Interactive Sheet Music

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Figure 1: *Screenshot of the System. The fretboard is displaying the arepeggio of minor-seventh in the key of E on a guitar with standard EADGBE tuning. The root of the arpeggio is colored blue and the 5th of the arpeggio is colored pink. Note that the notes on the staff lines are also colored.*

Abstract

In the year of 2013, printed sheet music is still the norm among musicians. Electronic sheet music has been around for more than 10 years. However, it is yet to be able to replace printed sheet music. This simply implies that electronic sheet music is not good enough. Electronic sheet music at the year of 2013 generally means no more than a PDF viewer with a playback button.

Here I introduce the idea of interactive sheet music, providing customization of sheet music layout and on-demand supplementary information for the musicians. Allowing the users to obtain information that they need on the system and eliminate information that they do not want from the system. A interactive sheet music system for standard Western music notation is built using HTML5 SVG canvas drawing and jQuery, allowing users to obtain a personalized music score which fits their specific needs.

I believe the idea of interactive sheet music is entirely new and unique, and I also believe interactive sheet music can become the reason for musicians to adpot electronic sheet music in the near future.

Keywords: Music, Music Score, Score, Guitar, Music Analysis, Automatic Music Analysis, Sheet Music, Lead Sheet, Standard Notation, Chord Diagram, Scale Diagram, Arpeggio, Fretboard Diagram, Fingerings, Jazz Theory, Music Education

Links: ⬛DL ⬛PDF ⬛WEB ⬛CODE

1 Introduction

With the exception of handwritten manuscript, sheet music means some form of music notation printed on paper. Printing enabled mass-production of sheet music. However, layout structure of a sheet music is almost impossible to change after printed. In addition, there might be redundant or missing information on the sheet music, depending on each individual musician's level of expertise or preference. To illustrate on this, chord fingerings, scale fingerings, chord progression analysis often fall into this directory. These information could be helpful to beginners, but they are often redundant to experienced musicians.

In this work, I plan to push the boundary and application range of electronic sheet music. I propose the idea of interactive sheet music to fill in an important gap between electronic sheet music and interactivity and customizability of electronic devices.

I have implemented a MusicXML parser and a SVG music engraver (Section 4). Many of the interactive features are customizable and can be disabled (Section 5). For instrument-specific supplementary information, I have implemented dynamic gutiar fretboard diagram (Section 6) and guitar chord diagram. For music analysis, I have implemented chord-tone analysis (Section 7).

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2 Related Work

Although music engraving software like Sibelius[1], Finale[2] or LilyPond[3] had become very popular among musicians. The main purpose of these software is still to produce printed sheet music. Sibelius Scorch[4] is a plugin to enable viewing and printing of sheet music in a browser. However, the sheet music is nearly non-interactive.

There are some dedicated apps on iPad for viewing music. Deep-Dish GigBook[5] is merely a PDF viewer with annotation function. Steinway Etude[6] is capable of rendering high quality sheet music, with some piano specific features such as highlighting parts for different hands with different color, and showing the keys to be pressed on a keyboard diagram. Yet, Etude does not allow users to import their own scores; it requires users to purchase scores in its in-app store.

The music analysis on teoria.com is the most interactive music score system that is available at the moment to my knowledge. It provides buttons as a mean to let the users to jump to different sections of the music. The "music analysis" provided in the system is a few lines of text being attached to the buttons. It would be great if a user can define a region in the score, and let the system attach the region to a button. Yet, this is not being implemented in our system because of time constrains.
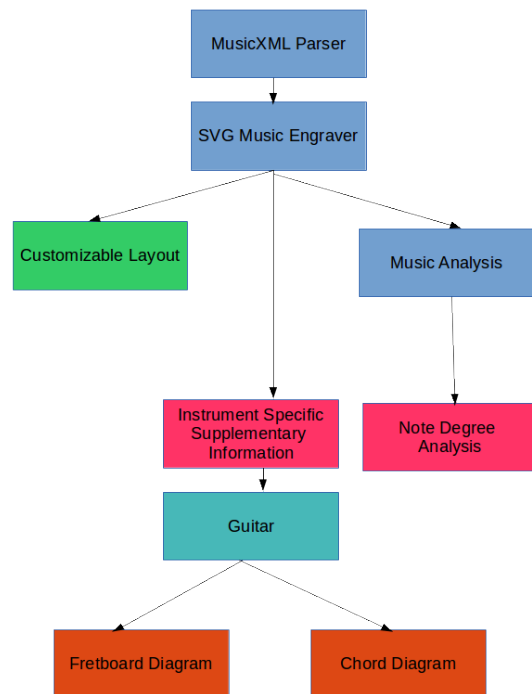
3 Overview

Figure 2: *Different parts of my interactive sheet music system.*

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[1] http://www.sibelius.com/
[2] http://www.finalemusic.com/
[3] http://www.lilypond.org/
[4] http://www.sibelius.com/scorch/
[5] http://deepdishdesigns.com/gigbook
[6] http://etudeapp.com

My system consists of the following components. Please see Figure 2 for how the different components are connected together.

