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Development of an Individualized String Pickup for Guitar Chord Recognition

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Abstract: There are various methods that are used for chord recognition. For an acoustic guitar, the typical pickup gets the summation of all signals which results in the cancellation of some frequency components in the overall signal. In most studies, an algorithmic approach to process the audio signal is used to identify the chords present. These methods produce an accuracy of roughly 70-90%; however, the algorithms can only detect basic chords.

In this research, a proposed system with an individualized string pickup will be used to offload the data acquisition process done by the chord recognition algorithm, effectively reducing the algorithm's complexity. The assisting hardware also opens the system to also recognize complex chords and basic chords alike. The hardware interface is a modified hex pickup for individual string output which is followed by an intermediary device that will process the signal before sending the data to the computer via USB. Tests show promising results, with strings being successfully isolated from each other.

Key Words: guitar; pickup; algorithm; chord recognition; music transcription

1. Chord Recognition

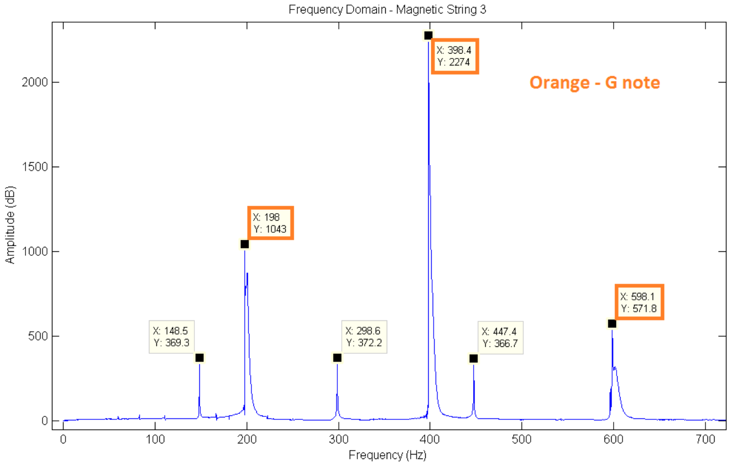
In music transcription, knowing what note or chord is being produced plays an important role in its overall functionality. Failure to accurately identify these notes and chords defeats the purpose of the entire piece [1]. Chord recognition plays an important role in solving this problem. For the guitar, the complexity is capped at a 6-note chord produced by the six strings. Software algorithms alone cannot solve this problem by itself. The current implementation of chord recognition relies solely on software algorithms. For instance, [2] and [3] used a purely software approach and produced an output with 60-90% accuracy.

2. METHODOLOGY

2.1 Analysis of existing problem

The following tests used a generic commercial non-hexaphonic magnetic pickup to get the raw signal from an acoustic guitar in standard tuning. The sound was then recorded using Audacity software. After that, wav files of the signals were generated using Audacity. The time domain signals from the wav files were then converted into the frequency domain using Fast Fourier transform in MATLAB.

Fig. 1. Signal of a note with a low fundamental



frequency amplitude output

As can be seen in the image above, the amplitude of the fundamental frequency of the signal is lower than the amplitude of its first harmonic. This might pose errors in some chord recognition algorithms that use the highest amplitude as its reference. Some of the average guitar musicians rely on reading chords via tablature. Tablature is a kind of music score wherein instead of notes; fret positions are being read. Without the extraction of fundamental frequencies producing an accurate tablature is very difficult.

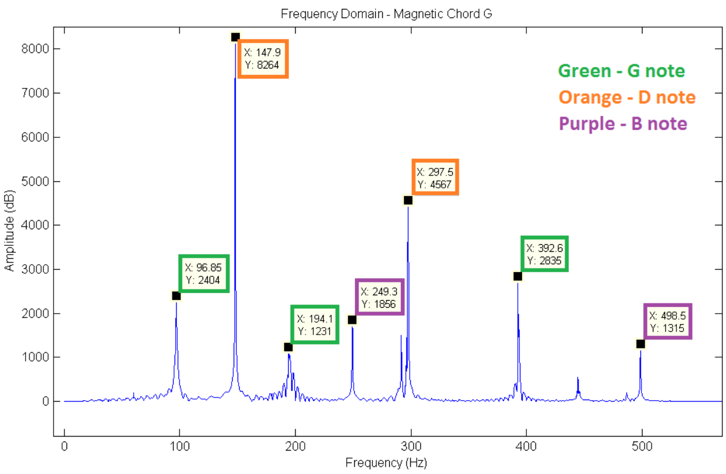


Fig. 2. Basic Chord G with a missing frequency

Based from the given figure, one can determine that the output is a basic G chord. Even though the fundamental frequency of note B is missing, other components of G chord are present such as note G, note D, and the harmonics of note B.

