CS 6170 - Project Proposal

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1 Introduction

Music in general is rich in structure. If one looks at the sequence of notes that make up a song, one can usually find repeating patterns, for instance, verses will often have exactly the same tune. Looking a bit more closely, one can observe that certain structures or phrases (shorter sequences of notes) occur frequently. On a more fundamental level, the notes themselves have a certain structure with regards to how we perceive them. We hear "pitch" in the log scale in terms of the frequency, i.e. we perceive two frequencies to be musically one semitone apart if their frequencies are related by a certain multiplicative factor. However, curiously, if a frequency is related to another by multiplication with an integer power of 2, then we perceive the notes to be "equal" musically. This implies that the notes can be thought of as lying on a circle (see figure 1), and that we can define a distance between two notes that respects this circular structure. This suggests the existence of meaningful topological structures, and this is just looking at a single note.

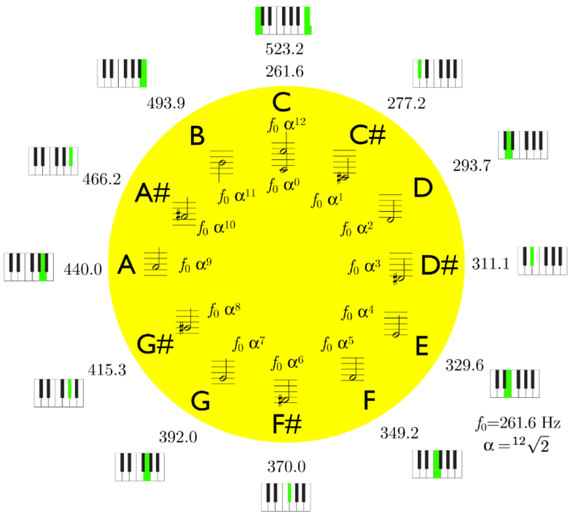

Figure 1: Circle of notes, from [4]

2 Project Objective

In this project, we will look at several similarity measures between notes, (ordered) sequences of notes, whole chords (unordered), and even beats, and look at topological structures present in these. We will extract these topological features for various kinds of music and see if these can be applied to higher level tasks such as genre classification, composer identification, and so on. We will also use these topological features to analyze popular music to see if it indeed has a 4 chord structure.

3 Data

We will be dealing with MIDI (Musical Instrument Digital Interface) format, which records musical "events" (i.e. playing a key on the keyboard) as "messages", which describe which key was played at what time and with what intensity. MIDI files for various songs are available online from [1, 2, 3]. This data is perfect for our project because it will allow us to extract the notes directly, as opposed to say audio data, where extracting notes is in itself a challenging task.

4 Background

Budney et. al. [4] apply persistent homology to musical data. This is the paper most of our project is based on.

In addition, we have (very briefly) looked at some other papers. Catanzaro [5] uses Euler's classical tonnetz to represent the musical intervals in a lattice to do modern generalizations like Riemannian geometry. On a very different note, Partch et al. [6] try to represent a tonality diamond structure where each of the two axes represent significant musical intervals. Chew E. [7] discusses various musical progressions along a spiral array in "The spiral array: an algorithm for determining key boundaries". Similar to this, the computer based music visualizers [8] demonstrate different moving patterns in real time as music progresses. One of the good use of computational topology was by Lewin [9] who researched an application of simplicial complexes and homology to the music dataset. On the same note, there have been some works by Callender, Quinn, and Tymoczko [10] who explore a topological approach to musical spaces using the voice-leading metric. Similarly, Buteau et al. [11] use topological motivic analysis to cluster the melodies and discover the musical motives behind it. Sethares et.al These are just few examples of how the music data as a whole has been explored.

5 Technical Contributions

We plan to analyze the data to find different topological structures, and extract topological features from the data. The current state-of-the-art analyzes similarity measures at the note level, chord level, beat level, or looking at the sequences of successive notes etc. It also validates this analysis by recovering the well known topological structures such as the circularity of octave-reduced musical scales, the circle of fifths, and the rhythmic repetition of timelines.

Our project uses these ideas but instead of just analyzing the datasets for simple structures and patterns, we plan to not only apply persistent homology techniques to these similarity measures, but also use those resulting barcodes as features to identify several interesting patterns. For example, some of our pattern-finding query can be,

- Identifying common chord progressions in popular music (popular music basically uses 4 chords transposed to whatever key the song is in – can we identify these?)
- Comparing the above chord progressions to the classical music
- Within a genre, analyzing differences between the musical style of different composers – do the clusters of topological features across musical works correspond to different composers?

Additionally, we plan to use topological features to solve some machine learning problems, which the state of the art hasn't done to the best of our knowledge, such as

- Genre classification
- Artist identification (assuming some music by the artist exists in the training set)

6 Expected Outcomes and Deliverable

If this project is successful, in other words if the topological features we come up with are meaningful, then we will report high accuracy scores on the proposed tasks.
We will hand in our source code along with an audio demo.

7 Evaluation

We have proposed several tasks, such as artist recognition, genre classification. These have their own notions of accuracy. We will report precision-recall plots for these. Some of our other tasks are more qualitative analyses (i.e. how is classical music different from pop music). For this, we will report qualitative results.

8 Proposed Methods

We plan to use mainly persistent homology along with some form of machine learning (k-Nearest neighbours for artist identification, and say multi-label classification with a simple neural network for genre classification).

9 Software

We plan to use Python for this project. For reading MIDI data, we will use the `Mido` libary (`https://mido.readthedocs.io`), and for the topological data analysis we will use `Ripser.py`.

10 Rough Timeline

In the first two weeks, we will focus on data collection: downloading, clean-up, manual labeling where required. In the third and fourth weeks, we will focus on reading the MIDI data, extracting topological features, and trying out simple benchmarks from previous works including [4].

After this, we will focus on our proposed tasks starting with genre classification and then continuing with artist recognition.

11 Project Summary:

11.1 What is an overview of your project?

Exploring and analyzing interesting topological structures and answer several real-world questions for the music data.

11.2 Why is the project worth pursuing?

Music is a composition of rich and complex topological structures in the nutshell. There is huge amount of information which is worth analyzing to get new perspectives and insights of the data.

11.3 What are your project objectives?

We will look at several similarity measures between notes, chords, beats etc. and extract the topological structures and features from the music data.

11.4 What are the questions you would like to answer?

After getting the topological features and structures, we can apply it to higher level tasks such as genre classification, composer identification etc.

11.5 What data will you plan to use?

We will be dealing with the MIDI format, which records musical "events" (i.e. playing a key on the keyboard) as "messages", which describe which key was played at what time and with what intensity.

11.6 How can we evaluate how successful your project is once it is completed?

We have proposed several tasks, such as artist recognition, genre classification. Some of these tasks come with ways to quantitatively evaluate them, some do not.

References

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