Mobile Clavier: New Music Keyboard for Flexible Key Transpose

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ABSTRACT

Musical performers need to show off their virtuosity for self-expression and communicate with other people. Therefore, they are prepared to perform at any time and anywhere. However, a musical keyboard of 88 keys is too large and too heavy to carry around. When a portable keyboard that is suitable for carrying around is played over a wide range, the notes being played frequently cause the diapason of the keyboard to protrude. It is common to use Key Transpose in conventional portable keyboards, which shifts the diapason of the keyboard. However, this function creates several problems such as the feeling of discomfort from the misalignment between the keying positions and their output sounds. Therefore, the goal of our study is to construct Mobile Clavier, which enables the diapason to be changed smoothly. Mobile Clavier resolves the problems with Key Transpose by having black keys inserted between any two side-by-side white keys. This paper also discusses how effective Mobile Clavier was in an experiment conducted using professional pianists. We can play music at any time and anywhere with Mobile Clavier.

Keywords

Portable keyboard, Additional black keys, Diapason change

1. INTRODUCTION

Musical performers need to show off their virtuosity for self-expression and communicate with other people. Therefore, communication through music is encouraged if they can perform not only in fixed places, such as concert halls and live halls, but anywhere outside, such as on streets and in parks. We propose mobile electronic musical instruments we developed that enable musicians to play music at any time and anywhere[1]. However, many instruments are still too large and heavy to carry. Portable instruments, on the other hand, that are suitable for carrying, have several limitations such as the narrow range of the diapason.

Figure 1: Mobile Clavier

We focused on portable keyboards in this research that are suitable for carrying. When we use such portable keyboards to play music that has a wide diapason range, the notes being played frequently cause the diapason of the keyboard to protrude. It is common to use Key Transpose in conventional portable keyboards, which is a function to shift the diapason of the keyboard. However, this function suffers from several problems, such as the feeling of dis-comfortable from the misalignments between keying positions and their output sounds, the difficulty in understanding the note set for each key, and the complexity of diapason changes.

Therefore, the goal of our study is to construct Mobile Clavier, which enables the diapason to be changed smoothly, making good use of the techniques acquired from conventional keyboards. It solves problems with Key Transpose by having black keys inserted between any two side-by-side white keys. The remainder of this paper is organized as follows. Section 2 explains the design of Mobile Clavier, and Section 3 describes its implementation. Section 4 describes our evaluation and related work. Finally, Section 5 presents conclusions and our plans for future studies.

2. DESIGN

2.1 Diapason-change Functions

We generally use Key Transpose and Octave Shift for playing notes that extend beyond the diapason range of the keyboard. Key Transpose slides the diapason by halftones with the equipment on the keyboard. If users set "Key Transpose + 2", the relations between all keys and their output sounds are those shown in Figure 2. Octave Shift slides the diapason by octaves.

Key Transpose suffers from problems. First, it creates feeling of dis-comfort from the misalignment between the keying position and its output sounds. A musician with per-

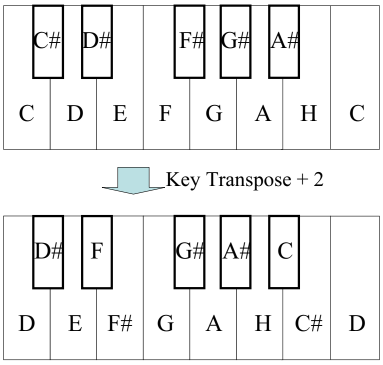

Figure 2: Change in sound through Key Transpose

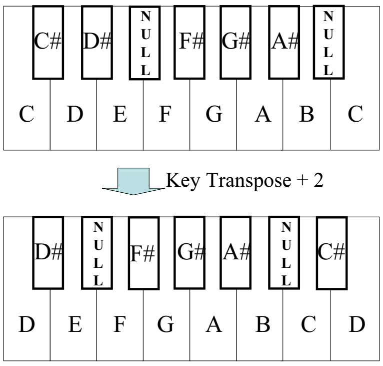

Figure 3: Key Transpose in Mobile Clavier

fect pitch feels special dis-comfort due to this misalignment. Therefore, musicians cannot play smoothly because of this dis-comfort. The second problem is that we cannot understand note sets of keys. This problem stands out especially when musicians frequently change the diapason. Finally, they cannot immediately change to the diapason they want because Key Transpose is not supposed to be frequently used when music is being played. Although Octave Shift does not encounter the first and second problems, on the other hand, it increases the frequency of transpose operations.

2.2 Additional Black Keys

We propose Mobile Clavier to resolve these problems, which is a compact keyboard that was black keys inserted between any two side-by-side white keys, as shown in Figure 3. Moreover, Mobile Clavier has NULL notes added to the definition of the 12-note scale, which we define as silent notes. The NULL notes are placed between the E and F notes, and between H and C notes, called "NULL keys".

For example, when a user operates "Key Transpose + 2" from the state at the top of Figure 3, the assignment of keys changes to the state at the bottom of the figure. If there were no NULL keys in Figure 3, the keys would be arranged like on conventional keyboards which are laid out with the D note on the left. The misalignment between keying positions and their output sounds is removed in this way.

One unit of Key Transpose in Mobile Clavier is a natural tone, because if we had allowed a halftone unit, all black notes would be assigned to white keys and all white notes would be assigned to black keys.

Musicians must be able to recognize the position of NULL

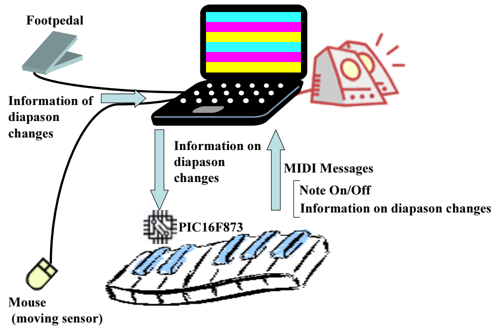

Figure 4: System structure

keys visually to play notes smoothly. Therefore, we propose that NULL keys are lit up in different colors from the others. In this way, we can understand the note sets of all keys.

