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

The digital age has changed the world of music dramatically. Music is no longer 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; they themselves can be purely digital creations. For example, using mathematics and concepts from chaos theory, it is possible to synthesize soundwaves that can sound like traditional non-digital instruments.

Computers can only interpret collections of numerical values contained within an array that make up a waveform, and thus the properties of these musical instruments become highly quantitative. However, when these waveforms are played through speakers, it would be easy for a human to identify what instrument they most closely resemble. Humans have a sense of hearing, and therefore can detect qualities of waveforms such as frequency, timbre and loudness from the sounds that they hear. Although computers are computationally superior, they have not yet mastered this task that humans can do so trivially. For this reason, I will use principles from machine learning for a musical instrument identification algorithm.

For this project, I will work to 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. Using concepts from acoustics such as formant spectra, Fourier analysis, and general signal processing techniques, I will attempt to determine a set of features that will allow a computer program to match a chaotically synthesized waveform to a real musical instrument.

The 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 as real-world musical instruments
- 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 allow these existing procedures to produce accurate and consistent output. This study will provide a surface level analysis of concepts from physics such as acoustics and signal processing that allow for accurate classification of musical instruments.

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For the execution of the project, I have worked with Prof. 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 producing the sound. 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.

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