REDESIGNING A PIANO ROLL: A MELODY INPUT INTERFACE THAT CAN PLAY MICROTONES WITH AN ARBITRARY NUMBER OF KEYS

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ABSTRACT

A piano roll plays a fundamental role in computer music production. As its name suggests, a piano roll is designed with the motif of a piano keyboard. In DAW software, synthesizers can produce a variety of synthesized sounds and simulated instrument sounds. Although various synthesized sounds and simulated instrumental sounds can be produced using synthesizers, the most common input format is a piano roll with keyboard input.

Although keyboard input is simple, especially for those familiar with it, it has a significant limitation in that notes that can be played are limited to those in 12 equal temperament. It is possible to change the actual frequency of keyboard sound by changing the tuning settings (which is called calibration). However, an input interface based on the concept of a piano keyboard has many limitations in terms of inputting microtones in cases where an octave is not composed of 12 tones (e.g., 17 and 24 equal temperament). Based on these problems, we propose an interface that allows users to customize temperament that can be played by a piano roll and to redesign a piano roll. Specifically, our interface allows users to move back and forth between editing temperaments and creating melodies. The temperament can be created in three different ways. Creating from scratch, editing an existing template temperament, or creating from an imported external audio file.

1. INTRODUCTION

The piano roll is an indispensable interface for computer music production. In DAW software for computer music production, it is common to input notes using a piano roll interface, even for instruments that do not use a keyboard, such as strings and wind instruments. A piano keyboard consists of 12 keys per octave, divided into seven white keys and five black keys. This keyboard interface is simple for those familiar with music, but has significant limitations: notes that can be played are limited to those of 12 equal temperament.

12 equal temperament is a quantized temperament that uses only 12 patterns of frequencies in an octave. A piano roll is used to input the sounds of instruments with a playing style significantly different from that of the piano. For stringed instruments without frets, such as the violin, the number of notes that can be played in an octave is not limited to 12, but when using piano rolls, the number is limited to 12. The violin may be played in a different temperament other than 12 equal temperament, for example just intonation; however, 12 equal temperament is generally used with piano roll. Most DAW software has a tuning function that allows a user to change the temperament that can be played on the piano roll. However, as long as the keyboard interface is used, the constraints of the number 12 cannot be avoided. To achieve more flexible music production, an interface that removes the restrictions of the piano roll and allows the input of notes of any tone, not limited to 12, including microtones, is required.

In this paper, we propose an alternative input interface to the piano roll, where a user can design the number of keys per octave and their respective frequencies. The proposed note input interface allows users to design their original musical temperament, avoiding the constraints of existing musical temperaments and piano roll keys.

Some musical equipment, such as samplers, enables music production not constrained by musical temperament, but it is difficult to compose melodies and accompaniments using samplers. The proposed interface also determines temperaments based on the sampling of external sound data. For example, the proposed interface enables the design of keys and temperaments from the sounds of birds, waves, and wind.

2. RELATED WORK

Research related to microtones is called n-EDO in the context of n-equal temperament other than 12 equal temperament and has been studied by microtonal researchers such as Erv Wilson. EDO stands for equal divisions of an octave. Erv Wilson found that the sounds of 17, 19, 22, and 31-EDO were comfortable and explored them [1]. Music theory research on new temperaments is important for discovering new temperaments; however, music can be made also without a formal knowledge of music theory just like music when music theory did not exist. In this study, we create tools prior to music theory.

Research on microtonal instruments has been conducted to explore tools that can play microtones. Bailey et al. [2] proposed microtonal clarinet, and Dabin et al. [3] proposed microtonal flutes by 3D modeling and printing. These instruments enable us to play music that differs from existing musical temperaments; however, physical instruments are not flexible and cannot be easily changed to other temperaments. If a performer wants to play a piece of music in various temperaments, the performer will need to design and use a different instrument for each temperament. For example, various types of guitars have been proposed to play microtones [4]; however, it is difficult to realize flexible temperament because of a fixed parts such as frets. Therefore, guitars that use frets have to be designed for each temperament. There are also fretless guitars, but the degree of freedom is directly related to the difficulty in playing, so it is not an instrument that everyone can easily handle.

