Report on assignement 2 of Data Capture and Processinig course

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Abstract

Spectral analysis is crucial in various fields, including signal processing as it allows for the examination of frequency components within a signal. In this report we will explore some fundamental technique on how we make spectral analysis over a voice signal.

Keywords: Signal processing, periodogram, windowing, spectral analysis.

1 Introduction

In physics, sound is a vibration that propagates as an acoustic wave through a transmission medium such as a gas, liquid or solid. [1].

Having a hardware component like a microphone that is able to capture those vibrations and transforming them to electrical discrete signal. Will let us perform processing and spectral analysis. For this purpose we will record our voice using the website [2], the passage will contain sound of me saying "Today is a good day!". We will be working on this passage. The signal as shown in the figure 1

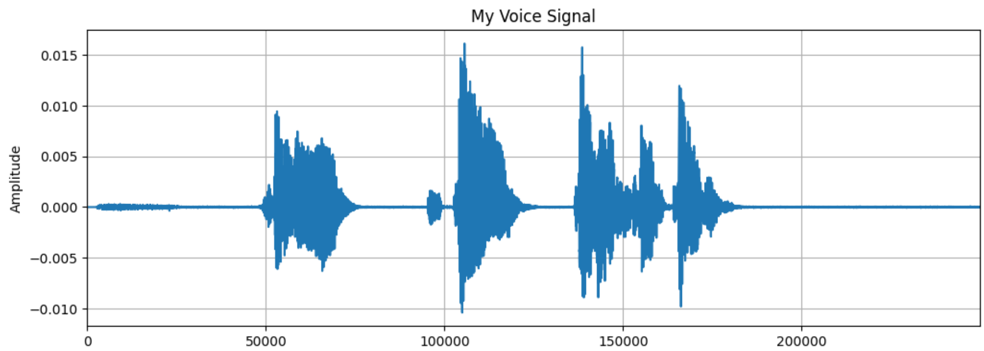

Fig. 1: Voice signal

2 Basic signal characteristics

After the recording and the acquisition of the signal. we will compute some basic characteristics

we will display the : duration, sampling frequency, mean value and energy of the signal as follow

$$mean = \frac{1}{N}\sum_{i=1}^{n} x_i \tag{1}$$

$$energy = \sum_{i=1}^{n} x_i^2 \tag{2}$$

$$var = \frac{1}{N}\sum_{i=1}^{n} (x_i - \mu)^2 \tag{3}$$

$$duration = \frac{N}{f_s} \tag{4}$$

Where:

- μ is the mean of the signal.
- N is the number of samples
- f_s is the sampling frequecy

After coding and computing these characterisitcs we got the values represented in Table 1

3 Frequency representation

In this section we will plot the periodogram without and with windowing options

Table 1: Signal characteristics values.

mean	2.7926092e-07
energy	0.5581704
var	0.001494264
duration	5.208

3.1 Periodogram without windowing

Using predefind function in scipy library we will calculate the frequencies and their corresponding power. the result is show in the next figure 2

