A Function-Oriented Interface for Music Education and Musical Expressions: “the Sound Wheel”

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ABSTRACT

In this paper, a function-oriented musical interface, named “the sound wheel”, is presented. This interface is designed to manipulate musical functions like pitch class sets, tonal centers and scale degrees, rather than the “musical surface”, i.e. the individual notes with concrete note heights. The sound wheel has an interface summarizing harmony theory, and the playing actions have explicit correspondence with musical functions. Easy usability is realized by semi-automatizing the conversion process from musical functions into the musical surface. Thus, the player can use this interface with concentration on the harmonic structure, without having his attention caught by manipulating the musical surface. Subjective evaluation indicated the effectiveness of this interface as a tool helpful for understanding the music theory. Because of such features, this interface can be used for education and interactive training of tonal music theory.

Keywords

Music education, Interactive tonal music generation

1. INTRODUCTION

In general, to master an instrument is not easy. It is thought that elaborate practice in the early childhood is important to get the ability for expert performance[1]. If the player is not so well experienced with his instrument, writing music with the instrument is also a tough work, since the player will be busy with thinking how to move his fingers, before thinking about the theoretical structure of the composition. Especially, improvisation of music, where the ability of playing and understanding of music theory is required simultaneously, is even more difficult. Such difficulties of playing instruments are obstacles for people who just want to compose music, or for people who are trying to study music theory without enough experience with an instrument.

In this paper, a function-oriented musical interface, which does not require practice of existing instruments, is presented. This interface is an easy tool for education and studying harmony theory of tonal music.

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2. EXISTING INTERFACES

Let us think about existing musical interfaces as tools for music theory study. First, let us consider an universal polyphonic instrument widely used in music education: the piano. The interface of the piano is a keyboard, with one concrete note height attached to each of the key. A big merit of this design is the clear correspondence between the playing actions and the note heights that will be produced. However, this design could also be taken as problematic, since the music theoretical functions of the played notes are not explicit. Therefore, if the player wants to play a certain chord with a certain function at a certain moment, he has to think which notes are belonging to that chord, then he has to think which keys are corresponding to those note heights, and then he has to think which fingers to use, before pressing the keys. This process might be no problem at all for an experienced player, but it is a burden for a beginner. One reason of this essential difficulty is the fact that the musical function of a musical surface (a collection of concrete notes) depends on the harmonic situation within a musical piece. In this sense, the piano is an instrument with a “surface-oriented” interface [1]. Another problem of the interface of the piano is that it does not treat the twelve pitch classes of the equal temperament equally. The physical positions of the twelve pitch classes are not the same. This results in the different fingerings of the pitch class sets of different keys, which is another obstacle for beginners.

Electronic musical instruments could be more suited for music education purposes, because functions like sequencers are available and could be used for playback support. For example, the TENORI-ON[2] is a loop sequencer based synthesizer, which can be operated relatively easy. In this instrument, the player puts notes to a looping sequence by pushing buttons that are ordered as a matrix, to which scale degrees are attached. This interface is easy to use, because the note heights belonging to a selected scale, or key, will be automatically chosen. However, tonal modulation is difficult to perform with these kind of interface, because a function to change the key or the mode intuitively is not present. Transposing functions are often implemented in electronic instruments, but transposition (i.e. shift of the tonal center) alone cannot solve this problem, because transposition is only a specific form of tonal modulation. Generally, tonal modulation can be a simultaneous change of the tonal center and the scale.

Another example might be the MIDI Chord Helper[3], which is a software-based instrument. Its interface has a matrix of buttons, to which concrete chords are attached. Therefore, one can play a chord with a single action. However, the concept of mode and tonal modulation is still not explicit enough in this interface. The subject of input are

[1]E.g., a musical surface corresponding to a musical function “a dominant chord of C major” could be “G3, B3, D4, F4”.