Research on tuning methods [5] and perception of microtones [6] has been conducted from a variety of perspectives [7], which has contributed to the development of microtonal music. On the other hand, we believe that developing a tool in advance and allowing users to freely design their temperaments will lead to the development of microtonal music through an example-based approach that differs from an approach of conventional music theory research.

The generalized keyboard proposed by Bosanquet in the 1870s is a keyboard capable of playing microtones, and was later extended by Erv Wilson and other microtonal researchers [8]. It is possible to play microtonal music with the generalized keyboard, but since its structure is significantly different from the piano keyboard we are familiar with, it is difficult to introduce it directly into the existing music production flow. In addition, there is a disadvantage in that it is difficult to intuitively understand notes that correspond to each key when considering frequent temperament changes. There is also a software for tuning microtonal scale called Scala [9]. Scala is a software that enables easy tuning of any temperament; however, it does not provide a function for music production like a piano roll.

Some existing music production software allows users to tune to any frequency when inputting notes to a piano roll. Software synthesizers such as PianoTeq [1] and Serum [2] are examples of such software. It is also possible to import and use tuning files related to a user's original temperament designed on sites such as Scale Workshop [3]. However, existing software synthesizers are designed to be programmed with piano rolls consisting of 12 keys per octave. Leimma [4] provides browser-based software to create temperament consisting of any number of notes with circular representation of the octave; however the melody creation part using the created temperament has not been considered and the number of keys on the keyboard is fixed to 12.

In our proposed interface, we enable users to redesign the input notes for piano rolls, while referring to the tuning methods of existing software such as PianoTeq and Leimma. These tuning methods employ a circular representation of an octave, which is not so new, as it can also be seen in other research paper, for example in [10]. What makes our interface particularly different from other software is that a user can go back and forth between melody input using the piano roll-like interface and temperament creation. In addition, the proposed interface provides a function to generate temperament from imported external audio files.

[1] https://www.modartt.com/pianoteq
[2] https://xferrecords.com/products/serum
[3] https://sevish.com/scaleworkshop/
[4] https://isartum.net/leimma

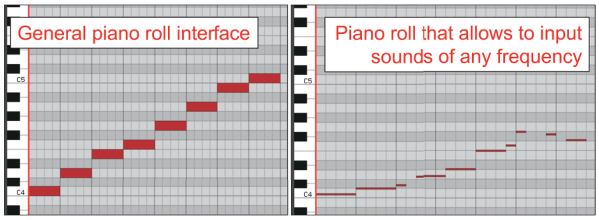

Figure 1. Implementation of a piano roll that allows input of sounds of arbitrary frequency.

3. A STRATEGY TO INPUT FREE TEMPERAMENT MUSIC

In this study, we investigate how to extend the existing interface of a piano roll to enable the input of notes with microtones and users' original temperaments. As an initial study, we implemented an interface in which quantization in the vertical axis direction (i.e., frequency direction) was disabled in the piano roll.

A comparison between the general piano roll and the piano roll implemented here, which allows the input of notes of any frequency, is shown in Figure 1. This interface allows the input of any arbitrary frequency microtonal notes. At first glance, this may seem to achieve the goal, but with a high degree of freedom in the frequency direction, it is difficult to maintain musical discipline and create melodies that have a pattern in pitch. MetaSynth [5], an existing music production software also has an input interface not quantized in the frequency direction. Although it is possible to produce pitches outside the equal temperament with such an interface, it is difficult to create a series of sounds that can be considered as music by many listeners. The introduction of microtones expands the range of music that can be produced. However, music production using microtones is difficult because microtonality does not have a widespread fully standardized set of compositional rules. The greater the freedom of the temperament, the more difficult it is expected to be to compose music.

While maintaining the goal of increasing the degree of freedom of programmable sounds, constraints are also necessary to make the music work as music. In general piano rolls, the constraint of 12 equal temperament and the music theory based on it guarantee the musical structure. Based on the above, the proposed interface does not provide complete freedom when programming notes, but provides freedom in key design. Note input can be performed in the same procedure as with conventional piano rolls, but the constraints of the number of keys (12 keys per octave) and the frequency assigned to each key existing in piano rolls are removed in our proposed interface.