MusicXML Parser, and Music Engraving(Sec. 4)

MusicXML, being a open source widely adopted format for Western music notation, is adopted as the import format of my system. Music notations rendered in HTML5 SVG Canvas are the base of my interactive sheet music system.

Customizable Layout (Sec. 5)

Allow the users to add the information that they need to their personalized sheet music, hiding information and disabling the functionalities that they do not need.

Dynamic Guitar Fretboard Diagram (Sec. 6)

Scale fingerings, arpeggios, or single notes for different parts of the music can be visualized easily on the fretboard diagram, helping guitarists to find their way on the fretboard. The fretboard is also customizable, allowing the users to choose note colors and set the number of frets.

Automatic Music Analysis (Sec. 7)

Automatic music analysis based on classical and jazz music theory, including chord tone analysis and chord-note relationship analysis.

4 MusicXML Parser, and Music Engraving

MusicXML, which is obviously based on XML, is the most widely supported open source format for Western music notation. Therefore, MusicXML is also the choice of format used in my system. A simple MusicXML parser is written to import music into my system.

I have referenced Vexflow, a open-source online music notation rendering API, when writing my engraving system. The reason that I did not use Vexflow directly is that, Vexflow does not provide DOM elements for adding javascript listeners to the music notations, which makes interactive sheet music impossible. Vexflow is the kind of electronic sheet music that is "a PDF viewer with a playback function" that I was talking about earlier.
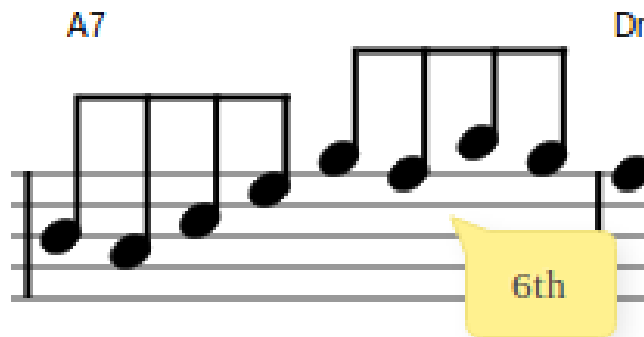

Figure 3: *A tooltip showing supplementary information when the cursor is pointing at a note.*

Music notation in my system is rendered on the HTML5 Canvas using a SVG drawing library called Raphael [7]. I have used Gonville music font [8] for all the music symbols and notations in the engraving. Quality music notation engraving in any scale is now possible with SVG. The library simplifies vector drawing in HTML5 by a whole lot. It also gives the proper handles for me to add interactivity to the system (Figure 3).

5 Customizable Layout

As discussed in the introduction section, there is no one size fits all for sheet music. Some musicians might want more supplementary information on their sheet music, while some other musicians might only want the notes on the staff lines. In a web-based framework, customizable layout of sheet music can easily be achieved using a combination of HTML5's canvas drawing, jQuery and CSS3.

The idea of customizable layout is the core idea of this paper. Lead sheet is the best example to illustrate the necessity of sheet music with customizable layout. According to Wikipedia, "A lead sheet is a form of music notation that specifies the essential elements of a popular song: the melody, lyrics and harmony...The lead sheet does not describe the chord voicings, voice leading, bass line or other aspects of the accompaniment. These are specified later by an arranger or improvised by a performer" [9]

A professional musician can improvise different parts on the fly. However, it is difficult for beginning musicians to come up with notes to play on the fly. Therefore, they will need aids on the sheet music. A perfect example for this is chord diagram. There are zillions of ways to play a chord on the guitar. Professional guitarist can of course make the right choice, playing the right chord at the right time. Yet, it will be hard for beginning guitarist to do so. Chord diagram can help the beginning musicians to play the chord. For this purpose, we can let the users decide if they want chord diagrams on the sheet music or not.
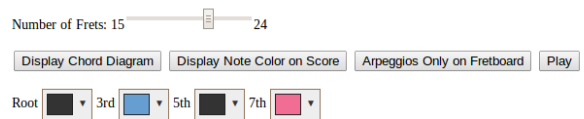

