Grant Bouvier

Computational Musicology

Final Project - Write Up

The Chroma Analysis of Metallica's *Master of Puppets*: A Discussion

Overview:

The ultimate objective of this project is to use chroma analysis methods on Metallica's 1986 thrash metal magnum opus *Master of Puppets*. The data gathered from the chroma analysis of each track will then be plotted in graphs to better visualize the pitched content of the recorded audio. The primary hypothesis is that the record will contain a significant concentration of tonal information around E and F notes across octaves. This hypothesis is drawn from the author's own experience with the musical material, and the idea that the design and tuning of the modern electric guitar lends itself to writing rock and metal compositions that are centered around E and F keys.

The author is somewhat new to programming in python, so a secondary objective of this project is to properly implement chroma analysis via the librosa library. Both a constant-Q transform and an short-time fourier transform are used to generate chroma graphs for visual analysis. A hop size of 512 samples was used (for both stft and cqt) with a fft window size of 2048 samples. The signal was divided into 12 pitch bins (for a chromatic distribution).

A Summary of Past and Relevant Work:

Chroma features analysis has been a topic of research and interest in signal processing for a significant period of time. A wealth of published research exist on using chroma features for music analysis and identification, ranging in general complexity from introductory to advanced. Two seminal work that seems to be heavily referenced are "Musical Similarity Analysis based on Chroma Features and Text Retrieval Methods" (Englmeier, Hubig, Goebl, Bohm) and "Audio Thumbnailing of Popular Music Using Chroma-Based Representations" (Bartsch and Wakefield). Both effectively describe algorithms most effective for pulling musically relevant harmonic and melodic signifiers from signal.

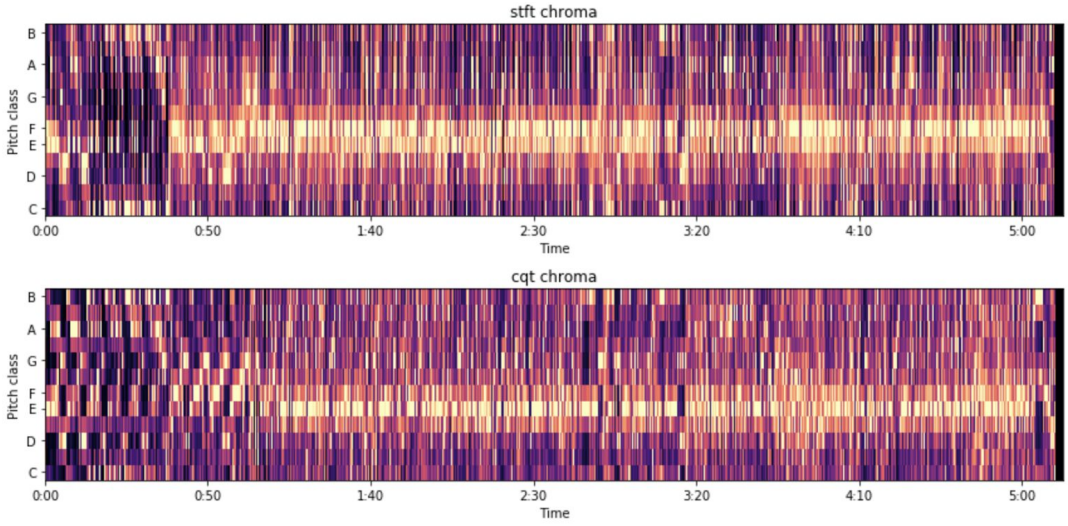
Unfortunately there has been fairly limited spectral research into heavy metal music specifically. The only significant and reliable work that has any relevance to this project is "Automatic Classification of Heavy Metal Music" (Mulder). This research does consider chroma vectors as a useful element in metal classification and analysis. Other than this work, the field appears to be somewhat thin on heavy metal signal processing and analysis.