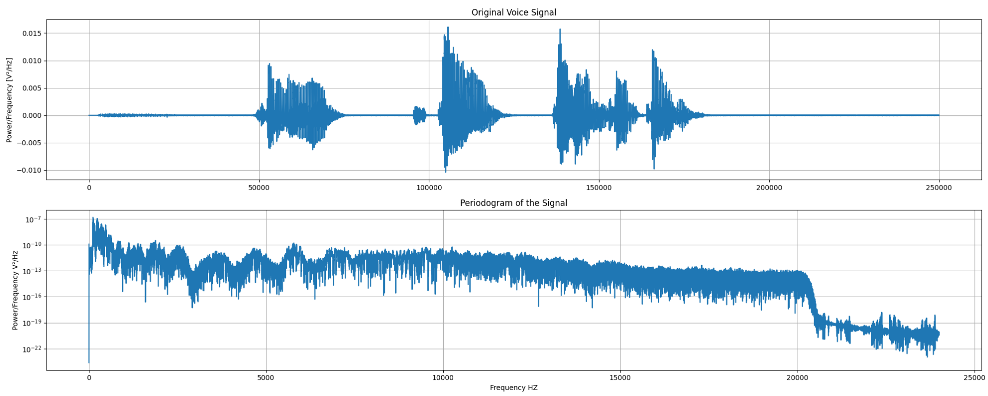

Fig. 2: Periodogram of the signal without windowing

3.2 Periodogram with windowing

In FFT Since Computers can't do computations with an infinite number of data points, so all signals are cut off at certain point and having a beginning and end. The window method reduces the ripple obtained in the spectrum frequencies, giving us a more accurate idea of the original signal's frequency spectrum. We will test both hamming and hann windowing technique.

Hamming Based on [3] windowing is simply an element wise between the original signal, and the window array, that is geenrated using a certain formula. This will make our signal go smoothlly from zero and also returns smoothly to zero at the end.

$$h(t) = \begin{cases} 0.54 - 0.46 \cdot \cos\left(\frac{2\pi t}{N-1}\right) & \text{for } 0 \le t \le N-1 \\ 0 & \text{otherwise} \end{cases}$$

the figure 3 shows the result of the Hamming windowing over the voice signal

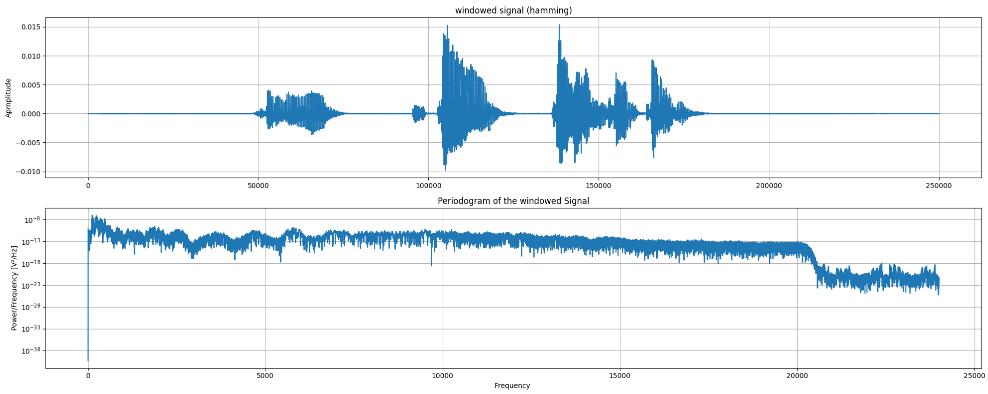

Fig. 3: Periodogram of windowed signal(hamming

Han Same as the previous windowing technique, but with different window generation formula

$$h(t) = \begin{cases} 0.5 \cdot \left(1 - \cos\left(\frac{2\pi t}{N-1}\right)\right) & \text{for } 0 \leq t \leq N-1 \\ 0 & \text{otherwise} \end{cases}$$

the figure 4 shows the result of the Han windowing over the voice signal

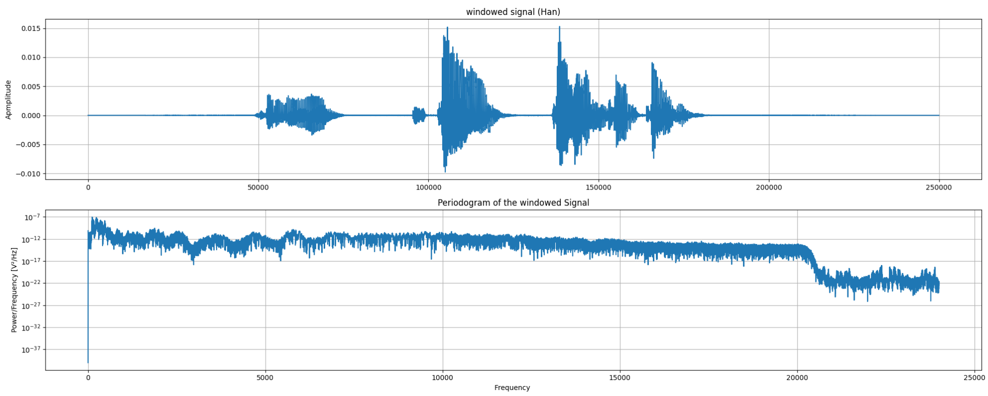

Fig. 4: Periodogram of windowed signal(han)