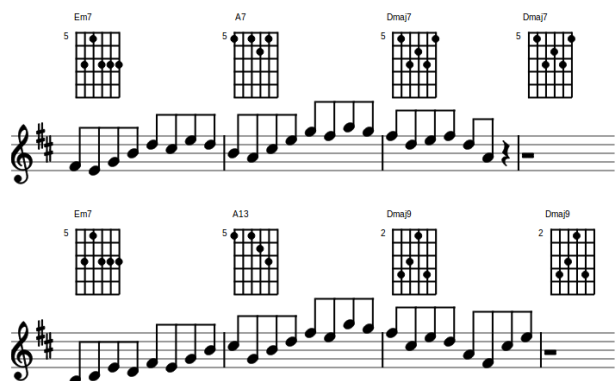**Figure 4:** *Toggles and controls of my system.*

Figure 5: *Sheet music with guitar chord symbols.*

[7] http://raphaeljs.com/

[8] http://www.chiark.greenend.org.uk/ sgtatham/gonville/

[9] http://en.wikipedia.org/wiki/Lead_sheet

Figure 6: *Sheet music without guitar chord symbols.*

6 Dynamic Guitar Fretboard Diagram

Unlike piano where the notes are laid out in a linear fashion from left to right, from the lowest note to the highest note, guitar's note layout is not linear. Most of the pitch can be played on more than one strings of the guitar. To professional guitarist this aspect of guitar is what they can exploit. However, it confuses beginner. They might have a hard time finding the notes they need on the fretboard. Moreover, they can have a hard time relating the notes on the staff lines to the different positions of the fretboard. This often prevents guitarists from learning how to read music. The dynamic fretboard diagram is designed to help this program.

First of all, the appearance of this fretboard diagram is inspired by the Vex Fretboard [Cheppudira]. In my system, the ratio of distance between frets on the diagram is identical to the ratio on real guitars.

$$s = \frac{w}{1 - 2^{-\frac{n}{12}}} \tag{1}$$

$$d = s \cdot \left(1 - 2^{-\frac{n}{12}}\right) \tag{2}$$

The above formulas are from [Mottola], where w is the width of the fretboard to be drawn, d is the distance from nut, s is the scale length and n is the fret number. This is the actual formula used in guitar making. However, this ratio makes notes on the higher frets hard to see. I do not have a solution for this at the moment.
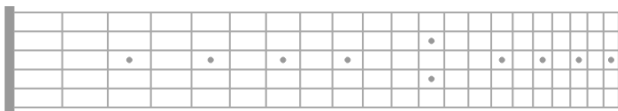

Figure 7: *Fretboard of a 21 fret electric guitar.*

Figure 8: *A 21 fret fretboard diagram.*

For those who are not not familiar to guitar, guitars are built with different number of frets. Acoustic guitar usually has 15 or 17 frets, while electric guitar usually has 21 (Figure 7), 22 or 24 (Figure 9) frets. Printed or static fingerboard diagram are fixed with one number of frets. However, there is no such limitation in a dynamic fretboard diagram at all. My system allows the users to change the number of frets on the fretboard diagram in runtime, allowing customization as promised.

The dynamic fretboard diagram is designed to help this problem. It has three main features.

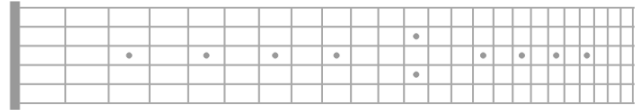**Figure 9:** *Fretboard of a 24 fret electric guitar.*
Image from http://www.flickr.com/photos/filippovancini/5738978047/

Figure 10: *A 24 fret fretboard diagram.*
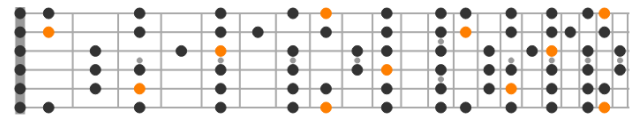
6.1 Visualizing Scales and Arpeggios

Figure 11: *C major scale drawn on the fretboard. Root (C) colored in orange.*

All possible positions of a scale on the fretboard will be displayed when either a key signature or a chord symbol is being clicked. In addition, users are able to toggle between visualizing the underlying scale (Figure 11) or the arpeggio (Figure 12) of the chord when a chord symbol is clicked.