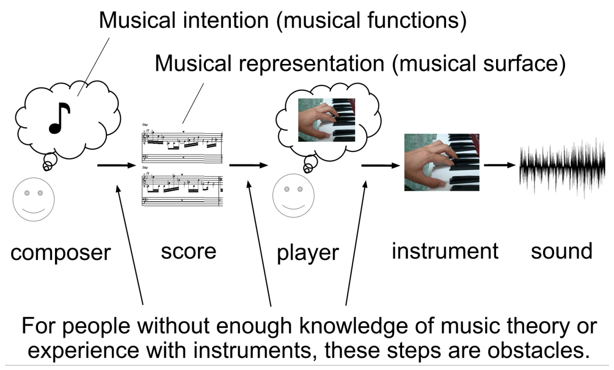

Figure 1: The flow of musical information from the composer's musical intention to sound signals. The composer converts his musical intention to a musical representation like musical scores. Then, the player interprets the information of a note sequence from the score, and converts it to playing actions of an instrument. The instrument generates the sound signals depending on the playing actions.

concrete chords, and not the key or the mode itself.

An example of the flow, how musical information is converted from musical intensions into sound signals, is shown in Fig.1. As a composer, or as a player, who wants to concentrate on the harmonic theoretical structure of his piece, the steps of converting musical functions into musical surfaces, and the steps of converting musical surfaces into playing actions of the instrument, could be obstacles, especially for beginners. Fig.1 shows the case where the composition and the rendering of sound is not performed at the same time, but in general, these two could be performed simultaneously, like as it is in improvisation of music. In that case, the conversion of musical functions into musical surfaces and the conversion of musical surfaces to playing actions have to be performed simultaneously, and the difficulty will be increased. A function-oriented musical interface, that can automatically convert musical functions into sound, will be helpful to reduce the above mentioned obstacles.

3. THE SOUND WHEEL

3.1 The concept of the Sound Wheel

The sound wheel is characterized by the following features:

1. The subjects to manipulate are the musical functions like pitch class sets, tonal centers and scale degrees, rather than the musical surface.
2. By employing a COF (circle of fifth[4])-type wheel shaped controller for the mode input, the correspondence with the harmony theory is visually evident. Since the COF treats all twelve pitch classes equally, modulation of the key can be performed easily.
3. The playing actions have simple correspondence with the harmony theory. Chord progression within the same key is performed by touching (or clicking) the wheel, and modulation is performed by rotation of the wheel.
4. It has an easy usability, realized by semi-automatizing the conversion process from musical functions into the musical surface.

Because of the above features, one can play this interface with concentration on the harmonic structure, without having one's attention caught by manipulating the musical surface. The sound wheel is implemented as a computer program using a touchscreen display. A picture of a playing scene of the sound wheel is shown in Fig.2.

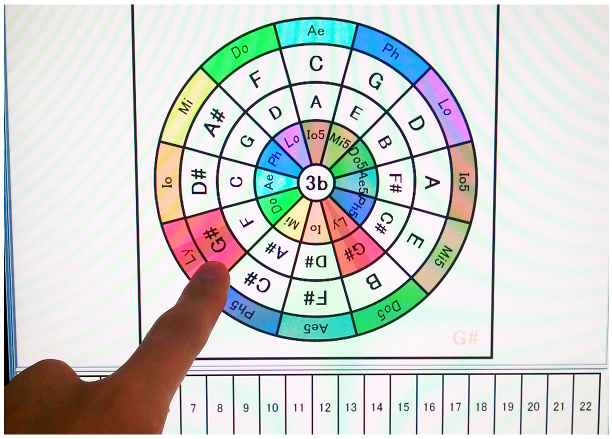

Figure 2: A playing scene of the sound wheel. The player touches the wheel and the keyboard on the display.

Most of the existing musical interfaces are surface-oriented interfaces, where the subject to manipulate is the concrete note height. The sound wheel takes the musical functions like pitch class sets, tonal centers and scale degrees as the subject to manipulate. A pitch class set is a collection of note heights that are used during a musical sequence, and a scale degree is a number that indicates a certain note height within a pitch class set. The pitch class sets employed in the sound wheel are "modes"[5], which are combinations of a tonic and a scale. A mode is a natural extension of the concept of key. The key has only two classes of scales: major and minor, but modes are not limited to these two scales. A tonic is a concrete note height (not distinguished with the "tonal center" in this paper), from which the scale starts, and a scale is an ordered set of concrete note heights within one octave. The domain of definition of scale degrees can be extended to all integers including negative values, so that it can indicate all concrete note heights belonging to a pitch class set. Thus, a concrete note height can be written as a function of a certain mode and a scale degree.

$$c = f(d, m_{t,s}) \tag{1}$$

where c is a concrete note height, d the scale degree, and $m_{t,s}$ a mode with t and scale s. By choosing an appropriate set of modes, all pitches of the equal temperament will be an element of the sumset of the range of the function shown in equation 1.

