CALIFORNIA SCIENCE & ENGINEERING FAIR
2019 PROJECT SUMMARY

Name(s)

Isabelle Katz

Project Number

J1713

Project Title

Characterizing Musical Instruments Using Waveform Analysis

Abstract

Objectives

Quantify the vague terminology that musical instrument experts use to qualitatively describe tone quality (e. g., creamy, bright and mellow) and categorize the timbre of different musical instruments and different brands of the same instrument (piano) using waveform analysis and a frequency domain color-fingerprinting technique I developed.

Methods

I recorded single notes (middle-C) from different instruments and from different piano brands. The procedure involved recording the musical note, trimming the time domain signal to a 3 second period that encompasses the attack, decay and sustain, and transforming the time domain function to the frequency domain, by using a Fourier transform algorithm in MatLab. In order to categorize the piano brand timbres I developed a color fingerprinting technique for characterizing the amplitude of the frequency domain peaks and created a tone metric by recording middle-C using bright and mellow settings on an electric piano.

Results

When comparing the data in the frequency domain, the major difference between the piano and the stringed instruments was the number and intensity of the high frequency peaks. On a comparative scale, the piano lacked high frequency structure, the guitar had a moderate level, and the violin had a rich structure. When comparing piano brands, Bosendorfer had the strongest fundamental peak relative to that of its first and second harmonic. Comparatively, while the Steinway fundamental is the strongest peak, it is only 1.5 times stronger than its first harmonic, and 5 times stronger than its second (whereas, the Bosendorfer fundamental peak was 50 times greater than its second harmonic). The Yamaha frequency spectrum shows a stark difference to the other brands because the amplitude of its fundamental frequency is less than that of its first harmonic.

Conclusions

Combining the color-fingerprinting technique and tone metric, I was able to: 1) distinguish between piano and stringed instruments; 2) differentiate among the various piano brands; and 3) categorize instrument tone color, ranging from mellow to bright. Music has a complex waveform, and while my project was based on data from a single note, the results are accurate and the analysis shows that the terminology used by music experts to describe the timbre of different instruments and different brands of pianos can be quantified by analyzing the note in the frequency domain.

Summary Statement

Musical instrument tone (timbre) is often described by experts using vague terms such as creamy, bright and mellow, so for my project I set out to quantify the timbre of these instruments and categorize their tone.

Help Received

I learned about sound waves from my science teacher, and read articles about the Fourier transform for analyzing sound waves. I watched MatLab videos on how to input and plot data in MatLab and how to calculate the Fourier transform in MatLab.