Setup and Technical Details:

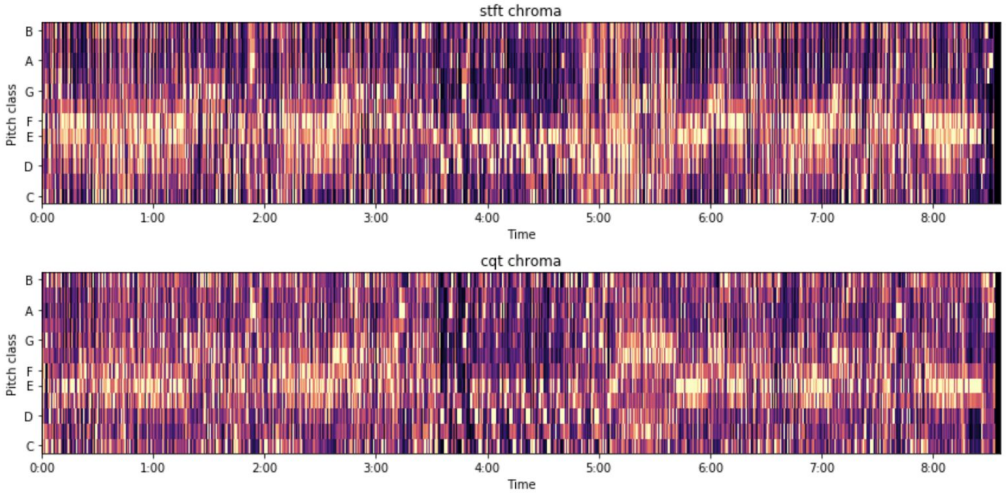
This project involved curating MP3 files of the original *Master of Puppets* record, which consists of eight tracks in total. These MP3 files were then put in the same file directory as a python script (including the librosa and numpy libraries). The sample rate is 44100 and the hop length 512 samples with an fft window of 2048, which are used to window the audio signal. A function is then used to apply the chroma_cqt and chroma_stft analysis to the desired audio file

(in this case a full length track from the record). Both of these chroma analysis provide different but useful data, so both were used. This function was then run for each audio file to provide chroma feature plots for every song on *Master of Puppets*. The tracks themselves are sequential in the code, but are also labeled via comments. Below are the first 4 sets of plots. The rest can be seen in the original code.

