering the signal. The Hanning window is typically preferred when the goal is to minimize spectral leakage, as it results in the least leakage while sacrificing some frequency resolution. On the other hand, the Hamming window offers a middle ground between reducing leakage and maintaining slightly better frequency resolution.

1.5 Conclusion

In this analysis, we have demonstrated the differences between the three windowing techniques: rectangular, Hanning, and Hamming. Each window has its strengths and trade-offs in terms of frequency resolution and spectral leakage. The rectangular window is best for frequency resolution but suffers from significant leakage, while the Hanning and Hamming windows mitigate leakage at the cost of slightly reduced frequency accuracy. Depending on the specific goals of the analysis (minimizing leakage vs. maximizing frequency resolution), one window may be preferred over the others.