6.2 Visualizing Single Notes

Different positions for a single note will be visualized on the fretboard diagram when a single note is being clicked on the score (Figure 13). The guitarist can then decide which is the best place for the note on the fretboard according to the diagram.

6.3 Sound

Corresponding pitch will be generated when the user clicks on the fretboard. The fretboard diagram uses MIDI.js[10], a javascript MIDI libary, for sound generation. User can play through a scale or an arpeggio on the fretboard with his or her mouse.

7 Automatic Music Analysis

There are many types of music analysis that are possible for my system. Chord tone analysis is implemented to evaluate if adding music analysis to a electronic sheet music is practical at all.

7.1 Chord Tone Analysis

Chord tones, the 3rd note and the 7th note of the underlying chord, are oftentimes regarded as the building block of jazz's melody in improvisation. The underlying harmony can be implied by the proper use of chord tones. Jazz teachers oftentimes ask their students to hit the two chord tones in every bar to "play through the changes".
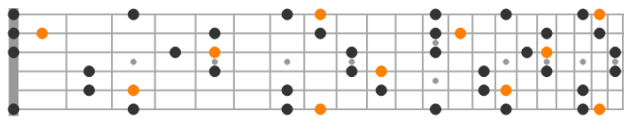
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[10]http://mudcu.be/midi-js/

Figure 12: *C major-seventh arpeggio drawn on the fretboard. Root (C) colored in orange.*
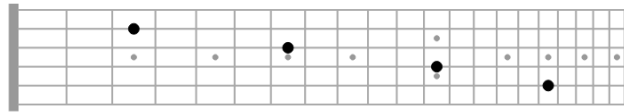

Figure 13: *Note D5 on different places on the guitar neck.*

In our system, the users can specify the note colors of the 3rd and 7th. With the colors, users can see how the chord tones are conntected to each other on the staff lines. They can also see how the chord tones are laid out on the fretboard (Figure 14).

8   Results

This system is still in its development stage. It is too early to say whether this system is successful. However, the system prototype enjoyed many positive feedbacks from my fellow classmates at the poster session for this Visualization class at Berkeley.

9   Conclusion and Future Work

I have successfully created an interactive sheet music system using HTML5, jQuery and CSS3. Although each individual elements of my project had been around for many many years, I believe this is the first time where all these elements are being put together nicely in a web browser with interactivity. There are infinite amount of information that can bee added to the sheet music, as long as the user can choose what kind of information he or she wants. It is possible to make this interactive sheet music a self-contained music learning system, with the "information" being either human generated or computer generated teaching resources.

On one hand, I have to meet the 8 pages requirement on this writeup. On the other hand, I do not want to disclose my ideas because I am seeing commercial values of them. Yet for the sake on meeting the 8 pages requirement, I have no choice but to put them here.

A Robust MusicXML Parser and Music Engraver

The MusicXML parser and music engraver in the current code only supports a small subset of music notations and symbols. Also, the music engraver is only based on my knowledge of how sheet music should look like. And I did not have adequate time to work on music engraving because I put my focus on the interactivity of my system. Therefore, the quality of the rendered music is heavily compromised. In the future, I would like to apply the knowledge in music engraving literature, like [Gould 2011] and [Gerou and Lusk 1996] for example, for quality rendering of music, to get professional engraving results like Figure 15.

Annotation System

Annotation is an essential tool to all musicians of all levels.
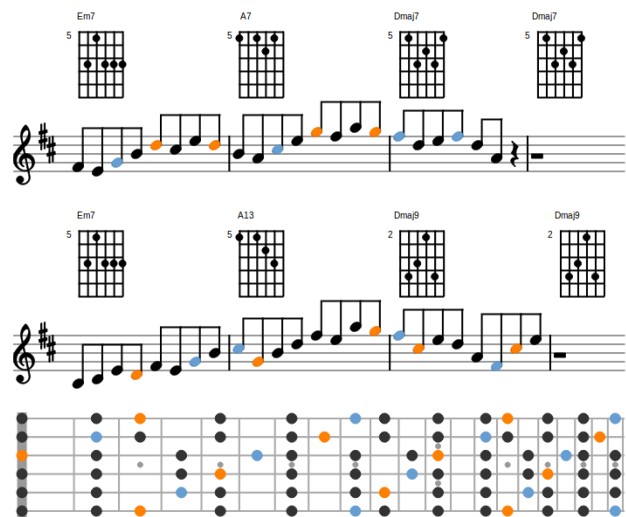

Figure 14: *Chord tones (3rd and 7th) are colored as blue and orange respectively. The fretboard is showing the A dominant scale, with the chord tones also labeled.*

Beginners may need to denote fingerings or chord choices. Working musicians may need to write down different arrangements, or solo order for a tune.

