Final Project: Midpoint Update

625.620 - Mathematical Methods for Signal Processing

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1 Introduction

The goal of the project has shifted slightly. The new goal is to use the Matrix Profile to create code tools that will recognize common structures and determine important musical motifs that reoccur throughout an entire album of music. Within albums there are often sections of the music that are repeated, typically with different instruments and in a different key, but the rhythm and general structure of the music subsection is the same. This is most frequently done in musicals. Albums/scores from musicals have the additional goal of telling a story from the beginning to end. The composers choose these short motifs (musical segments) that will have a particular meaning to the listener and the plotline. The motifs are repeated throughout the musical in order to allow the listener to feel comfortable with this phrase of music. Thus, by the time this musical phrase becomes the main aspect of the music, the listener is already familiar with it and can recall the vital aspects of the plot when they previously heard this phrase. These musical motifs are used as a way to bring the entire storyline full circle.

Unfortunately, we do not have an infinite amount of time to sit and listen to musical soundtracks endlessly in order to determine what the specific motif(s) used throughout the score is(are). Fortunately, the authors Molly and Alyson love the musical 'Wicked' and have already put forth the time and effort needed in order to easily recognize the motifs from the 'Wicked' Score/Soundtrack. This is the soundtrack that will be used for our manual process of comparisons and to start writing the code (i.e. our training set). Other soundtracks for musicals, such as 'Les Miserables' (which makes frequent use of motifs), will be used as a test to see how well the code does to recognize these important motifs and themes.

The general process has remained the same. We intend to convert the songs from MP3/MP4 format into WAV format [6] to be able to manipulate the signals and display plots using the tools from ThinkDSP, Matrix Profile, and additional tools that we can develop. ThinkDSP could be used to examine the tonals and primary frequencies for the songs. Once the waveform has been manually examined, Matrix Profile will be employed in order to determine the sections of the wave that are common (or perhaps, dissimilar) to each other. We will develop our own tools or do additional research to find sorting and classification tools to understand the results from the Matrix Profile and identify the structure of the song as well as the important motifs within the entire album.

2 Brief Literature Review

When looking into the Matrix Profile code, a series of important resources were determined as well as given to us for reference. These resources are listed below and briefly explained how they could be useful for this project. We have the original matrix profile paper by the Eamonn Keogh research group, including definitions of the distance profile, matrix profile, and introduction to their

algorithms [1]. Additional matrix profile resources, code, examples, and data can be found at [5].

Two papers by the research group which are specific to music analysis are [3] and [4]. It appears that [3] is newer and more improved than [4], so [3] has been the focus of our studies thus far.

To understand how to prepare our data for use in matrix profile, we examined the methods presented in [3]. Their main source is [2] which we began examining, but did not finish yet since we have just begun to explore matrix profile.

For preliminary analysis, we plotted spectrograms and other analysis of the songs using [7] after converting the .mp3 files to .wav using [6].

3 Pre-Analysis

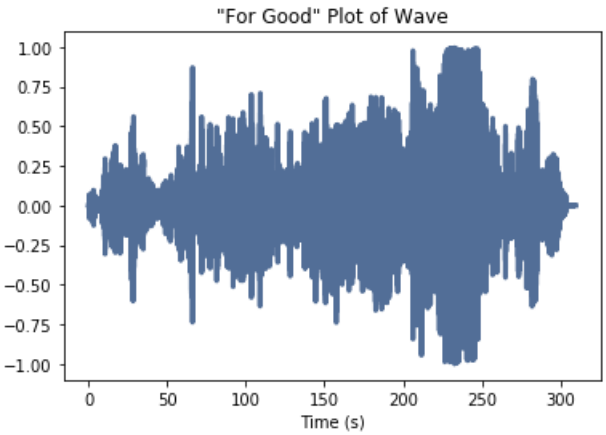
The goal of the this section is to start the manual analysis of the subset of songs we have selected to start working with. As previously mentioned, the 'Wicked' Soundtrack has been selected for analysis and we begin the manual process with the two songs 'For Good' and 'Dear Old Shiz'.