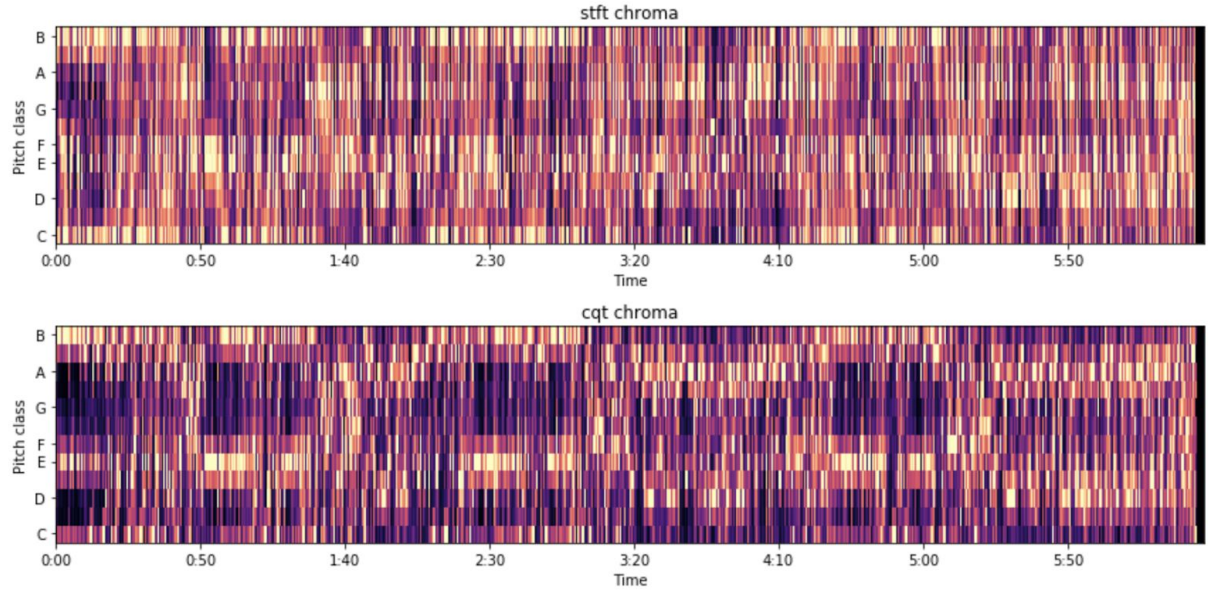
Track 1 - Battery



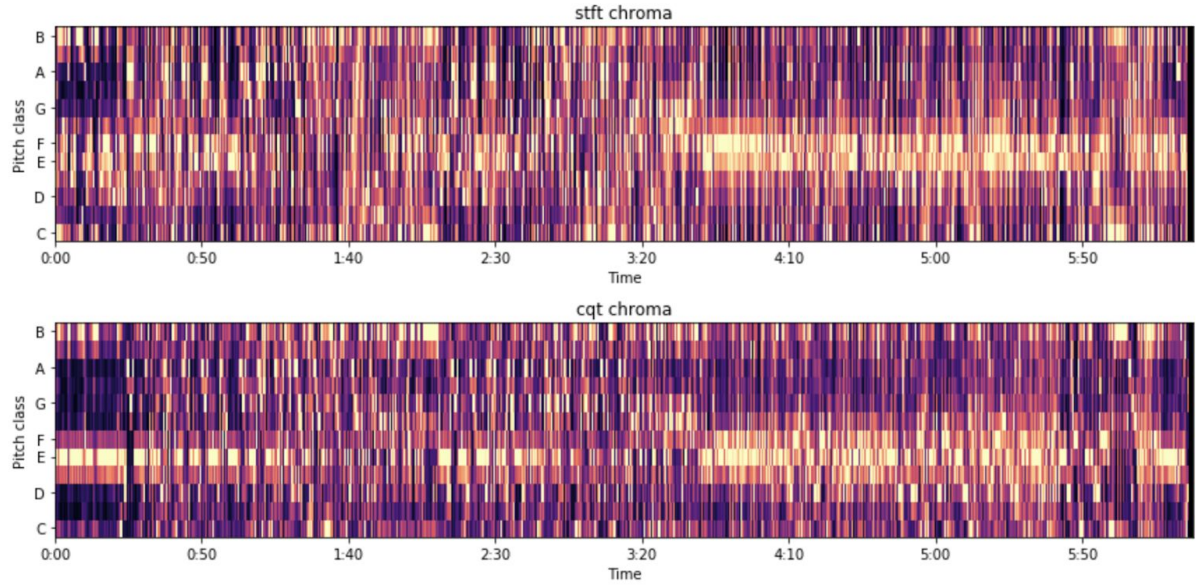
Track 2 - Master of Puppets



Track 3 - The Things That Should Not Be



Track 4 - Welcome Home



Data Analysis and Results:

Based on the plot sets derived from the chroma analysis of *Master of Puppets*, it seems as though the original hypothesis holds up. The record displays a clear compositional tendency for the songs to center around E and F with minimal deviation. There was an attempt to apply smoothing to the chroma analysis which was ultimately unsuccefuly, however the unrefined chroma data on its own illustrates a significant band of concentration in the chromatic range predicted.

Historically this record is considered among the most relevant and important works of the era, going on to be very influential in the genre and rock music at large. It is fair to say that this record therefore represents a somewhat accurate depiction of metal music in the mid 1980s. It is impossible to determine if the tuning and design of the modern electric guitar itself played a role in the development of the songwriting tendencies of this genre at that time, but one could make a case for the correlation. The lowest tuned string of the guitar in standard tuning is E, which allows for chords based on the low E to dominate faster paced music as it can be played quickly with minimal hand movement. Further research and testing would be needed to prove this correlation.

Conclusion:

This project was a success in that the original hypothesis was met and that the author was able to effectively implement chroma analysis with librosa in python. For future projects, it could be advantageous to integrate chroma smoothing or filtering to the plots, but even the raw chroma data yielded valuable information that could be used to support the hypothesis.