One notes that the scale degree itself does not indicate any concrete note height. It indicates a concrete note height, only when a mode is determined together with it. The sound wheel acts as a converter from an abstract note, with only a scale degree defined, to a concrete note, taking the mode as the parameter.

3.2 Basic scales employed in the Sound Wheel

Seven heptatonic scales and five pentatonics are chosen as preset scales of the sound wheel. If one tries to divide the twelve pitches within one octave into seven steps as equally as possible, one gets seven heptatonic scales which are inversions to each other. I will call these scales Gregorian scales (taken from the well known Gregorian modes[5]). On the other hand, if one tries to divide the twelve notes within one octave into five steps as equally as possible, one gets five pentatonic scales which are inversions to each other. These seven Gregorian scales together with the five pentatonic scales are basic scales that cover a wide range of traditional, classical and contemporary music. The seven Gregorian scales are named like the following: Lydian, Io-

Table 1: The concrete intervals in seminotes for each basic scale employed in the sound wheel.

scale degree	1	2	3	4	5	6	7
Ly	0	2	4	6	7	9	11
Io	0	2	4	5	7	9	11
Mi	0	2	4	5	7	9	10
Do	0	2	3	5	7	9	10
Ae	0	2	3	5	7	8	10
Ph	0	1	3	5	7	8	10
Lo	0	1	3	5	6	8	10
Io5	0	2	4	7	9	12	14
Mi5	0	2	5	7	9	12	14
Do5	0	2	5	7	10	12	14
Ae5	0	3	5	7	10	12	15
Ph5	0	3	5	8	10	12	15

nian, Mixolydian, Dorian, Aeorian, Phrygian, and Locrian (shortened as *Ly*, *Io*, *Mi*, *Do*, *Ae*, *Ph*, and *Lo* in the sound wheel) . The scale *Io* is also known as the major scale, and *Ae* is also known as the natural minor scale. Since the five pentatonic scales can be seen as subsets of Gregorian scales, these scales are notated as *Io*5, *Mi*5, *Do*5, *Ae*5, and *Ph*5 in the sound wheel. The scale *Io*5 is also known as the major pentatonic scale, and *Ae*5 is also known as the minor pentatonic scale. There are many variations of the above mentioned scales like the harmonic minor scale or the blue note scale. The reason for choosing the above "basic" seven Gregorian scales and the five pentatonic scales will be described later. The concrete intervals of the above twelve basic scales are listed in Table.1.

Now, note that the number of pitches within one octave: 12, the number of basic Gregorian scales: 7, and the number of basic pentatonic scales: 5, has the following relation:

$$12 = 7 + 5 \tag{2}$$

3.3 Interfaces of the Sound Wheel

The characteristic mode controlling interface of the sound wheel is shown in Fig.3. It consists of two coaxial independently rotatable wheels. The colored and uncolored wheels are the "scale wheel" and the "tonic wheel", respectively. Both wheels are divided into twelve sections. The twelve pitch classes of the equal temperament are attached to each section of the tonic wheel, so that the neighbouring pitch classes are five degrees, i.e. seven seminotes apart. This configuration is well known as the "circle of fifth", and it is widely used to understand the relation between keys.