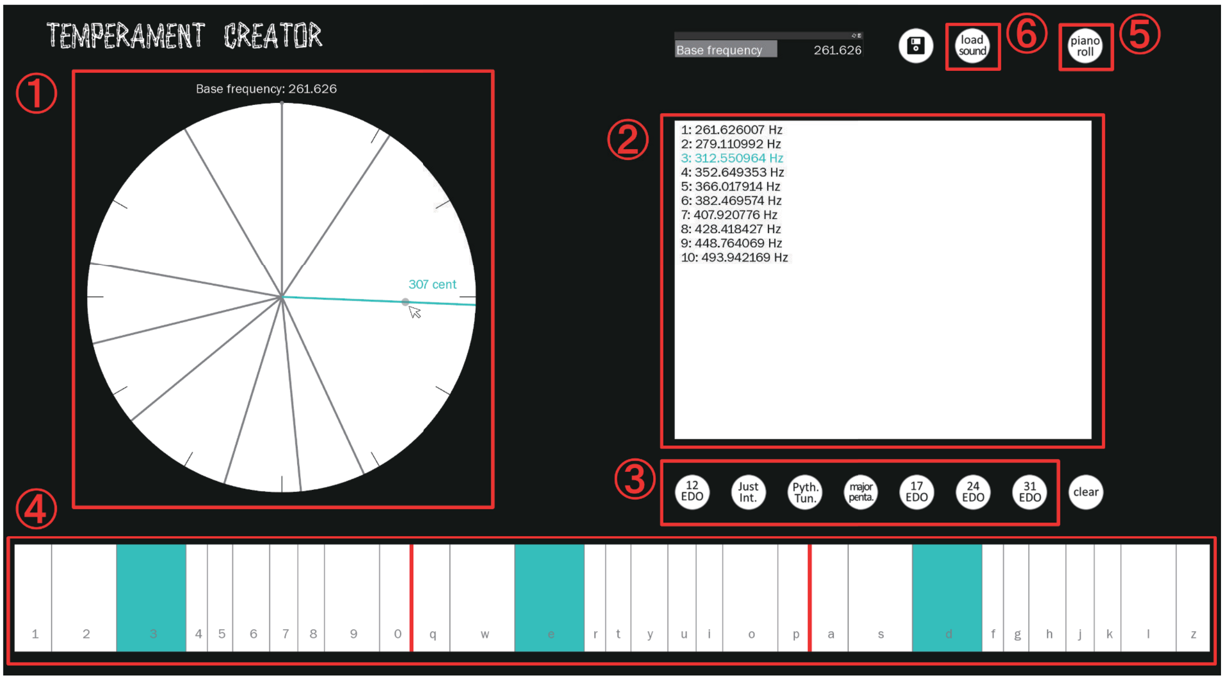

Figure 2. Screen capture of the tuning function of the proposed system.

4. SYSTEM OVERVIEW

In this section, we describe the overall structure of the proposed system. The proposed system consists of two interfaces: one for creating a custom temperament, and the other for programming music based on the created temperament. Figure 2 illustrates the screen capture of the temperament creator interface.

The pie chart on the left (1) is an interface that enables users to adjust the frequency of each key in cents[6], and to add or delete new keys, with an octave being one cycle. The lines on the circle represent each key. The frequency corresponding to each keyboard key is displayed in a text format on the right side (2). This pie chart interface is implemented with reference to PianoTeq's advanced tuning mode. The main difference between our interface and PianoTeq is that our interface allows users to create temperaments from scratch, and the number and the width of keys can be determined arbitrarily.

4.1 Loading Temperament Information from Templates

The proposed interface is implemented as an extension of a piano roll, so it can be used to input notes in the same way as a piano roll. It is possible to create a keyboard with 12 equal temperament by selecting one of the available temperament templates (3). It is also possible to create other keyboards, such as just intonation, Pythagorean tuning, major pentatonic scale, 17-EDO, 24-EDO, and 31-EDO with only one click of a button. Although these temperaments and scales do not necessarily have 12 notes per octave, the interface is designed to ensure that they can all be handled within the same scheme.

When creating a musical temperament, the corresponding key is reflected in the lower part of the interface (4) so that a user can play a note to check the sound. The keyboard is displayed for three octaves. The width of each key corresponds to the interval. In the case of equal temperament, the keys are spaced uniformly, but in the case of a temperament in which the intervals are not uniform, the spacing of keys varies according to the intervals. This is equivalent to the function of flexibly moving the position of frets in a stringed instrument with frets, such as a guitar. The interval steps of common keyboard and string instruments are uniform in semitones, but they are not always uniform in microtones. By changing the width of the keyboard according to the interval, a user can intuitively understand the interval between the left and right keys. The user can easily imagine the pitch of the sound just like fretless guitar. Our proposed keyboard interface follows the principle that the leftmost position produces lower tones and the rightmost position produces higher tones, making it more intuitive than the interface of generalized keyboard.

