# Modification of electric timbre using the Fourier transform

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## Introduction

Timbre is the auditory sensation perceived from a tone independent of volume and pitch (Smalley, 1994). This property of a tone is what allows one to identify a sound with a specific instrument. With the ability to modify the timbre of input and produce a new tone, one could improve the richness of a produced sound to shift from a lower quality timbre such as electronic production to a more appealing timbre like acoustic production.

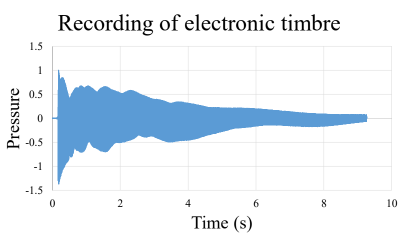
Given the qualitative nature of timbre, algorithmically modifying timbre would seem an ineffective method of "improving timbre." However, this data can be modified to produce quantities associated with timbre.

The pressure-time data acquired by microphone is not useful in the raw form and must be converted by the Fourier transformation into intensity-frequency data which displays partials (sets of frequencies) which can be analyzed. These partials determine timbre.

Determining the fundamental frequency is an essential step of this process. According to Doval and Rodet (1993), studies involving real-life acoustic notes do not behave as the perfect equations derived from the general wave equation or the Fourier Transform, and the most appropriate way to approach the problem is to use Bayesian reasoning (probability models). This can be applied to other variables as well.

The purpose of this project was to take two different recordings from electronic and acoustic instruments and develop an algorithm that modifies the timbre of one to imitate the other. The goal was to develop a method to change an electronic input to resemble an acoustic sound while minimizing the delay in sound reproduction.

## Materials & Methods

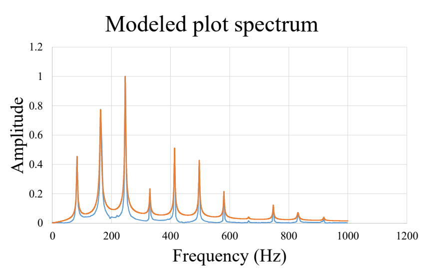



Graph 1 (left): This is a pressure-time graph from a low E played on an electric guitar as its energy dissipates over 9 seconds. Fourier analysis was focused on the section of decay that appears constant after the fall of the initial attack of the tone.

## Materials & Methods (cont.)

Audio recording data was collected in the *.wav file format from the performance of 15 notes on both an acoustic and an electric guitar (Pan & Lieb, 2018). This recording was exported as separate notes from Audacity software (see Graph 1). Samples of length ten times the fundamental frequencies were extracted from each *.wav file. These samples were analyzed with the Fourier transform to observe plot spectrum characteristics including the amplitude and bandwidth series. Regression analysis was used to determine the relationship between the acoustic data and the electric data. This regression was then used as an algorithm to simulate tones of acoustic timbre from data of electric timbre (see Graph 2). This algorithm was applied to the 15 electric tones in data resulting in 15 modified tones.

A test was planned to be given to 30 subjects with a sound recording and a sheet of questions asking for the subject to identify the tones within the recording as acoustic or electric. After completing the tests, the papers were to be collected and graded for accuracy. A 1-sample t-test was planned to determine whether the mean score was below a 20%. This would determine the effectiveness of the algorithm.




Graph 2 (left): This is an intensity-frequency graph of the same low E in graph 1 with the reproduced intensity-frequency (orange) that is entirely dependent on the amplitude and bandwidth series data which were acquired from the original (blue) Fourier data analyzed from the recording.

## Results

The null hypothesis was that the average accuracy of timbre identification was equal to 20%. The alternate hypothesis was that the accuracy was below 20%. A statistical test was not conducted due to test scores not being collected; therefore, the effectiveness of the algorithm could not be determined. It was, however, determined that

## Results (cont.)

matrix mathematics was not a viable method of translating the series of bandwidths from one spectrum to another. With the data provided, the matrix of electric bandwidth coefficients was indeterminant. This implied that a matrix that could translate all elements from one set of bandwidth coefficients to the other does not exist.

## Conclusion

The purpose of this study was to discover an algorithm that would accurately transform an electric guitar recording to one that is perceived as acoustic. This study was built on the assumption that timbre is accurately quantified by a series of bandwidths and amplitudes.

Due to the suspension of school caused by the coronavirus disease, the testing of the algorithm could not be completed this year as subjects were expected to listen to the recordings in one room. With no results aggregated from the study, it could not be proven that the matrix-based algorithm was successful or not successful in translating electric guitar timbre into an acoustic timbre.

Given the results of the indeterminant matrix, it can be concluded that the translation of bandwidth series cannot be modeled with matrix-based calculations.

Improving upon this study, a better method of plot spectra data collection could have been developed to incorporate the effect of loudness on the Fourier transform. Also, a separate algorithm could be implemented to incorporate the translation of bandwidths.

## References

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