WebHexIso: A Customizable Web-based Hexagonal Isomorphic Musical Keyboard Interface

Hanlin Hu
University of Regina
hu263@cs.uregina.ca

David Gerhard
University of Regina
gerhard@cs.uregina.ca

ABSTRACT

The research of musical isomorphism has been around for hundreds of years. Based on the concept of musical isomorphism, designers have created many isomorphic keyboard-based instruments. However, there are two major concerns: first, most instruments afford only a single pattern per interface. Second, because note actuators on isomorphic instruments tend to be small, the hand of the player can block the eye-sight when performing. To overcome these two limitations and to fill up the vacancy of web-based isomorphic interface, in this paper, a novel customizable hexagonal isomorphic musical keyboard interface is introduced. The creation of this interface allows isomorphic layouts to be explored without the need to download software or purchase a controller. additionally, MIDI devices may be connected to the web keyboard to display the isomorphic mapping of note being played on a MIDI device, or to produce control signals for a MIDI synthesizer.

1. INTRODUCTION

Since Euler introduced *Tonnetz* in 1739 [1], mathematician, composers, computer scientists and instrument designers are interested in musical isomorphism, which presents algorithms of arrangement of musical notes in 2-dimensional space so that musical constructs (such as intervals, chords and melodies, etc.) can be played with same fingering shape regardless the beginning note [2].

Based on this concept of musical isomorphism, there have been a number of keyboard-based interfaces (instruments) being built over the last hundred years. At the beginning, the keys on the keyboard were designed in the shape of a rectangle resembling that of the traditional keyboard. This is called "square" or "rectilinear" isomorphism. Since the limitations of the square isomorphism (*e.g.* the degenerating of layouts, which is passing by some notes in a equal temperament with particular layouts [2]), interface designers prefer hexagonal shaped keys on the keyboard over the last decade. They can be categorized to hardware and software. As for hardware, there are the AXiS keyboards, Opal, Manta, Tummer and Rainboard [3]; As for software, there are Hex Play (PC) [4], Musix Pro (iOS) [3], Hex OSC Full (iOS) [5] and Hexiano (Android) [6] .

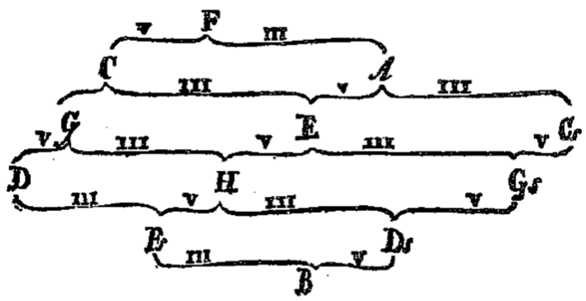


Figure 1: Euler's Tonnetz

In addition to the limitation of square isomorphism, there are two main constraints of isomorphic keyboard design: firstly, most of the interfaces can provide only one particular isomorphic layout, which means the layout is not changeable or in the other word, the device is not customizable, therefore the performers or composers are "locked in" to a single layout. Although learning a single layout may be desirable in some circumstances, one of the main advantages of isomorphic keyboard design is the fact that many different layouts with different harmonic relationships are available in the same framework. For this reason, we think that the limitation of a single isomorphic layout on most hardware instruments is a significant disadvantage which should be addressed.

Secondly, when performers or composers play on the physical appearance of an isomorphic keyboard, their hands can easily block the display so that the name or colour of keys is not easy to see. For traditional single-layout instruments, this is not an issue because performers memorize and internalize key-actuator positioning, but for reconfigurable digital instruments, where colour may be the only indication of the function or note of an actuator, the problem of actuator occlusion may be considered significant. One possible solution would be to separate the display of the reconfigurable keyboard from the actuators. Although this separation may be considered a step back in terms of usability and control/display integration, it may serve to facilitate exploration of this new class of reconfigurable interfaces. Further, although it is possible to plug a MIDI device into an iPad and play isomorphic software such as Musix Pro, practically speaking, because many MIDI devices draw power over the USB port, it is sometimes impractical or impossible to connect a MIDI device to an iPad or other external display.

