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Interactive Guitar: Musical Software That Teaches Guitar Through an Interactive Game Interface and Audio DSP

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1. Introduction

This paper presents a Silverlight-based, interactive, computer video game that teaches a user how to play guitar. The seven major goals for this system is that it is 1) entertaining, 2) intuitive, 3) educational, 4) easy to set-up, 5) requires no special equipment, 6) runs on any operating system, and 7) uses a real electric guitar.

There are two components to this game; a major component (Sliding-notes), and a minor component (Tab Creator). Sliding-notes consists of displaying notes for the user to play on a guitar, and testing if the user played the notes correctly. The Sliding-notes interface, which is described in detail in Section 3, consists of "sliding-notes with background music". This type of interface has been proven to be entertaining and intuitive through the success of video games that use a similar interface, such as Guitar Hero [1], and Rock Band [2]. Sliding-notes tests if the user played the corrrect note(s) using a Multi-Rate IIR Filter based Pitch(es) Detection Algorithm.

Tab Creator is optional and the user uses it only if she wants to create her own unique note sequences, known as "guitar arrangements" or "tabs". Tab Creator consists of an intuitive interface that is described in more detail in Section 3.

Both Sliding-notes and Tab Creator are developed in C#.NET 4.0 with Silverlight 4.0. This enables both components to run on a Windows, Mac, or Linux computer.

There have been several video games already developed that are similar to the system proposed on this paper. However, none of them satisfy all seven of the goals meant for this system.

For example, two very popular video games that used a similar interface were Guitar Hero and Rock Band. However, these games do not use a real guitar, but a plastic guitar with colored buttons. Therefore, they do not satisfy goals "7" and "5". Also, the games are not educational, and hence do not satisfy goal "3".

A few systems that use a more realistic guitar include Disney and US Music Corp.'s "Disney Star Guitarist" [3], and "Power Gig", which will be released in October, 2010 by Seven45 Studios [4]. However, both of these require a guitar that is custom built for their respective games and hence do not satisfy goal "5".

2. Theory

2.1 Overall Approach

As mentioned previously, this system has two components: Sliding-notes and Tab Creator.

Sliding-notes' main purpose is to test whether or not a user plays certain notes correctly on an electric guitar at the right time. Sliding-notes does this by analyzing the electric guitar's output signal when the user is told to play a particular note through Sliding-notes' interface. Figure 1 shows this process.

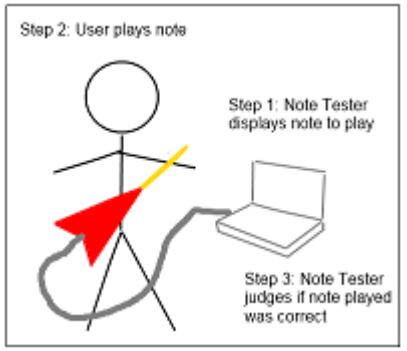

Figure 1 Sliding-notes displays a note for user to play and tests user's ability to play the given note .

For Sliding-notes to be able to analyze the guitar's signal, there must be a hardware connection between the guitar and the computer. This connection is as follows: the guitar output connects to a guitar cable, which connects to a simple adapter to convert the 6.3mm male phone plug of the guitar cable to a 2.5mm male microphone plug, which connects to the computer's microphone input. The computer sound card can than sample the signal from the microphone input, and Sliding-notes can analyze the resultant digitized data. Figure 2 shows an overall description of this process.

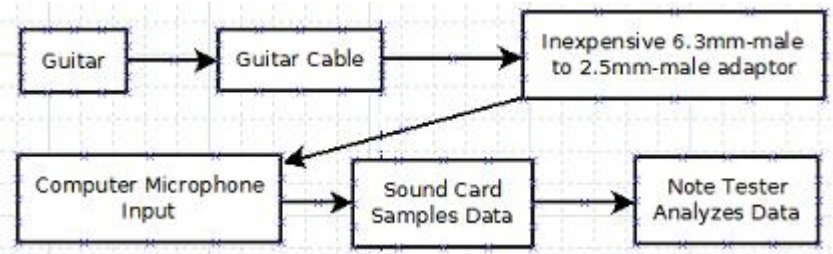

Figure 2 Flow Diagram of hardware connection

Tab Creator's is used to create guitar arrangements that can be played in Sliding-notes. A tab can be combined with a song of the user's choosing and loaded and played from Sliding-notes. This satisfies goal "1" for users who feel the default tab-song combinations available are not entertaining enough.

It is now clear that this system satisfies all seven goals. The "sliding-notes with background music" interface is entertaining (1) and intuitive (2), the game is educational (3) because it helps the user learn how to play notes on a real guitar (7), it is easy to set-up as there are no complicated components or special equipment to put together (4 and 5), and it is platform independent (6).

2.2 Guitar Output

The guitar outputs an electrical signal that has the frequency characteristics of the note strummed with a few harmonics added. For example; if an A4 is strummed, which has a frequency of 440 Hz, the electrical signal output from the guitar will have a frequency of 440 Hz with a few harmonic frequencies added onto the signal. This can be seen in Figure 3.