I would like to create an annotation system with the following features.

Adding comments using textbox

Textbox is one of the most basic annotation tool. My system should of course include it.

Adding annotations to a group of notes, bars and systems

The system should allow users to choose a group of notes, bars or systems using a rectangular drag box, attaching annotations to the notes.

A better Fretboard Diagram for Guitar

The fretboard diagram now shows notes all over the neck. However, it's confusing because guitarist's hand can only stay in a position for a time. It would be helpful to show only fingerings for one position at a time (Figure 16). However, there are currently no algorithms for finding positions for scales correctly. Therefore, it requires creating also a scale / arpeggio positions database.

Chord Progression Analysis

Simple chord progression analysis can be enabled by displaying the chords using the Nashville number system, which basically assigns a unique number, from 1 to 7, to the different chords in a scale (Figure 17).

Tips on Harmonization

Figure 15: *Professional music engraving.*
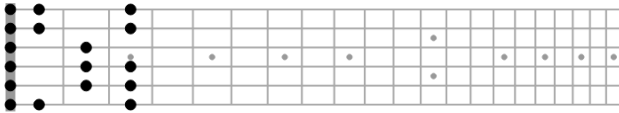*Image from Wikipedia Music Engraving page.*

Figure 16: *C major scale in open position.*

Lead sheet does not indicate chord voicings for the chords and notes. However, some kind harmonization of is a must for chordal instruments to play solo, without accompaniment of other instruments. It would be very helpful if the system can suggest chord voicings for harmonization for the melody line when the user desires so.

This requires the system to have a chord database. When the user points at a note, the system should find all chords which fit the underlying harmony of the music, and also the note being pointed at is at the top of the chord. The system should be able to save the choices of voicings.

Auto harmonization of the whole song is also possible with the database, However, in my opinion the system should only provide tips to the musician. The musician should be the one making musical choices, choosing the chord voicings and harmonization that sounds good.

More Instrument Specific Supplementary Information

The system now contains instrument specific supplementary information for guitar only. I would like to add instrument specific information for other instruments as well, such as chord diagram (Figure 18) for piano or automatically generated tablature for harmonica. Since my knowledge is only limited to guitar, I would have to consult musicians of other instruments.

Online Collaboration

Unlike the current system where the supplementary information is precoded, users will be able to add their own infor-

C	Dm	Em	F	G	Am	Bdim
I	ii	iii	IV	V	vi	vii°

Figure 17: *Chords and their corresponding numbers in the Nashville numbering system in the key of C major.*
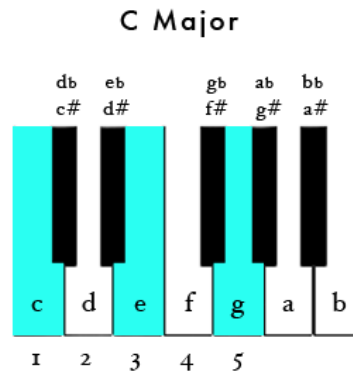

Figure 18: *Chord fingering for the C major chord on the piano.*
Image from http://en.wikibooks.org/wiki/Piano/Chords_(and_pop_examples).

mation to the system by using the annotation system and the harmonization system in the future. It is also possible to add a comment system similar to CommentSpace ([[Willett et al. 2011]]), allowing different users to comment on other users' added information to the score.

Figure 19: *Online Guitar Lesson through Skype^{TM}*
Image from Harcum Music School's website.

Online music lesson through video conference software like Skype^{TM} is becoming a popular trend. In traditional music lesson, music teachers oftentimes add marks and annotations using pen or pencil to their student's sheet music, highlighting key points in the music. Yet, this is not possible at the moment for online music lesson because the student and the teacher are not physically at the same place. A online collaboration system will be able to solve this problem. The teacher can add annotations and remarks to his or her student's sheet music directly through internet. With the online collaboration system of my sheet music system, online music lesson will become more effective.

User Study

This system is built based on my personal experience in mu-

sic, jazz and guitar. A user study is necessary to know if the features in my ststem is helpful to other musicians.

Anyways, I hope my work can become a catalyst for revolutionizing sheet music. And most importantly, with electronic sheet music we do not need to cut down trees anymore. Thanks very much for reading.

Acknowledgements

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