4.2 Piano-roll-like Melody Input Interface

Once the temperament is decided, a user can press the piano roll button in the upper right corner (5) to switch to the melody input interface. The switched interface screen is shown in Figure 3.

The interface in Figure 3 is almost the same input interface as a typical piano roll. The difference is that sounds are based on the user's original temperament, and there is no distinction between white and black keys since the interface is no longer based on the piano. The only reason

[5] https://uisoftware.com/metasynth/

[6] A cent is a unit of 1,200 equal divisions of an octave. In the case of the 12 equal temperament, a semitone is 100 cents.

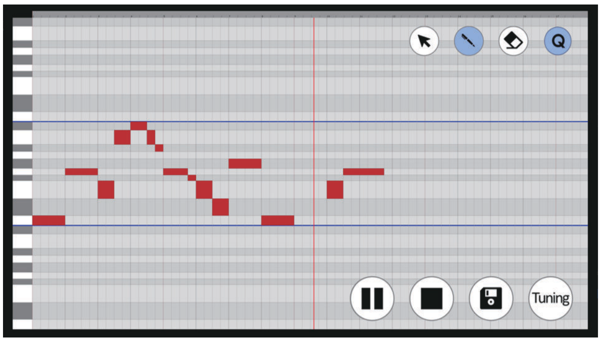

Figure 3. Our piano-roll-like melody input interface. Each note has a different height based on a created temperament.

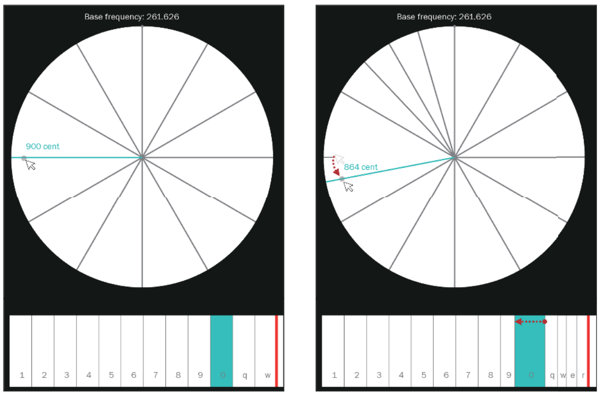

Figure 4. Editing tones of a temperament template to customize notes in a scale. An example of changing the tuning from 12 equal temperament and adding some tones. The width of keys on the keyboard changes flexibly according to the interval.

why our proposed interface has bright and dark keys is to make it easier to distinguish them from adjacent keys.

In the current implementation, only two types of tones are available when a melody is played back with this interface: sinusoidal wave and rectangular wave tones. Although timbre is an important factor in creating melody, our interface currently does not take it into account, and we are considering to extend the interface to enable it to work with external sound sources in the future.

4.3 Customization of Temperament

By clicking on the tuning button at the lower right of Figure 3, a user can return to the temperament creation interface and tune the temperament while editing the melody.

Figure 4 shows the editing of 12 equal temperament keys to create original temperament keys. As shown in Figure 4, by editing the lines on the pie chart, a user can change the frequency of notes assigned to each key, as well as add and delete keys.

In general, tuning of musical instruments is performed by setting the frequency of the note A4 to 440 Hz or 442 Hz and using that as the basis. However, since the proposed interface is not limited to 12 types of pitch classes, it is inappropriate to use A4 as the basis. Therefore, the proposed interface calculates the frequencies of other keys based on the frequency of the lowest note in the octave (e.g., note C in the case of 12 equal temperament).

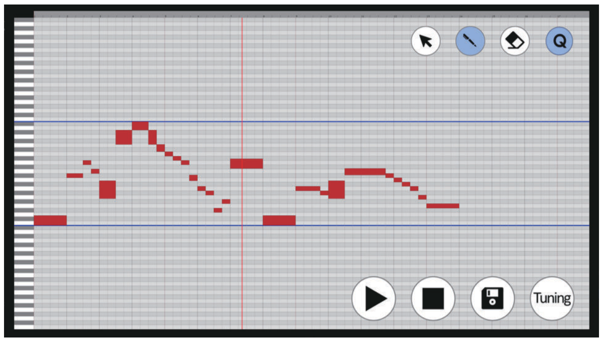

Figure 5. Mixing multiple temperaments in one melody.

