PRELIMINARY RESULTS ON STRING INSTRUMENT RECOGNITION

Jason Smalridge[1], Luis Rodrigues[1], and Lisa Lorenzino[2]
[1]Dept. of Mechanical and Industrial Engineering, Concordia University, Montreal, Canada, luisrod@encs.concordia.ca
[2]Schulich School of Music, McGill University, Montreal, Canada, lisa.lorenzino@mcgill.ca

ABSTRACT

This paper analyzes and compares the spectrum of three string instruments obtained from the Fast Fourier Transform of the sound waves. It is shown that comparing the spectrums of different instruments holds a strong potential to be used as a first stage of an automatic instrument recognizer.

1. Introduction

The most important elements required to identify musical instruments are: envelope, timbre and spectrum.

1.1 Envelope

The envelope of a sound is the shape of its amplitude over time and is divided into 4 parts: attack, decay, sustain and release (ADSR). The attack and decay are often referred to as the transient portion of the sound, with attack being the onset of the sound. They are both important in identifying a source because they hold information about the way the sound is produced. A sound produced from a bowed instrument (violin) will have a longer transient then a struck instrument (guitar). If the sustained portion and release of the sound is played by itself without the transient, then it is very difficult to identify the source.

1.2 Timbre

The most important aspect of a sound is unfortunately the most difficult to analyze. The word timbre (pronounced Tam-ber) describes the aspect of a sound which allows the ear to distinguish two different sound sources which are playing the same pitch at the same level. Even though there are no direct answers as to how to analyze the timbre of a sound, it has to do with the slight variations of both the pitch (and partials) which is called vibrato or jitter and amplitude which is called tremolo. Other factors may include the way that the instrument is constructed and how it resonates certain frequencies. Some instruments tend to have a low common partial throughout all their frequencies that is the product of the materials used for constructing them having their own natural resonant frequency.

1.3 Spectrum

By analysing the spectrum of a note, one can obtain an instrument's signature harmonic series. The Fast Fourier Transform [1] is the mathematical tool used to produce the spectrum and therefore the signature. Often the fundamental frequency is the first and most dominant partial, but sometimes the instrument produces noise and sub-harmonics that create partials below the true fundamental [2]. Sometimes the fundamental can even be removed without affecting the tonal quality.

In the 1960s Claude Risset at Bell Laboratories performed experiments analyzing and synthesizing a trumpet. He discovered that removing certain frequencies did not change how the human ear perceives the instrument. By removing the partials above the 4000 Hz threshold a trumpet could still be identified. He discovered that the important characteristics for identifying an instrument were the slight variations in frequency (vibrato) and of amplitude (tremolo) of the partials over the duration of the sound [3]. Based on these results, in this paper we will analyze and compare the spectrum of three string instruments.

2. Methodology and Results

In this paper we analyze the spectrum of a Fender acoustic guitar, a Fender Telecaster electric guitar and a Fender short scale Squire electric bass. Six notes were sampled for each instrument and then the Fast Fourier Transform function was used to obtain the spectrum. The six notes were:

-LowE(0):	82Hz
-A(1):	110Hz
-D(1):	146Hz
-G(1):	195Hz
-B(2):	246Hz
-HighE(2):	329Hz

2.1 Acoustic Guitar

We noticed that depending on where the string was plucked, the partials would change amplitudes. When the string was plucked above the sound hole, there was normally only an average of 4 partials with significant peaks. The rest of the partials had such low amplitudes that they were almost equal to the background noise. When the string was plucked close to the bridge (Figure 1) there was a much more even distribution of the partials' amplitudes. When the string was plucked above the soundboard (middle of the string), the partials were completely inconsistent in amplitude.

Problems that arose when recording the data were due to a natural resonant frequency from the guitar. This partial constantly appeared throughout all the notes before the fundamental. In some cases it merged with the harmonic series and created a second harmonic partial that was an octave above the first. In other cases it merged with the fundamental to create two peaks side by side, therefore confusing the location of the fundamental.