Now let us think, how to arrange the seven basic Gregorian scales to the scale wheel around the tonics. One can put the seven basic Gregorian scales to the scale wheel, so that the seven modes, made from the facing tonics and Gregorian scales [2], are generating the same pitch class set, i.e. they are belonging to the same key. The reason of choosing the basic scales as the preset scales of the sound wheel, that are inversions to each other, was to make this possible. In the arrangement of Fig.3, the scales are put in the order so that similar scales are close to each other. In addition, the major-type and minor-type scales are colored with warm and cold colors, respectively. Therefore, it is easy to recognize the harmonic function visually. In the same way, the five basic pentatonics can be arranged around the tonic wheel, so that the five modes, made from the facing tonics and pentatonic scales [3], are generating the same pitch class set. Note that the relation of Eq.2 makes it possible to arrange the seven Gregorian scales and five pentatonic scales just fitting into the twelve sections of the scale wheel.

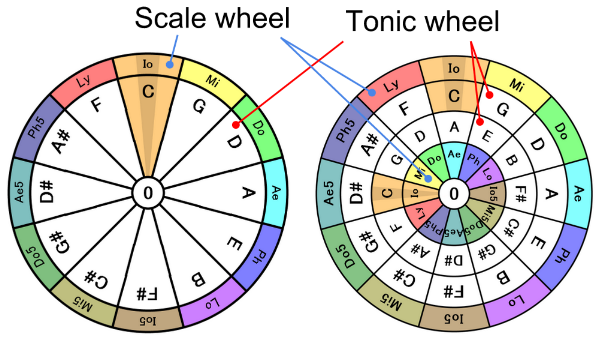

Figure 3: Two types of the mode input interface of the sound wheel. It is composed of the scale wheel which is painted with different colors, and the uncolored tonic wheel. The right one is a variation, in which two scale wheels and two tonic wheels are provided, in order to have a better prospect over modes belonging to the same key. In this figure, (C,Io) is selected as the active mode.

A variation of the design is showed in the right side of Fig.3, in which two coaxially aligned wheels are added to the previous two wheels, so that the relative keys[5] are sitting close together, i.e. so that *Io* is facing *Ae*. The angle between the outer and the inner scale wheel, as well as the angle between the outer and the inner tonic wheel, is fixed to 90 degrees. This realizes a configuration, where the seven (or five) modes generating the same pitch class set are sitting close together, improving the prospect over the modes with the same key.

An important feature of the sound wheel is the fact that, rotation of one wheel relative to the facing wheel, corresponds to tonal modulation. Rotation of the scale wheel relative to the tonic wheel results in the change of the combination of the scales and its facing tonics. In other words, the pitch class set of the resulting collection of modes is changed. This means nothing but tonal modulation. Especially, rotation of one unit (30 degrees) corresponds to modulation to dominant or subdominant keys. Thus, the more the wheel is rotated, the farther the key is modulated. This simple correspondence between tonal modulation and rotation of the wheels will help intuitive comprehension of the concept of tonal modulation.

By touching (or clicking) one of the fan-shaped sections of the wheels, the pair of the tonic and the facing scale at that position will be selected as the active mode. Simultaneously, a chord, whose notes are a subset of the pitch class set of the active mode, will be selected as the active chord. By preset, this chord will be the tonic triad of the active mode, i.e. the chord consisting of scale degrees one, three, and five on the active mode scale. The octave degree of freedom of the tonic note height is controlled by the touching position. By touching the left half of the fan-shaped section, the tonic note height on the lower direction will be chosen, and by touching the right half, the opposite one. Thus, chord progression within a same key can be performed by simply touching the sections of the wheels.

As supplemental functions, the sound wheel has a chord arpeggiator, a sequencer, a semi-automatic melody sequence generator based on a probabilistic generation model[6], a virtual keyboard with scale degrees attached to each key, and a MIDI signal processor for signals from external MIDI

[2] In the case of Fig.3, those modes are: (F,Ly), (C,Io), (G,Mi), (D,Do), (A,Ae), (E,Ph), (B,Lo).

[3] In the case of Fig.3, those modes are: (F♯,Io5), (C♯,Mi5), (G♯,Do5), (D♯,Ae5), (A♯,Ph5).

devices, like keyboards. Individual notes can be played using the virtual keyboard or external MIDI keyboards. The sequence generator generates sequences using notes within the pitch class set of the active mode together with the information of the active chord, and this will help the player to perceive the mode and its tonal center during playing. Using these supplemental functions, one can play simple pieces just by touching and rotating the wheels.

