Mapping Chaotically Generated Synthesizers to Real World Instruments with Machine Learning and Harmonic Analysis

The digital age has changed the world of music dramatically. No longer is music recorded on strips of electromagnetic tape, but as arrays of numbers held within a computer program. Even musical instruments need not be physical vessels of wood or metal with vibrating strings or membranes but can themselves be purely digital creations. For example, using mathematics and concepts from chaos theory, we can synthesize soundwaves that can possibly sound like traditional non-digital instruments.

When these chaotic waveforms are played through speakers, it may often be easy for a human to identify what musical instrument it most closely resembles. Humans have a sense of hearing, and can detect qualities of waveforms such as frequency, timbre and loudness from the sounds that we hear. Conversely, computers are restricted to collections of numerical values contain within an array that make up a waveform, and thus the nature of these musical instruments goes from qualitative, to quantitative. The problem lies within the fact that humans can so trivially make map almost any sound to a corresponding musical instrument, but a computer would find the same task far more challenging. For this reason, I will use principles from machine learning for a musical instrument identification algorithm.

For this project, I will construct a computer program that can match the waveform produced by a chaotic synthesizer to a physical musical instrument. This program will be constructed using standard machine learning classification algorithms such as Stochastic Gradient Descent, K – Nearest Neighbors, and Decision Trees. Since the strength of a machine learning algorithm is generally based upon the quality of the input variables, the bulk of this project will be reliant on principles from physics to determine an appropriate set of input features to use for such a program. Using concepts from acoustics such as formant spectra, Fourier analysis and general signal processing techniques, I will determine a series of features that will allow a computer program to match a chaotically synthesized waveform to a real musical instrument.

A completed project will include the following pieces:

1. A computer program that can map an arbitrary waveform to a real-world instrument
2. A set of chaotically synthesized waveforms classified a real-world musical instrument
3. An analysis of the validity and performance of the machine learning algorithm based upon the set of chosen input features.

Since many standard machine learning algorithms already exist, the success of the project is contingent on producing the set of input parameters that allows these existing procedures to produce accurate and consistent results. This study will provide a surface level analysis of concepts from physics such as acoustics and signal processing that allow to produce these results.

For the execution of the project, I have worked with Dr. Kevin Short to outline a bi-weekly checkpoint- like schedule. We have collaboratively assembled a small library of sound files which have been labeled based on the particular instrument playing them. Additionally, I have amalgamated a collection of both digital and physical resources on the topics of machine learning, digital signal processing, acoustics and numerical computation. Work for this project will be built around an 8 – 12 hour per week schedule. The results of this project will be formalized into a written thesis as well as presented to members of the UNH Physics department for review by the end of Fall 2020.