In this paper, we present a novel web-based hexagonal isomorphic musical keyboard interface, which is customizable, scalable, and MIDI enabled. It can be used as a software instrument, a composition device, an educational tool of musical isomorphism, and an assistive screen interface for performance.

2. MUSICAL ISOMORPHISMS

The word "isomorphism" has the prefix "iso," which means "equal," and an affix term "morph," which means "shape." Isomorphism, then, refers to the property of having an identical shape or form. The concept of isomorphism applied to music notations is that for an isomorphic arrangement of notes, any musical construct (such as an interval, chord, or melody) has the same shape regardless of the root pitch of the construct. The pattern of constructs should be consistent in the relationship of its representation, both in position and tuning. Corresponding to transposition invariance, *tuning invariance* [1] is another requirement of musical isomorphism. Most modern musical instruments (like the piano and guitar) are *not* isomorphic. The guitar in standard tuning uses Perfect Fourth intervals between strings, except for the B string which is a Major Third from the G string below it. Because of this different interval for one pair of strings, the guitar is not isomorphic.

Isomorphic instruments are musical hardware which can play the same musical patterns regardless of the starting pitch. Isomorphic arrangements of musical notes introduce a number of benefits to performers [7]. The most notable of these is that fingerings are identical in all musical keys, making learning and performing easier. Modern instruments which display isomorphism include stringed instruments such as violin, viola, cello, and string bass [3]. It should be noted in this case that although the relative position of intervals is the same for every note on the fingerboard of a violin, the relative size of each note zone may change, with the notes being smaller as you move closer to the bridge of the instrument. The traditional piano keyboard is not isomorphic since it includes seven major notes and five minor notes as a 7-5 pattern.

Thanks to this 7-5 pattern design, performers can easily distinguish in-scale and out-of-scale notes by binary colours, but the performer must remember which white notes and which black notes are in the scale in which they are performing. Because the piano is not isomorphic, different fingerings and patterns are required when performers play intervals and chords in different keys. This is one of the reasons that the piano is difficult to learn: each musical construct (*e.g.* the Major scale) must be learned separately for each key (*e.g.* C Major, G Major, F Major *etc.*)

The first physical appearance of an isomorphic layout was decided by Hungarian pianist Paul von Jankó in 1882 [8]. The *Jankó keyboard* shown in Fig. 2 was originally designed for pianists who have small hands that can cause fingering difficulties when stretching to reach the ninth interval, or even the octave, on a traditional keyboard. By setting every second key into the upper row and shaping all keys identically, the size of the keyboard in the horizontal direction shrinks by about half within one octave. After making three duplicates, the performer can play intervals or chords by putting the fingers up or down to reach

[1] Tuning invariance: where all constructs must have identical geometric shape of the continuum

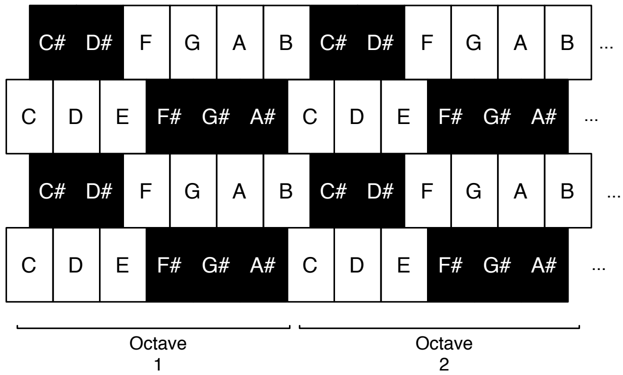


Figure 2: Jankó Keyboard tessellation

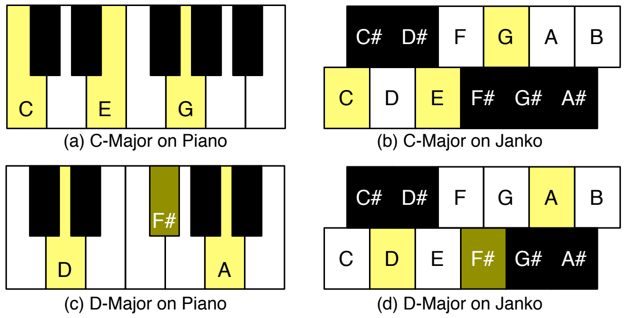


Figure 3: Isomorphism in the Jankó keyboard as compared to polymorphism in the piano keyboard.

the desired notes. Each vertical column of keys to the adjacent column are a semitone away, and the horizontal row of keys to the adjacent row is a whole step away. This design never became popular since performers are not convinced of the benefits of this keyboard and they would instead have to spend more time learning a new system [9].