4.4 Mixing Temperaments in One Melody

Users can switch between the temperament creation interface and the piano roll-like melody input interface as many times as they want. In addition, one of the unique features of the proposed interface is its ability to mix multiple temperaments. It is possible, for example, to enter a melody in 12 equal temperament for the first half of the melody and then in 17-EDO for the latter part. Modulation is a common concept in music, but with our interface, it is possible to change temperaments during a tune.

Figure 5 shows a melody with 24-EDO temperament added to the melody that was programmed with the original temperament shown in Figure 3. In the proposed interface, it is possible to change the temperament flexibly while editing a melody, so that a user can change any single note to a note that is not included in the original temperament. There are times when a composer may want to intentionally put a note outside the current temperament while composing, but in the case of 12 equal temperament, the option of a wrong note is limited to few options. Since the proposed method can assign a note of any frequency to a key, it provides a variety of options for a wrong note.

4.5 Creating Temperaments from External Audio File

Although a temperament can be easily created using our pie chart interface, it is necessary to go through a trial and error process to find a temperament that can be considered music. It would not be difficult to create a temperament with minimum musical problems by editing a temperament template, but the originality would be diminished if an existing temperament was used as a basis. To solve this problem, we implemented a function to create temperaments from an existing audio file. A user can import external audio file to be used to create a new temperament by clicking on the "load sound" button at the upper right (6) of Figure 2.

The expression method of sampling, which uses sounds of everyday life to create music, has become popular. Our interface enables sampling for temperament creation such that frequencies used in everyday sounds are assigned to

#	Temperament	Frequencies [Hz]
1	12 equal temperament	[261.63, 277.18, 293.67, 311.13, 329.63, 349.23, 369.99, 392.00, 415.31, 440.00, 466.16, 493.88]
2	C-major pentatonic scale	[261.63, 293.67, 329.63, 392.00, 440.00]
3	Just intonation	[261.63, 279,07, 294.33, 313.96, 327.04, 348.84, 370.64, 392.45, 418.60, 436.05, 470.93, 490.56]
4	24-EDO	[261.63, 269.29, 277.18, 285.31, 293.66, 302.27, 311.13, 320.24, 329.63, 339.28, 349.23, 359.45, 369.99, 380.84, 392.00, 403.48, 415.31, 427.47, 440.00, 452.89, 466.16, 479.82, 493.88, 508.36]
5	Mixture of 12 equal temperament and Just intonation	[261.63, 277.18, 279,07, 293.67, 294.33, 311.13, 313.96, 327.04, 329.63, 348.84, 349.23, 369.99, 370.64, 392.00, 392.45, 415.31, 418.60, 436.05, 440.00, 466.16, 470.93, 490.56, 493.88]
6	Randomly created 5 tones	[261.63. 290.81, 362.37, 419.01, 473.63]
7	Randomly created 12 tones	[288.06, 310.53, 323.34, 338.66, 362.94, 392.49, 406.08, 426.86, 464.17, 497.83, 517.09, 550.42]
8	7 tones sampled from from chicken crows	[341.30, 423.10, 506.52, 540.17, 580.01, 629.65, 681.66]
9	7 tones sampled from the sound of ripples	[323.00, 343.19, 365.71, 416.46, 463.43, 532.34, 603.61]

Table 1. Examples of created temperaments.

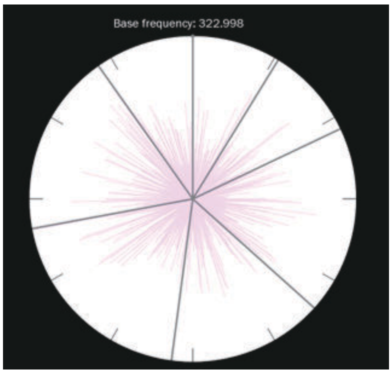

Figure 6. Creating a temperament from external audio file. The light red area in the pie chart corresponds to the spectrum of the imported audio data.

keys. For example, by importing an audio file of bird sounds, users can design a keyboard with the frequencies of bird sounds.