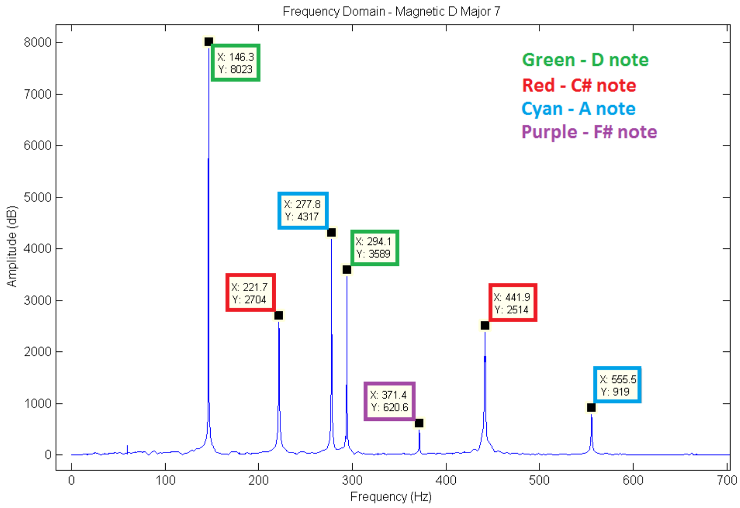


Fig. 3. Magnetic D Major 7

In the figure above, all required frequencies for the complex chord D Major 7 are present but existing chord recognition algorithms will have a hard time identifying the chord played in this signal. This is due to the fact that this complex chord is composed of two basic chords.

A test was also done to show the limitations of existing music transcription software to detect complex chords. Chordify [4], a software for music transcription, gave good results when basic chords were tested. When a complex chord was included in the input signal, the software was not able to recognize those chords. Case in point, Chordify had an accuracy of around 80% for the song cover of Jar of Hearts by Boyce Avenue [5]. The song is composed of 98 chords but the software got 21 of those chords wrong. Another test was done to check the accuracy of the software given an input coming from a generic commercial non-hexaphonic magnetic pickup. A wav file of the signal output of the pickup was generated using Audacity. Then, the wav file was uploaded onto the web application software. The software was able to determine all the basic chords played but when Dmaj7, a complex chord, was played, there was no output. It was tested multiple times but the results are the same.

2.2 Development of individualized string pickup

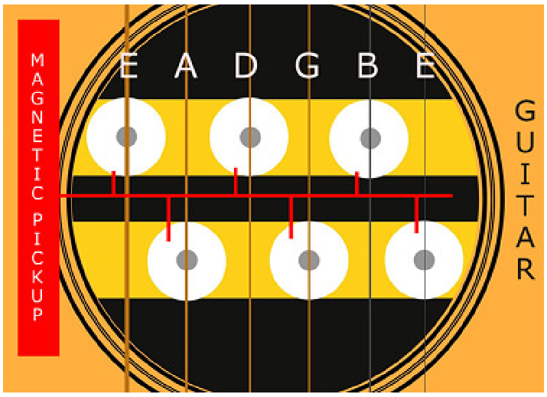


Fig. 4. Individualized String Pickup

To improve the versatility of chord recognition, a method in acquiring individualized signal from each string was implemented using a single coil magnetic pickup for each strings. With this, the chord recognition algorithm that will be implemented for this system is less computationally expensive because the signal was already separated. It is also hoped that this approach will aid issues concerning the process of note extraction.


Fig. 5. Plastic Bobbins

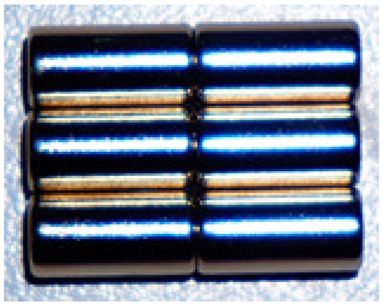


Fig. 6. Neodymium Magnets

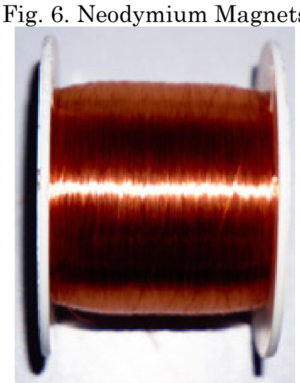


Fig. 7. AWG 37 Magnetic Wire

Several numbers of prototype magnetic pickups with various amount of coils ranging from 100-2000 has been produced and tested to see which number of coils could produce a clean and acceptable signal for each strings. The design of the magnetic pickup was implemented using a cylinder-shaped neodymium magnet as a core, a bobbin made of plastic to hold the magnetic wire in place and overhead projector film, and a gauge AWG 37 magnetic wire for the coil.

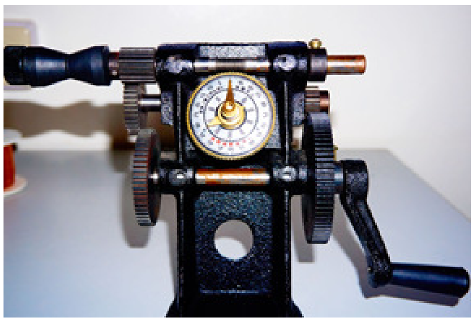


Fig. 8. Coiling Machine

During the process of making a pickup, a coiling machine was used to keep track of the amount of coils and to also speed up the process.