This arrangement of notes on the Jankó keyboard is isomorphic because a musical construct has the same shape regardless of key. Consider a Major triad (Fig. 3). the C-Major triad has the notes C-E-G, while the D-Major triad has the notes D-F♯-A. On the piano keyboard, these triads have different shapes, but on the Janko keyboard (and on any isomorphic keyboard) these triads have the same shape. In fact, every major triad has the same shape on an isomorphic keyboard.

There are three reasons why hexagonal shaped keys are better than rectangular shaped keys:

1. The rectangular shaped keys of an isomorphic keyboard does not meet the requirement of transposition invariance perfectly, because the Euclidean distance between two keys is not identical. For example, in Fig. 2, the distance between C and D in horizontal direction does not equal the distance between C♯ and D in vertical direction. However, the regular hexagonal shaped keys make the distances identical.

2. It is easy to find three adjacent keys to close into a triangle on Jankó layout, such as C-D-C♯. This relationship has been modelled with equilateral triangle by Riemann as triangular Tonnetz in Fig. 4, which is explored from Tonnetz [11]. Since the regular hexagon is the dual of the equilateral triangle, for each key, the hexagonal shape is good to present this relationship.

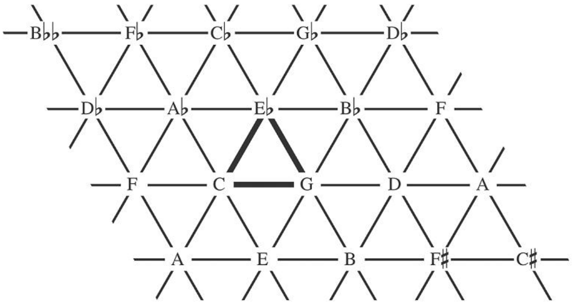


Figure 4: Tonnetz as regularized and extended by Riemann and others [10]

3. Each hexagon has six adjacent hexagons, while each square only has four adjacent squares. More adjacent notes means more harmonic connects and a more compact note arrangement for the same number of notes.

3. WEBHEXISO

WebHexIso is a novel customizable web-based musical isomorphic interface. There are few existing web-based musical isomorphic interface available online such as "CanvasKeyboard" [12]. However, the "CanvasBoard" is uncustomizable interface with a particular layout — Wicki-Hayden [13].

3.1 Basic Design

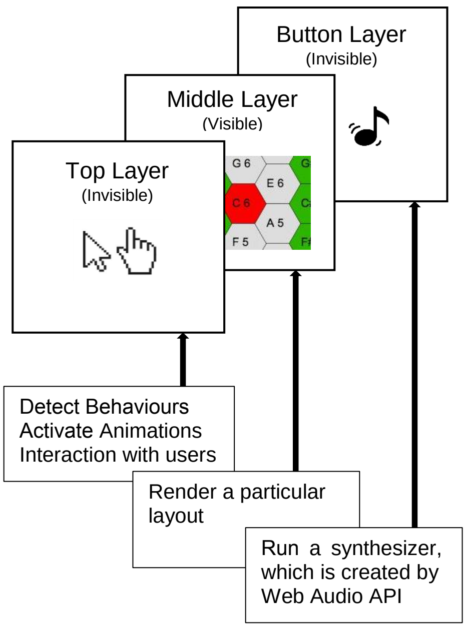
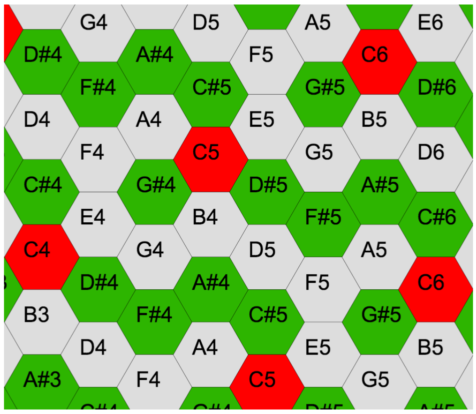