We can see that both the methods have effects on the resulted periodogram, since the lengths of the bars have shortened, giving us a more clear idea of the variation of the power par rapport to the frequencies.

we can clearly see that higher power is at the beginning in the frequency axis. so it would be interesting to visualize that slice of the periodogram. As shown in the next figure 5

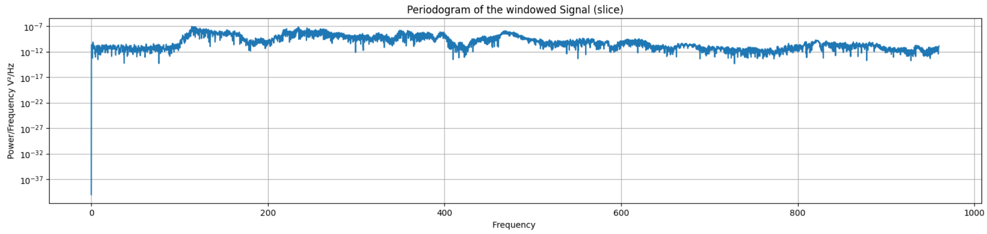

Fig. 5: Periodogram of windowed signal(sliced)

higher power from 150 to 400 Hz indicate that these frequencies are dominant frequencies in our signal, we can think of them that they are the frequencies that characterizes our voice signal.

4 Effects of sampling and window lengths on periodogram

In this section we will plot the periodogram, on testing various sampling frequencies to see the efects, and also the window length effects.

Different sammling frequencies in this part we will try these sampling frequencies, $fs/100$, $fs/1000$, $fs/10000$. The figure 6 shows the resulting periodograms

we can see that the more we have less samples, the more we have lot of space between frequencies.

Different window lengths in this part we will try these window lengths, $N/5$, $N/10$, $N/100$, $N/1000$. The figure 7 shows the resulting periodograms

5 Code and implementation

All of the methods presented in this paper, are implemented in a jupyter notebook using python programming language, and libraries like numpy and scipy for numerical array manipulation, librosa for voice signal reading and matplotlib, for visualizations.