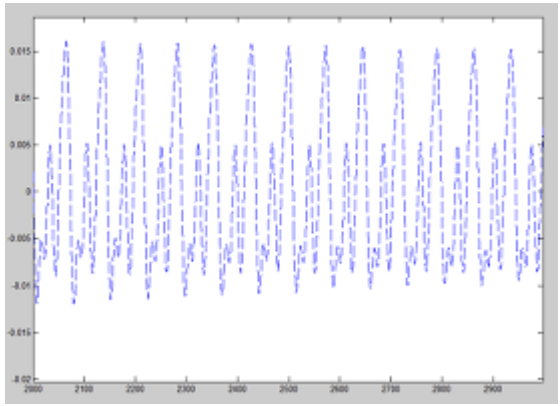

Figure 3: a plot of the A4 note (440 Hz) from an electric guitar

The guitar output signal is sent is sampled by the sound card at 16-bit resolution and 44.1 KHz when it enters the microphone input.

2.3 Signal Analysis

A multi-rate IIR filtering scheme is used to determine the frequency of the guitar output signal. This is particularly useful for mutli-pitch testing, which is needed when the user plays a chord (a series of notes). Using this scheme, it is possible to test the high frequency notes of a chord at a different sampling frequency than the low-frequency notes of a chord. It is best to use the lowest sampling frequency without aliasing so that the normalized frequency between two notes (frequency/ sampling frequency) is as large as possible. This enables a lower-order IIR filter to be used and hence reduces processing time.

For example, an E chord, as shown in Figure 4, consists of a wide range of frequencies from 82.4 Hz to 329.6 Hz. Therefore, if a single rate filtering scheme is used, the lowest possible sampling frequency without aliasing is 660 Hz (but in practice it is better to use a little bit higher than Nyquist rate so this example will use 700 Hz). Filtering between a low E (82.41 Hz) and an F (87.31 Hz) requires a high-order filter at a sampling frequency of 700 Hz. This is because the difference between the notes in digital frequency is very small at this sampling rate: .118 (82.41/700) and .125 (87.31/700), for a difference of about .007. However, by using a multi-rate filtering scheme, the sampling rate can be down-sampled to 175 Hz. Then the digital frequencies will be .471 (82.41/175) and .499 (87.31/175), for a difference of .28. Since the latter contains a 4 times larger difference between the frequencies, a much lower order filter

can be used to distinguish between the two frequencies. By using a lower-order filter, computation time is reduced.

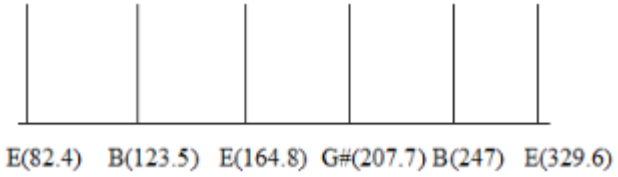

Figure 4 The frequencies of an E-Major Chord

Figure 5 Difference in digital frequency between 82.4 Hz and 87.3 Hz if the sampling frequency is 700 Hz is .125 - .118 = .007

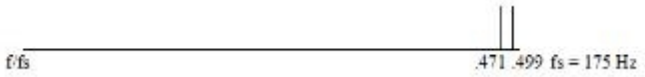

Figure 6 Difference in digital frequency between 82.4 Hz and 87.3 Hz if the sampling frequency is 175 Hz is .499 - .471 = .028

To prevent aliasing, a low-pass filter is used before each down-sample operation. After certain down-sample operations, a range of frequencies is analyzed using IIR filters to determine which notes were played. As explained previously, down-sampling before analysis can enable the use of lower-order filters and reduce computation time. A diagram of the scheme is shown in Figure 7.

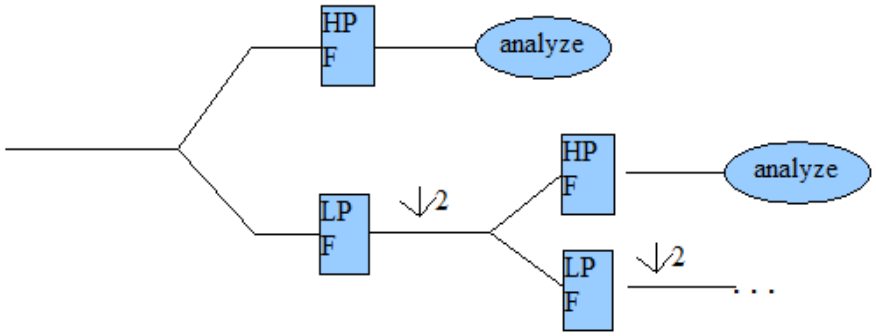

Figure 7 Multi-rate filtering scheme used to identify notes played from a electric guitar signal

3. Game Play

3.1 Sliding-notes Interface

This interface is a “sliding notes with background music” interface. In this type of interface, there is background music and notes sliding toward the user. When the notes reach a designated area, the user must play the note. If the user plays the note correctly, the music continues as normal. Otherwise, a buzzer sound is played with a version of the song with that note filtered out.