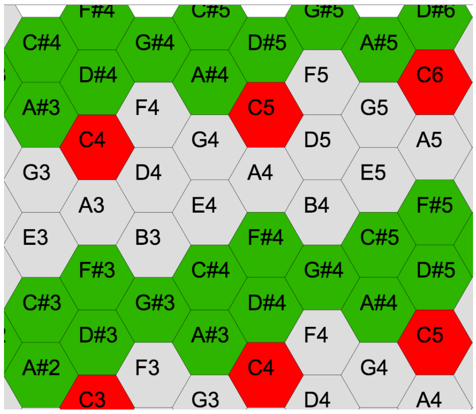
Figure 5: Over-layer design

The basic design of the interface is based on over-layer strategy. There are three layers as shown in Fig. 5: The button layer, which is invisible to users, is used for running a synthesizer on the background. The synthesizer is created by Web Audio API [14], which is able to produce many different musical instrument sounds. The middle layer, which is visible to users, is used for rendering a particular isomorphic layout chosen by users. The top layer, which is invisible to users, is used for bundle listeners to detect users' behaviours (navigation, click and touch). Once listeners detect a click or touch behaviour, animation of the clicked tile will be activated and synthesizer will to called to sound a note.

3.2 Features



(a) Gerhard Layout



(b) Park Layout

Figure 6: Isomorphic layouts rendered in the middle layer of WebHexIso. Root note (C) is red, and notes that would normally be black on a piano are marked in green.

The interface provides options for selecting typical layouts (Harmonic table, Wicki-Hayden, Jankó, etc.), and additionally, users can define their own custom layouts by choosing the musical interval in horizontal and vertical directions.

Users can also switch the direction of the layouts horizontally (the Zigzag direction of hexagonal grid [15] faces north) or vertically (the Armchair direction of hexagonal grid [15] faces north). Users can choose any note for the tonic, and can choose to colour notes based on any scale, key, or mode. The colour of layouts, the size of the keys and the type of synthesizers are manageable.

3.3 Scalable Multi-touch API and Web MIDI API

Beyond the basic design, by using Multi-touch API with touch events functions to control the multi-touch behaviour, the interface provides an opportunity to be used as a mobile application. The WebHexIso and other existing mobile apps such as Musix Pro have similar functionality, when the web-based interface is opened in a modern browser.

Furthermore, the Web MIDI API [16] allows MIDI musical controllers transfer data by USB. Once a musical controller plugged-in while the WebHexIso is open, the WebHexIso will detect and identify the controller and receive MIDI notes data from the controller. Fig. 7 shows when WebHexIso detects the AXiS-49 is plugged-in, the corresponding layout is shown on the screen. Moreover, the Web MIDI API also allows data transfer from WebHexIso to MIDI devices, which allows WebHexIso activates plugged-in slave MIDI device and either play notes on a synthesizer, or send note event and layout patterns to it.

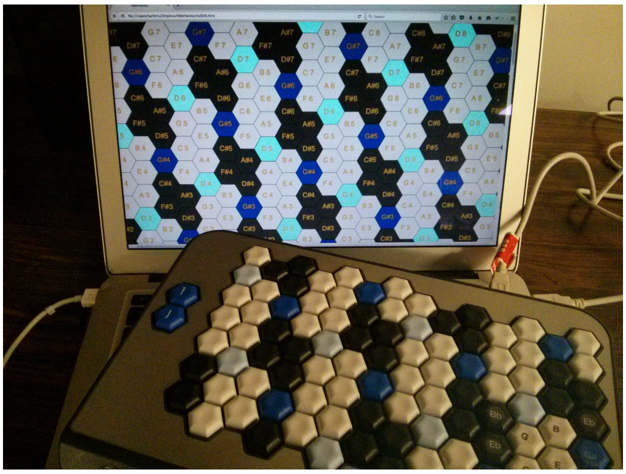


Figure 7: The interface shows harmonic table layout on the screen when AXiS-49 is plugged-in

3.4 Limitation

Depending on the browser and computer being used, WebHexIso may have increased latency. On a modern browser and recent computer, the latency should not be noticeable, but on slower systems, if WebHexIso performs slowly to the point that a noticeable lag is present between the activation of a key and the sounding of a note, it would be possible to disable some features (like multitouch) to increase performance at the cost of functionality.