Notebook is accessible in this github repository: LINK

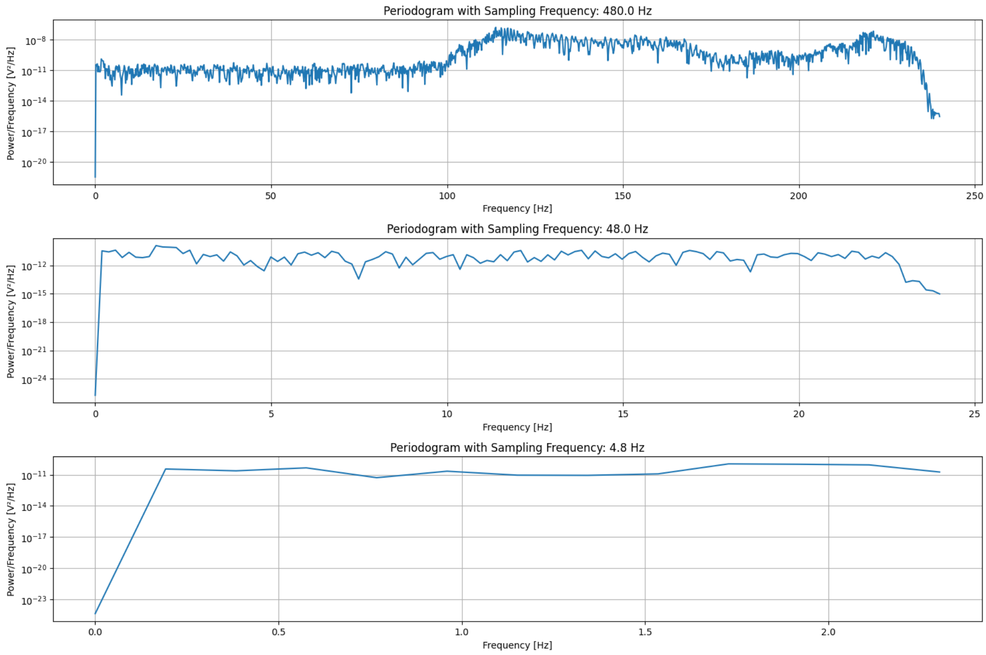

Fig. 6: Sampling effects on Periodogram

References

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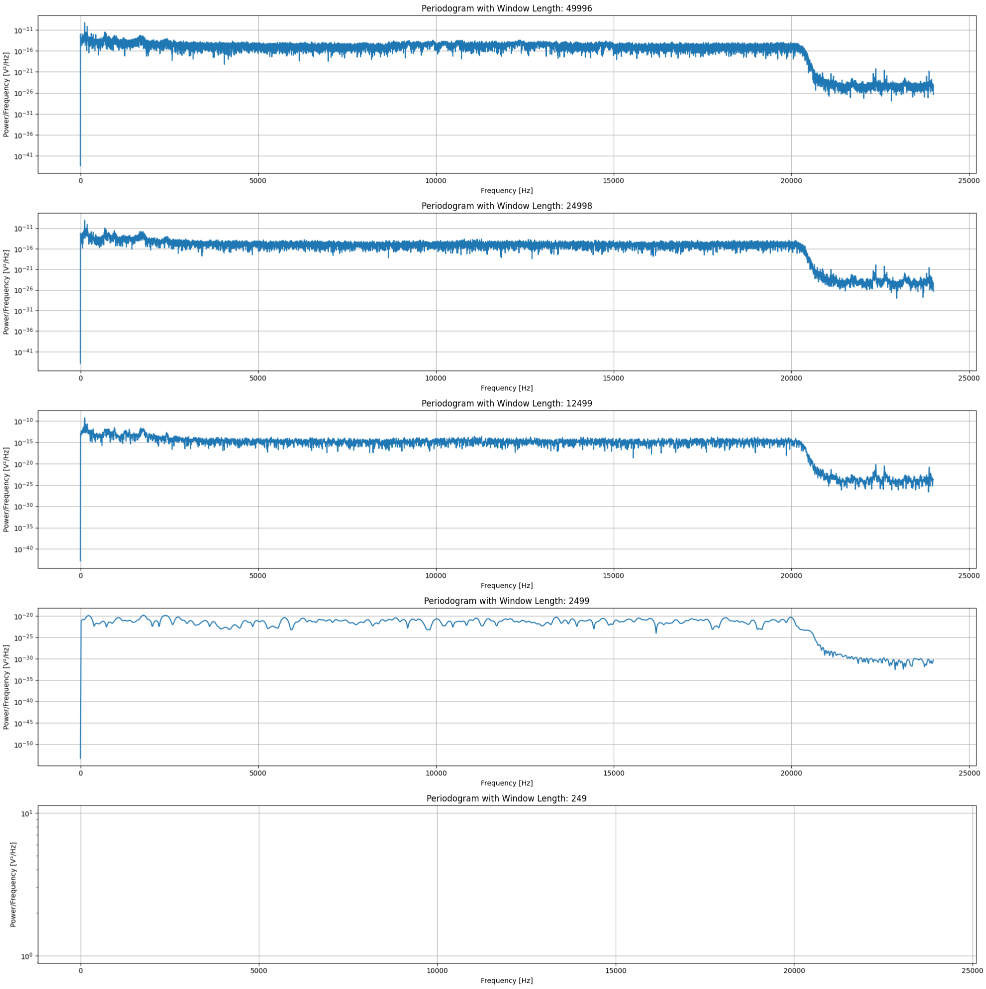

Fig. 7: Differents window lengths effects on Periodogram