Fig. 9. Prototype Pickup

After producing 6 copies of the pickup shown in the image above, they are assembled and soldered on a printed circuit board. A separate external wire connected to each magnetic pickup was also soldered onto the board to be used as an interface between the pickup and the audio jack of the computer.

The distance between the strings of an acoustic guitar was also taken into consideration when the pickups were attached to the board. Making a small pickup will result into a signal with -50db recording. Similarly, a larger pickup will produce a signal close to 0db recording. The problem with a large pickup is it would not fit the board, thus making something in the middle of the two. With that in mind, the prototype hexaphonic magnetic pickup that was built has pickups large enough to detect a signal that is ready for processing while avoiding contact with adjacent pickups, hence the zigzag pattern of the pickups in Fig. 4. Then, the finished pickup was attached inside the guitar to avoid interrupting the guitarist from playing.

3. RESULTS AND DISCUSSION

Guitar strings produce sounds with vibration of the strings, a wave that moves in opposite direction. This wave will then overlap with each other which is the succeeding vibration. The succeeding vibration will now produce harmonic multiple of the first wave produced, which are referred to as standing waves [6].

As mentioned earlier, the signal in Fig.1 has problems regarding the amplitude of the fundamental frequency while Fig. 2 has missing harmonics. These signals are not acceptable inputs for this research. An ideal signal would have the following characteristics: a peak amplitude high enough for extracting critical information, a fundamental frequency that has an amplitude greater than the harmonics, and an adequate sampling rate to distinguish several harmonics with good resolution. For this research, a signal is considered viable for processing if the peak amplitude of a single note/chord signal has a voltage of at least 10mV peak-to-peak.

Since existing chord recognition algorithms are having problems in the detection and transcription of complex chords, simply having an ideal signal is still not enough. Case in point, the signal in Fig. 3 is an ideal signal but it is also complex chord.

Results from prototype magnetic pickup with turns 1000 below are disregarded, due to the fact that it was not able to show any good results or any distinct amplitude from the input signals. The only string it would work would be strings 1 and 2, but still produced an undesirable output.

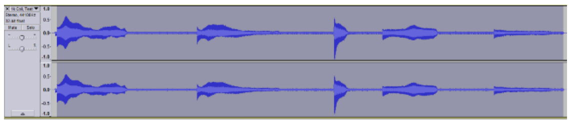


Fig. 10. 1200 turns single coil magnetic pickup individual string test

Guitar strings differ from each other with their diameter. This enables the guitar to produce different sounds given that the all strings are pressed at the same fret. The thicker the string the louder sound it produces. Loudness of a sound is referred to the amplitude of the signal. From figure 10, string 1 and string 2 produced a clear output with sufficient amplitude. Magnetic pickup with 1200 turn were tested with string 3 to 6 but produced an almost negligible amplitude.

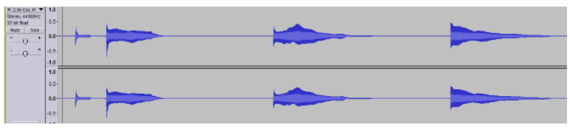


Fig. 11. 2.5k turns single coil magnetic pickup individual string test

For figure 11, the prototype magnetic pickup with 2500 turns were used in strings 3 to 6 since these particular strings produced an output with low amplitude when a pickup with 1200 turns was used. The figure above shows an acceptable and clear output for strings 3 to 6.

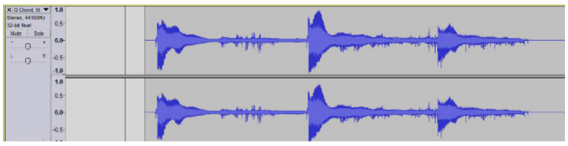


Fig. 12. G Chord on single coil magnetic pickup placed on 5th string.

Based from the results, pickup that has approximately 1200 turns and above produce a more reliable output signal. Those pickups were placed in near proximity to the strings such that those strings are almost touching the pickups but not enough to make contact should the user opt to pluck or strum it.

It is observed that the amount of crosstalk varies across the six strings. By strumming all strings but individually observing each string, it is found that the 1st, 5th and 6th strings of the guitar were successfully being isolated by their corresponding pickup. The 2nd, 3rd, and 4th strings exhibit crosstalk with each other, although faint. The goal for the next pickup design is to significantly reduce the crosstalk between these strings.

4. CONCLUSIONS

With the development of the individualized string pickup, the inherently noise-free characteristic, and more importantly, the little amount of crosstalk between strings, of the new pick-up ensures reliable and consistent feature-extraction of the signals for chord recognition.

The technology opens more opportunities for software to support the additional hardware, leading to better features. The individualized string pickup can also be used to develop new applications for stringed instruments, especially for assisted learning and chord transcription.

Future work will concentrate on determining viable chord recognition approaches, which can range from simple template-matching with dynamic time warping, to Hidden-Markov Modelling, and further sophisticated techniques such as Artificial Neural Networks.

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