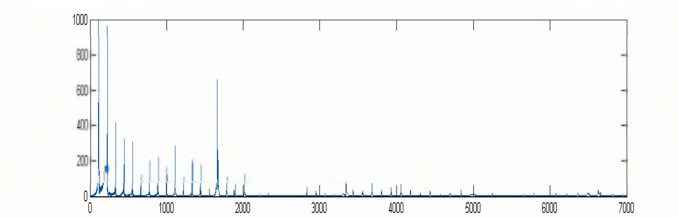

Figure 1 – A string when plucked at the bridge (acoustic guitar)

2.2 Electric Guitar

We noticed a difference in the bass strings and the treble strings in the electric guitar. The electric guitar is fabricated with a slanted single coil pickup. This allows the pickup to be closer to the bridge under the high pitched strings and farther away for the low pitch strings. This would allow the higher strings to pick up more energy in the higher partials much like when the acoustic guitar strings were struck near the bridge (Figure 2). The only difference being that the acoustic guitar could not project enough amplitude to allow the microphone to record it.

Problems arose when analyzing the fundamental frequency for the high pitch strings because the fundamental was much lower in amplitude than the rest of the partials. The position of the pick up explains why the fundamental, and the lower partials, have less amplitude in the higher strings than in the lower strings.

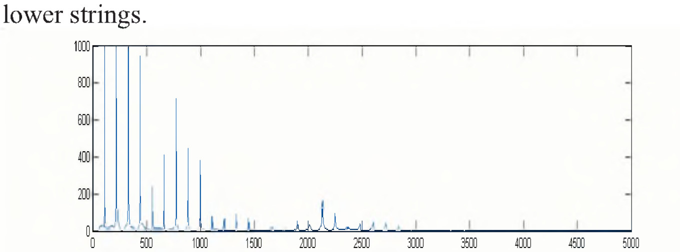

Figure 2 – A string (electric guitar)

2.3 Electric Bass

We had a difficult time with the data from the bass. The first partial in the series acted differently than in previous recordings. The low strings had partials that were almost nonexistent, but the higher strings had the same partials with higher amplitudes (Figure 3). The highest string produced the highest amplitude for this partial. We believe that the microphone used to record the sample did not have a high frequency response at that level. As this partial moved higher, the microphone was able to pick up the frequency better.

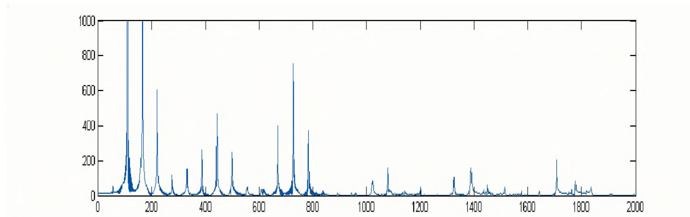

Figure 3 – A string (electric bass)

As can be seen in Figure 4, the frequency response only really begins at 55 Hz. The first two tones the bass produces have fundamentals below this point. The samples that were taken were seen to be one octave lower than the samples taken from the guitar.

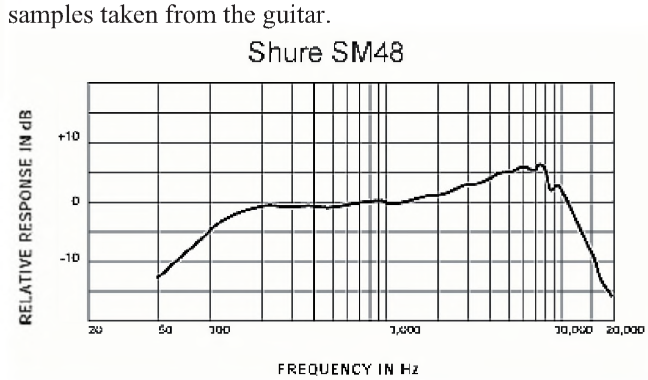

Figure 4 – Frequency response of the microphone

3. CONCLUSIONS

In this paper we analyzed and compared the spectrum of three string instruments obtained from the Fast Fourier Transform of the sound waves. It was seen that comparing the spectrums of different instruments holds a strong potential to be used as a first stage in an automatic instrument recognizer. The potential applications of automatic musical instrument recognition range from assisting hearing impared subjects to aiding an individual to identify musical selections from a database containing a given instrument.

REFERENCES

[1] A. V. Oppenheim, *Digital Signal Processing*, Prentice Hall, 1974.
[2] H. F. Olson, *Music, Physics and Engineering*, 2nd. Edition, Dover, 1967.
[3] J. R. Pierce, *The Science of Musical Sound*, W.H. Freeman Company, 1983.

ACKNOWLEDGEMENTS

The authors would like to acknowledge Mr. Paulo Tavares for stimulating discussions about the potential applications of an automatic musical instrument recognizer. The second author would also like to acknowledge NSERC, NATEQ and Concordia's Co-op Institute for partially funding this research.