1) To start the game, a user chooses a song to play
2) Then, graphical objects overlaid with a number (graphical frets) slide toward the user from the back of the screen to the front along a “guitar string”. The “guitar string” the objects slide on correspond to the guitar string the user should eventually strum. The numbers overlaid onto the graphical objects correspond to the fret of the guitar neck where the user’s fingers should be placed. The fret number and string combined correspond to a particular note. For example, a fret number 2 on the D string corresponds to an E note. These notes correspond to guitar notes in the playing background song.
3) When a graphical fret enters a designated area, the user must strum the corresponding note on his/her guitar. If the user plays the note correctly, the song continues to play as normal. If the user plays the note incorrectly, a
version of the song with that note filtered out and replaced with a buzzer sound is played.

An illustration of this can be seen in Figure 8.

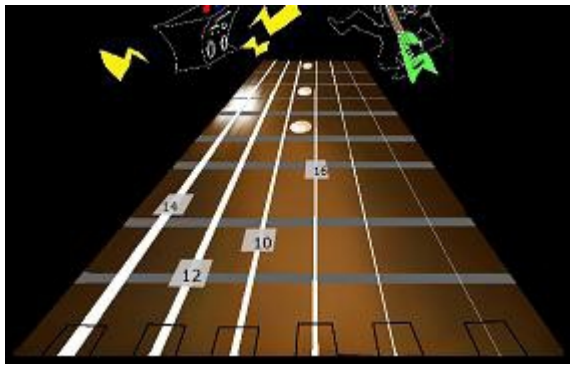

Figure 8: Shows a series of notes that the user must play. When the graphical frets are within the black lines (the designated area), the notes must be played. In this example, the user will soon play the 12th fret on the A string, followed by the 10th fret on the D string, etc…

3.2 Tab Creator

This optional component allows the user to develop an original guitar arrangement that can be combined with a song of the user's choosing. This provides the user flexibility to add more song options. For example, the user may want to play with a song that is not a default song, therefore the user will use this component of the software to create a guitar arrangement for the song. The song/guitar arrangement combination can then be loaded into Sliding-notes and played.

The interface of Tab Creator consists of 6 strings for the six strings of a guitar. The user loads a background song that corresponds to the tab that is being crated. The user places notes on the strings and can chose a note length and fret number. The length of the note on the string corresponds with the time duration of the note in the song. The number in the center of the note is the fret number the note corresponds to. This is shown in more detail in Figure 9.

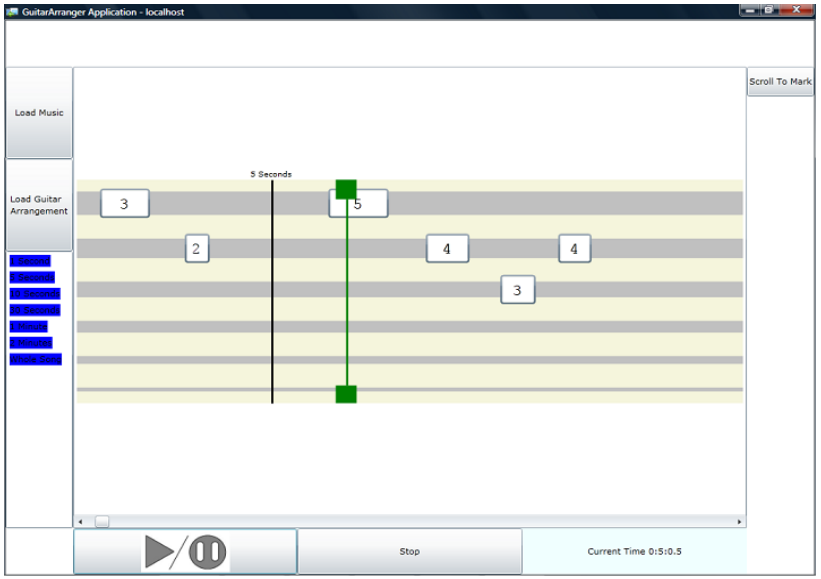

Figure 9 Interface of Tab Creator. There are strings for the six strings of the guitar. The frets are displayed as numbers on each note. The time duration of the note corresponds to the physical length on the interface.

4. Conclusion And Future Plans

This system is designed to help people learn and practice guitar in a fun and entertaining way. It is able to utilize modern technology such as Silverlight to have the potential to be more accessible for more people then comparative systems.

However, several improvements are necessary. For example, a computer-vision based hand-tracking component would be very useful for checking that the user's hand position is correct. In a future release of this software, we hope to add that component. Also, we hope to create a web-based application where users can keep track of their scores and share guitar arrangements.

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