4. CONCLUSION AND FUTURE WORK

A novel customizable web-based hexagonal isomorphic musical keyboard interface has been introduced. Users can define or select different isomorphic keyboard by themselves. This interface is online and free so that more people could have the chance to access the isomorphic keyboards. By using multi-touch API, the web-based interface can implement behaviours as a mobile application. It also could be used as an assisting screen of isomorphic layouts for performance when a MIDI controller device, such as AXiS-49, is plugged-in.

In future, more MIDI devices will be recognized by WebHexIso when their MIDI names are built into the database. Furthermore, a user-interface study of can be conducted. Based on this system, the composers can find more isomorphic layout patterns, which will benefit performance.

5. REFERENCES

[1] L. Euler, “De Harmoniae Veris Principiis per Speculum Musicum Repraesentatis,” in *Novi commentarii academiae scientiarum Petropolitanae*, St. Petersburg, 1774, pp. 330 – 353.

[2] B. Park and D. Gerhard, “Discrete Isomorphic Completeness and a Unified Isomorphic Layout Format,” in *Proceedings of the Sound and Music Computing Conference*, Stockholm, Sweden, 2013.

[3] ——, “Rainboard and Musix: Building Dynamic Isomorphic Interfaces,” in *Proceedings of 13th International Conference on New Interfaces for Musical Expression*, 05 2013.

[4] A. Milne, A. Xambó, R. Laney, D. Sharp, A. Prechtl, and S. Holland, “Hex Player — a virtual musical controller,” in *Proceedings of the 11th International Conference on New Interfaces for Musical Expression(NIME)*, Oslo, Norway, 2011, pp. 244 – 247.

[5] SkyLight and Denryoku, “Hex OSC Full,” http://www.sky-light.jp/hex/, Online.

[6] D. Randolph, J. Haigh, and S. Larroque, “Hexiano,” https://github.com/lrq3000/hexiano/, Online.

[7] V. Goudard, H. Genevois, and L. Feugere, “On the Playing of Monodic Pitch in Digital Music Instruments,” in *Proceedings of the 40th International Computer Music Conference (ICMC) joint with the 11th Sound and Music Computing conference (SMC)*, Athens, Sep 2014, p. 1418.

[8] P. von Jankó, “Neuerung an der unter No 25282 patentirten Kalviatur,” German patent 25282-1885.

[9] K. Naragon, “The Jankó Keyboard,” *typescript*, pp. 140–142, 1977.

[10] D. Tymoczko, “Geometrical Methods in Recent Music Theory,” *MTO: a Journal of the Society for Music Theory*, vol. 1, 2010.

[11] H. Riemann, “Ideen zu einer “Lehre von den Tonvorstellungen”,” in *Jahrbuch der Bibliothek Peters*, 1914 – 1915, pp. 21 – 22.

[12] S. Little, “CanvasBoard,” https://github.com/uber5001/CanvasKeyboard, online. Accessed on 8-Jan-2016.

[13] K. Wicki, “Tastatur für Musikinstrumente,” Swiss patent 13329-1896.

[14] W3C, “Web Audio API,” https://www.w3.org/TR/webaudio/, Online. Draft 8-Dec-2015.

[15] H. Hu, B. Park, and D. Gerhard, “On the Musical Opportunities of Cylindrical Hexagonal Lattices: Mapping Flat Isomorphisms Onto Nanotube Structure,” in *Proceedings of the 41th. International Computer Music Conference*, Denton, Texas, 2015, pp. 388–391.

[16] W3C, “Web MIDI API,” https://www.w3.org/TR/webmidi/, Online. Draft 17-March-2015.