3.1 Introduction to the Music

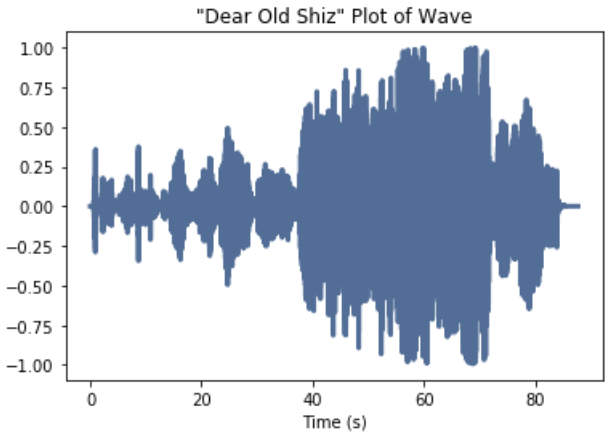
A little background into the music will help to understand why these songs were selected and how we can start the manual process. Throughout the musical, a lofty lilt is used to signify a story between the two main characters Elphaba and Galinda. This motif is first noticeable in the second song of the score called 'Dear Old Shiz'. This is our introduction to the "Galinda and Elphaba Story" where they go back in time to explain how the two of them first met. The motif is continuously used throughout the musical, often when Elphaba and Galinda are about to talk about each other or sing with each other. This all leads up to the major plot song called 'For Good'. This song is where the entire musical comes together to show how two people who hated each other at first end up becoming best friends and changes the others' life "for good". The composer wants us to remember all of the other major plot points that led up to this moment so that the words have a stronger meaning and we, as the audience, recall everything the characters went through in order to make it to this song. The motif intensifies the emotions that are intended to be felt when this song is performed.

3.2 Beginning the Pre-Analysis

The analysis is still being done; however, we have started the process of plotting and examining the subsections of the two songs.



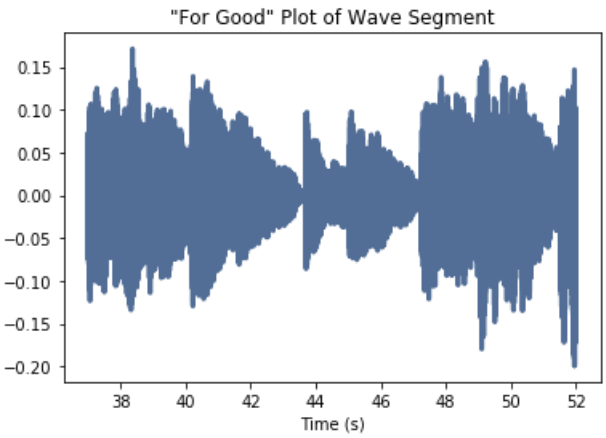
(a) The original full wave of 'For Good'.



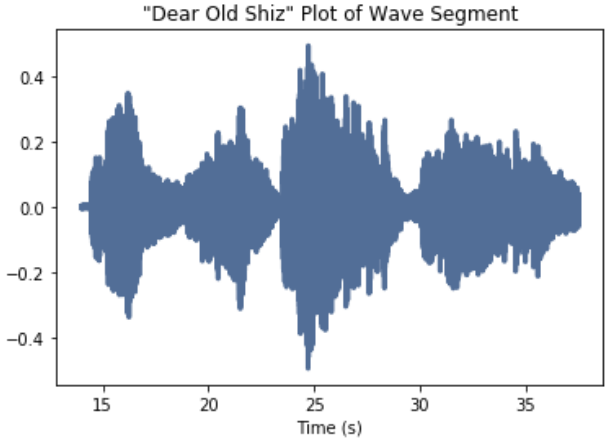
(b) The original full wave of 'Dear Old Shiz'.

Figure 1: The two original waves.

Now we crop the two songs to the sections that contain the motif in question. For the song 'For Good', this starts at 37 seconds into the songs and lasts for about 15 seconds. For the song 'Dear Old Shiz', this starts at 14 seconds into the songs and lasts for about 23.5 seconds. The plots below contain the waves of these segments.



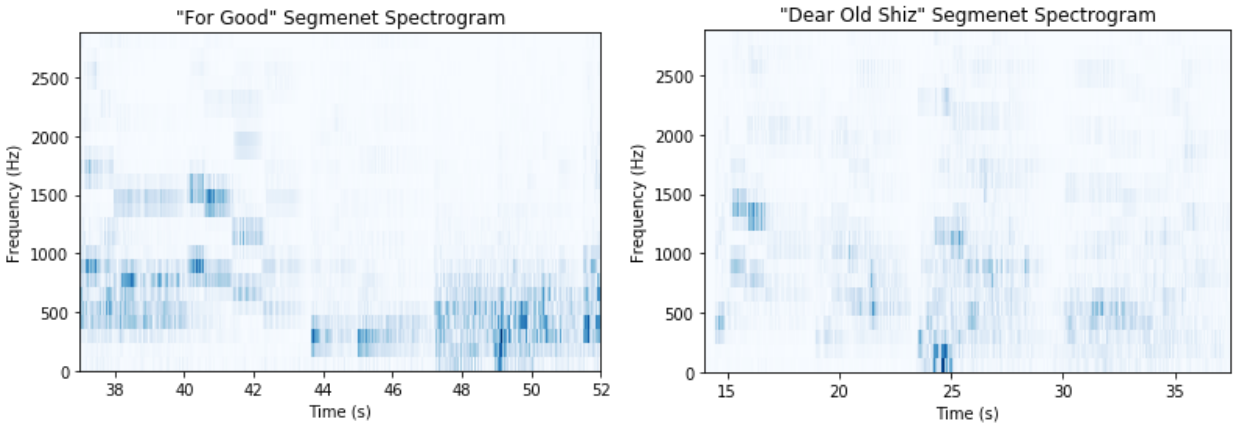
(a) The subsection of 'For Good'.