4. EVALUATION

The sound wheel was evaluated via a questionnaire. First, eight adult subjects with experience of playing conventional instruments at least two years were asked to evaluate the instrument that they are most used to play, by judging a score in five steps: 1 (strongly disagree), 2 (disagree), 3 (neutral), 4 (agree), 5 (strongly agree), about the following statements from $S1$ to $S12$.

- $S1$: The correspondence of the playing actions and the generated sound is easy to comprehend.
- $S2$: It is fun playing.
- $S3$: The required playing actions are easy.
- $S4$: It is easy to handle as an instrument.
- $S5$: It is suited to play melodies.
- $S6$: It is suited to play chords.
- $S7$: I can play it well.
- $S8$: I can play with it as I desire.
- $S9$: One can improve the playing ability of it within a short time of practice.
- $S10$: I want to play it further.
- $S11$: It is suited for music composition.
- $S12$: It helps understanding music theory.

Next, after the explanation of the usage of the sound wheel, the subjects were asked to practice the sound wheel as long as they wanted. Then, they were asked to evaluate the sound wheel, in the same way like above. For practical reasons, a mouse was used as the input device instead of a touchscreen display. The hypothesis: "the sound wheel does not have difference with conventional instruments", was tested by the Student's t-test with significance level of 5%. The results of the evaluation are shown in Fig.4. Negative significant difference was found in $S5$. This is reasonable since the evaluation was done with a normal display and a mouse, but together it implies the difficulty of playing melodies using scale degrees instead of concrete note heights. On the other hand, positive significant difference was found in $S6$, $S11$, and $S12$. Significant difference of $S12$ was still present with a test with significance level of 1%. This indicates that the sound wheel indeed was received as helpful for understanding music theory. This result was checked also by the Wilcoxon rank-sum test with significance level of 5%, in which positive significant difference was again observed in $S6$ and $S12$, but not in $S11$. Further evaluations with more test subjects will enhance the precision of this result.

5. CONCLUSIONS

A function-oriented musical interface, named the sound wheel, was presented. In this interface, the subjects to manipulate are the musical functions, like pitch class sets, tonal centers and scale degrees, rather than the musical surface. By employing a COF-type wheel shaped controller for the mode input, the correspondence with the harmony theory is visually evident. The playing actions have simple correspondence with the harmony theory. Chord progression within the same key is performed by touching (or clicking) the wheel, and modulation is performed by rotation of the wheel. It has a easy usability, realized by semi-automatizing the conversion process from musical functions into the musical surface. Because of such features, one can play this interface with concentration on the harmonic structure, without having the attention caught by manipulating the musical surface. Subjective evaluation indicated the effectiveness of this interface as a tool helpful for understanding the music theory. Therefore, this interface can be used for education and interactive training of tonal music theory.

As future issues, sophistication of the semi-automatic sequence generation will be expected. At the moment, constant velocity and quantized timing is used for all generated notes, but by employing performance rendering technologies[7], automatic composition[8, 9], together with improvements of techniques to capture the player's musical intension, sequences with more human-like expressions might be able to be generated.

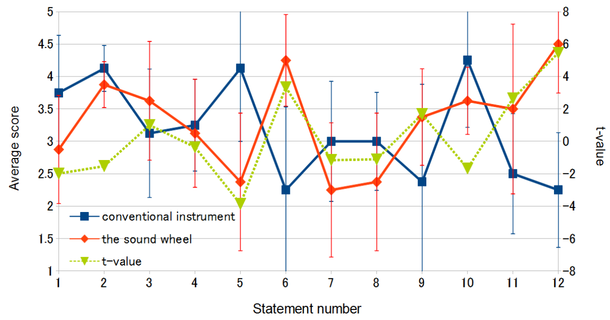

Figure 4: The result of the evaluation. The blue and red symbols represent the average score of each statement concerning conventional instruments and the sound wheel, respectively. The green symbols represent the t-values. Significant difference was observed in $S5$, $S6$, $S11$, and $S12$.

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