We are unbothered if the birds do not sing at the frequency of 12 equal temperament. From this, we thought that the frequencies of birdsong and ocean waves could be sublimated into music. Whether the actual temperament created from the external audio files will be musically good depends on how it is used, but we believe that it is a function that makes it easier to create a temperament than starting from scratch.

Figure 6 shows a pie chart example for the actual case of creating a temperament from the sound of a chicken clucking. The spectrum of the audio file is represented by the line in light red on the pie chart. Here, the most predominant spectral components for a time interval of audio length are selected as tones. This is accomplished by extracting the peak of the spectrum within a predetermined frequency range and assigning keys to a predetermined number of peaks. In the example shown in Figure 6, a range of one octave is set by searching for peaks within the range of 200-600 Hz and using the highest peak as the reference frequency. Tone frequencies outside the octave range are adjusted using octave equivalence to keep them within the range. Here seven peaks of the spectrum are searched and assigned to keys.

5. EXAMPLES OF CREATED TEMERAMENTS

Table 1 summarizes several examples of temperaments created with our proposed interface. The temperaments from no.1 to no.4 can be generated from the prepared templates at the click of a template selection button. The most basic way to use our interface is to load the prepared template template and tune them. This corresponds to the general tuning of the instrument. Alternatively, the template temperament can be used as is, in which case the proposed interface is equivalent to a conventional piano roll when a 12 equal temperament is used. Many softwares such as PianoTeq, Scale Workshop, and Leimma provide these templates as the basic function.

The temperament no.5 is the mixture of 12 equal temperament and just intonation. Since the frequencies of the lowest tones are the same in our interface, there are 23 tones in total [7] . With this temperament, the user can choose whether to use the 12 equal temperament or the just intonation for every single note. The capability to realize a piano roll with a mixture of multiple temperaments is a unique feature of the proposed interface.

[7] Generally, the frequency of the note A4 is set to 440 Hz in just intonation. The proposed interface creates a temperament based on the frequency of the lowest note.

The temperaments of no.6 and no.7 are randomly created temperaments using our proposed interface. It is up to the user to create a listenable melody from these temperaments. However, with this interface, it is possible to create a melody in the piano roll while changing the temperament, and vice versa. Through repeated trial and error, both originality and uniqueness of the melody can be pursued. The number of keys in an octave is expected to increase with repeated trial and error, however, there is no limit to the number of keys per octave in our interface as long as it can be displayed on the screen. Although Leimma has a similar temperament creation function, Leimma only provides the temperament creation part and does not support the creation of melodies or editing of temperament while creating melodies.

The temperaments of no.8 and no.9 are temperaments created from imported external audio files. The temperament no.8 is a temperament created based on the peak information in the spectrum of a 2.5-second-long chicken crows. The temperament no.9 is a temperament sampled from the sound of ripples which is 1.5-second-long. Here, seven peaks are extracted for each temperament, however, since the spectrum itself is visualized, it is easy to increase the number of keys to be assigned according to the user's preferences.

The several temperaments shown here are only examples of the temperaments that can be freely created with the proposed interface. In the same way that the user can freely create melodies in the piano roll, the temperament can be freely edited with this interface.

The evaluation of the usability of the proposed interface is a topic to be addressed in the future research because it depends on the subject's skill of using DAW software. Whether the melody is good or bad all depends on the user's ingenuity. We will investigate how to support composing with the newly defined temperament in our future study.

6. DISCUSSION

In this study, we proposed an interface that allows users to freely create original temperaments and redesign piano rolls. For a long time, the concept of musical temperament had been static, and users were rarely allowed to change it freely, only to modify the tuning of existing instruments. Conventionally, notes in an octave were divided into 12 tones, and it was difficult to express a finer interval change.

12 equal temperament is the most popular musical temperament of all time. Nonetheless, other temperaments have also been used, especially in Eastern Asia and Arabic music. In addition, in contemporary music, temperaments other than 12 equal temperament, such as microtones, are essential. These examples demonstrate that there is a good chance that other attractive temperaments exists that we have not yet encountered. We believe that exploring musical temperaments will lead to the discovery of new music.