(b) The subsection of 'Dear Old Shiz'.

Figure 2: The segmented waves.

The spectrograms of both of these segments are plotted; however, they are still being examined for importance. It does not seem like a time dependence is the most important aspect of these segments. Thus, we want to examine the frequencies and amplitudes more than we want to focus on the time dependency.

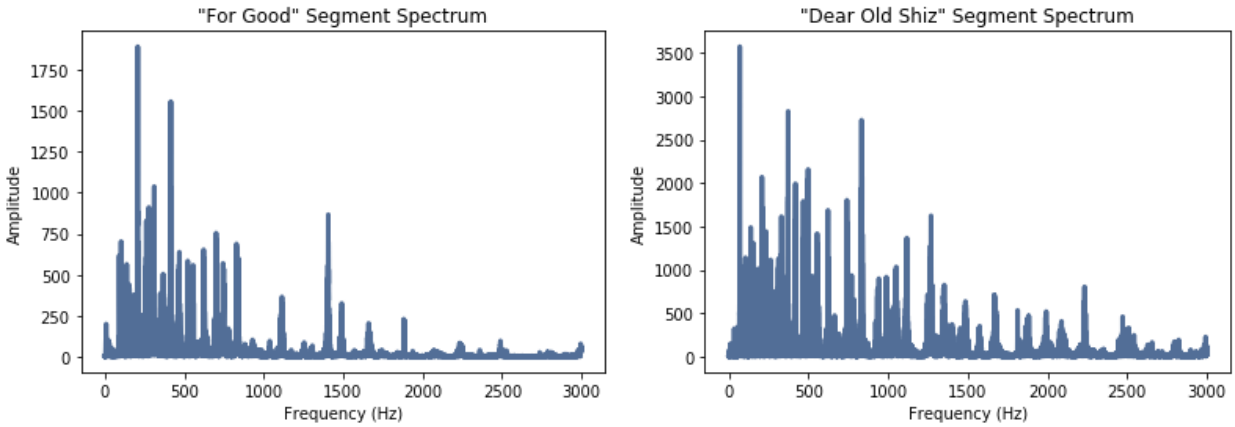


(a) The subsection of 'For Good'.

(b) The subsection of 'Dear Old Shiz'.

Figure 3: The segmented waves spectrograms.

Finally, we plotted the spectrum for each of the segments in order to see how the amplitudes and frequencies compare within the smaller portions of the songs. Unfortunately, it looks like the amplitudes for the smaller frequencies differ largely and the middle frequencies, around 1500Hz are similar.



(a) The subsection of 'For Good'.

(b) The subsection of 'Dear Old Shiz'.

Figure 4: The segmented waves spectrums.

3.3 Conclusion

Further analysis is still necessary in order to determine whether or not we can mathematically determine that these two share the common motif.

References

[1] Yeh, C., Zhu, Y., Ulanova, L., Begum, N., Ding, Y., Dau, H., Silva, D., Mueena, A., Keogh, E. (2016). *Matrix Profile I: All Pairs Similarity Joins for Time Series: A Unifying View that Includes Motifs, Discords and Shapelets*. Retrieved from https://www.cs.ucr.edu/~eamonn/PID4481997_extend_Matrix%20Profile_I.pdf.

[2] Muller, M., Kurth, F., Clausen, M. (2005). *Audio Matching Via Chroma-Based Statistical Features*. Retrieved from https://www.semanticscholar.org/paper/Audio-Matching-via-Chroma-Based-Statistical-Mueller-Kurth/5814542a2d8f9c316a295dfc740e27a98043834d.

[3] Silva, D., Yeh, C., Zhu, Y., Batista, G., Keogh, E. (2015). *Fast Similarity Matrix Profile for Music Analysis and Exploration*. Retrieved from https://www.cs.ucr.edu/~eamonn/final-fast-similarity-3.pdf.

[4] Silva, D., Yeh, C., Batista, G., Keogh, E. (2016). *SiMPLE: Assessing Music Similarity Using Subsequences*. Retrieved from https://www.cs.ucr.edu/~eamonn/MP_Music_ISMIR.pdf.

[5] Yeh, C., Zhu, Y., Ulanova, L., Begum, N., Ding, Y., Dau, H., Silva, D., Mueen, A., Keogh, E. *Matrix Profile I: All Pairs Similarity Joins for Time Series: A Unifying View that Includes Motifs, Discords and Shapelets*. Retrieved from https://sites.google.com/site/icdmstamp.

[6] Zamzar Online File Conversion. Retrieved from https://www.zamzar.com/convert/mp4-to-wav/.

[7] Downey, A. *ThinkDSP*. Retrieved from https://github.com/AllenDowney/ThinkDSP