Coding Project 2: Parsing musical frequency signatures

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**Abstract**

In this report, we talked about how to use Gabor Transform to analyze frequencies of a music clip. We isolated and reconstructed the music clip by instruments with different frequencies. We then plot the spectrograms of the sound clip as well as the amplitude over time of each instrument for a clearer visualization of the clip.

# Introduction

Musical notes are defined by their associated frequencies which are measured in Hertz (Hz). In this particular clip, two particular instruments are being used: the bassline and the guitar. The bassline has frequencies of around 0Hz to 250Hz and the guitar has frequencies of around 83Hz to 1200Hz.

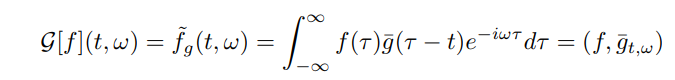
In this report, we will use Gabor transform to create spectrograms and study the frequencies from the sound clip. We will try to isolate and reconstruct different types of instruments from the clip.

# Theoretical Background

In this section we will talk about Gabor Transform and its discrete variant; the main mathematical tool we used to analyze the frequencies of the sound clip.

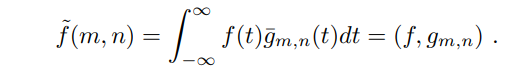
## The Gabor Transform

The Gabor transform, also known as the short-time Fourier transform, is a mathematical tool that decomposes a signal into a series of time-frequency components. The Gabor transform is a convolution of the signal with a set of functions known as Gabor wavelets, which are obtained by modulating a Gaussian function with a sinusoidal wave. The Gabor wavelets are characterized by two parameters: the center frequency and the bandwidth. The center frequency determines the frequency of the sinusoidal wave, while the bandwidth controls the spread of the Gaussian envelope. The Gabor transform can be represented mathematically as a convolution of the signal x(t) with the Gabor wavelet g(t, f):



## The Discrete Gabor Transform

The Gabor transform is computed by discretizing the time and frequency domain of the continuous-time Gabor transform; therefore, we need to consider the discrete version of the mathematical equation:



This is called the Discrete Gabor Transform (DGT). The time domain and the frequency domain are sampled uniformly. The Gabor wavelets are then discretized in both time and frequency domains to obtain a set of discrete-time Gabor wavelets. The DGT is then defined as the inner product of the signal with the discrete-time Gabor wavelets. The resulting time-frequency representation of the signal is a two-dimensional array, where the amplitude of each component at a given time and frequency is given by the magnitude of the corresponding inner product.

# Numerical Methods

In the code, we used Gabor Transform to create spectrograms for different frequencies of sounds. We isolated and reconstructed instrument types from the clip. After using Gabor Transform on the frequencies, we filtered around the peak frequencies which are in our regime of interests. We then isolated the bassline and the guitar separated using a simple filter, getting only their corresponding frequencies. We then plots the spectrograms, as well as the amplitude of the frequencies over time, as shown in the graphs in the Results section.

# Results

Graphical user interface

Description automatically generated

This graph shows the spectrogram of the sound clip. From then graph we can see that the frequencies mainly focused on two parts: one at around 50Hz and another at around 280Hz.

Chart

Description automatically generated Chart

Description automatically generated

These two graphs show the amplitude of bassline and guitar over time. We can see that the bassline in the first 20 seconds have constant gaps in between while the guitar is played constantly. Both instruments are played more constantly after 30 seconds.

# Conclusion

With the use of Gabor transform, we can decompose the music based on different frequencies easily. We can get a music sample with only the instruments we want. In this report we isolate and reconstruct the sound clip by different instrument type.

In this project, I learned how to use Gabor transform to decompose music. There are some drawbacks to this technique. For example, if the instruments used have similar frequencies, it would be hard to distinguish them apart to isolate them separately.

# Acknowledgment

Equations and definitions taken out from Kutz Book.