According to the sound dissonance curve proposed by Helmholtz [11], 12 equal temperament tones are not composed of only the notes with low dissonance. If we consider only dissonance, we can say that just intonation is the best temperament. The reason for the popularity of 12 equal temperament is that they are easy to transpose keys. In this sense, musical temperament may be something that can be more freely defined.

Because the temperaments of a musical instrument influence its design, changing the temperament is difficult if the same physical instrument is to be used. However, in this age, music production using computers has become common, and flexibly changing musical temperaments using software is possible. In the future, when everyone is free to design their original musical temperament, we may be able to discover rules for how to create good musical temperaments and how to identify bad ones.

Tones in temperaments other than 12 equal temperament are often unfamiliar. This could simply be because our ears are not accustomed to them. As the number of music with such temperaments increases, it can be expected that our perception for sounds other than 12 equal temperament will be developed. To achieve this, it is necessary to increase the amount of such music data in the future. We believe that the proposed interface will help increase the number of music with such new temperaments.

New temperaments are often not applicable to well-known musical theories. Thus, it is necessary to develop technology to assist in composing music in temperaments encountered for the first time, and this will be our future task. In addition, we would like to build an environment, where anyone can use the proposed system by converting it into a VST plug-in. Although only sinusoidal wave and rectangular wave sound can be played on the current interface, we are considering to realize melodies with richer tones using existing sound sources by converting to VST plug-in. Since the impression of a melody changes depending on the tone of the melody, the exploration of the tone is also a future research topic.

Currently, the proposed interface does not take into account the components of music other than the melody. In making music, we must also consider harmony, accompaniment, and many other elements. In the future, we would like to extend our interface to remove the restriction of existing temperament in various musical elements.

The evaluation of the proposed interface is a major issue to be addressed in the future. We are considering to conduct a user study in which subjects actually operate our interface. To do so, we need to carefully consider the evaluation method, since it is expected to be greatly affected by how the subjects are accustomed to the conventional temperaments, and most listeners are 12 equal temperament educated listeners. If a user study were to investigate whether the flexibility of the melodies that can be created has been increased, it would be obvious without the need to conduct the study. The important points in the evaluation are how much the increased flexibility of the melody contributes to the creation, the usability of the interface, the ease of composing, and the adequecy of the interface design. We are currently considering a method to realize a user study that removes various influences as much as possible by carefully selecting subjects to be evaluated.

Acknowledgments

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7. REFERENCES

[1] T. Narushima, *Microtonality and the tuning systems of Erv Wilson*. Routledge, 2017.

[2] N. J. Bailey, T. Cremel, and A. South, "Using acoustic modelling to design and print a microtonal clarinet," in *Proceedings of the 9th Conference on Interdisciplinary Musicology (CIM14), Berlin, Germany*, 2014, pp. 4–6.

[3] M. Dabin, T. Narushima, S. T. Beirne, C. H. Ritz, and K. Grady, "3d modelling and printing of microtonal flutes," 2016.

[4] J. Schneider, "The microtonal guitars of harry partch," *Soundboard Scholar*, vol. 1, no. 1, p. 5, 2015.

[5] W. A. Sethares, "Adaptive tunings for musical scales," *The Journal of the Acoustical Society of America*, vol. 96, no. 1, pp. 10–18, 1994.

[6] F. Bailes, R. T. Dean, and M. C. Broughton, "How different are our perceptions of equal-tempered and microtonal intervals? a behavioural and eeg survey," *PloS one*, vol. 10, no. 8, p. e0135082, 2015.

[7] G. J. Balzano, "The group-theoretic description of 12-fold and microtonal pitch systems," *Computer Music Journal*, vol. 4, no. 4, pp. 66–84, 1980. [Online]. Available: http://www.jstor.org/stable/3679467

[8] D. Keislar, "History and principles of microtonal keyboards," *Computer Music Journal*, vol. 11, no. 1, pp. 18–28, 1987. [Online]. Available: http://www.jstor.org/stable/3680175

[9] Manuel Op De Coul, "Scala." [Online]. Available: https://www.huygens-fokker.org/scala/

[10] A. Barate and L. A. Ludovico, "Generalizing messiaen's modes of limited transposition to a n-tone equal temperament," in *Sound and Music Computing*, 2015, pp. 287–293.

[11] H. L. Helmholtz, *On the Sensations of Tone*. Dover, New York, 1954.