2.3 Diapason Changes

Since conventional interfaces achieve Key Transpose by halftones or octaves, it is difficult for musicians to change the required diapason quickly. Therefore, they have to stop performing to do this. Additionally, the more portable the keyboards, the more frequent the number of diapason changes.

We propose hardware and software approaches to diapason changes operation without interrupting musical performances. The hardware solution uses buttons mounted on the keyboard. The software solution enables musicians to preset points to change the diapason. When the piece being performed reaches these given points, the system automatically changes the diapason. The advantage of the software solution is that musicians do not have to learn additional operations to change the diapason. However, they cannot change it freely, and the audience cannot understand how the diapason is changed visually. We therefore focused on the hardware approach in our study. We propose the following four approaches to changing the diapason:

1. Keyboard equipment

A keyboard generally has several items of equipment, such as switches and wheels. We can use these as part of an interface to change the diapason. Musicians do not need to have new hardware to change the diapason with this method. However, if there is too great a distance between keys and the equipment, musicians has to remove their hands from the keys and stretch their arms to reach the equipment to change the diapason.

2. NULL key

We can use NULL keys to change the diapason. Musicians can change it without removing their hands from the keyboard with this method. Since the positions of the NULL keys change frequently on the other hand, it is difficult for musicians to change the diapason.

3. Foot device

We can use a foot device, such as a foot mouse or a foot controller. Although they enable smoother operation, users must carry these devices around.

4. Sensor

We attached a movement sensor to the keyboard. When the musician moves the keyboard itself to the right or left, the diapason of the keyboard changes higher or lower. This method does not require any hardware to be carried around, and we can change the diapason intuitively while using both hands. The sensor on the keyboard, on the other hand, needs to be sufficiently accurate and the area for using it is restricted to an even surface.

Figure 5: Completely lit up black keys

3. IMPLEMENTATION

We implemented a prototype of Mobile Clavier using Roland's OXYGEN8 as the basic keyboard. OXYGEN8 is equipped with 25 full-size keys and 8 assignable rotary controllers that are assigned different MIDI parameters. Figure 4 outlines the structure of the prototype system.

The interface to change the diapason, such as the NULL keys and movement sensor, sends the information for changing the diapason to the PC.

The PC sends then the lighting information to a programmable integrated circuit (PIC) microcomputer via serial communication. The PIC controls the lighting for the black keys. The software on the PC was programmed with Microsoft Visual C++ 6.0 on Windows XP, and the software on the PIC was programmed in C language on Microchip Technology's MPLAB.

3.1 Additional Black Keys

Since we can easily detach keys and attach them to OXYGEN8, we detached all keys at once and laid out white key and black key in turn. The total number of keys was as the same as it was before. There is a photograph of Mobile Clavier in Figure 1.

An octave in the prototype is wider than that on conventional keyboards, and there is a space between the white keys, because the prototype has two newly black keys inserted into the conventional octave. As a result, when feeling playing the prototype is different to that when playing conventional keyboards. Although novices play some incorrect notes, they eventually solve these problems by feeling. This problem did not occur on the next version of the prototype, which had additional black keys inserted with the same octave range the conventional keyboards.

We need a distinct method of distinguishing NULL keys from other black keys. We created clear black keys of silicon resin (Figure 5) for the prototype. The sides and bottoms of the clear black keys were black, and white LEDs were inserted in the clear black keys. The NULL keys become white when the LEDs lit up.

3.2 Diapason Changes

We implemented the diapason changes explained in Section 2.4. In this section, we will explain the implementation of the foot controller, which can make good use of the techniques acquired on conventional keyboards. We use Roland's GFC-50 as the foot controller. It has five pedals and one shift switch mounted that enable a maximum of 10 diapason change patterns to be set. Although it took some time to adjust the changes, we could change it smoothly even while using both hands.

Table 1: Procedure for experiment

No	Content	
1	Play sub instrument.	1st Full Execution
2	Play main instrument.	1st Full Execution
3	Train main instrument.	Practice
4	Play main instrument.	2nd Full Execution.
5	Train main instrument.	Practice
6	Play main instrument.	3rd Full Execution

4. EVALUATION

We evaluated the availability of the Mobile Clavier through subjective evaluation by the first author and an objective evaluation by six pianists.

4.1 Subjective Evaluation

The first author practiced and played several pieces of music with the prototype. He has been playing the piano for over twenty years. He can also play these pieces with acoustic pianos.

This paper reports the usability of Mobile Clavier based on BWV846 (Figure 6) composed by J. S. Bach. The width of the diapason for the prototype is one octave and five degrees as the prototype has twenty-five keys. The width of the diapason for BWV846, on the other hand, is three octaves and four degrees, more than twice that of the prototype.

Figure 6 shows the musical score for BWV846. The numbers in the score are the pedal numbers for GFC-50. The player pushes the foot pedal at the numbered point in the score[1]. Additionally, the top left of Figure 6 shows the pedal configuration for this score. "Up *number*" means that the conventional diapason set in the prototype becomes a higher "diatonic * *number*". For example, when the musician engages "Up 1" at the top of Figure 3, the notes set for all keys become those at the bottom of the figure.

The test subject took sixty minutes to acquire the ability to play BWV846 in allegro, which is directed in the score. Moreover, the more he practiced and familiarized himself with the prototype, the more he solved the problem with octave width.

However, when he was unfamiliarize with the prototype, serious problems occurred with the timing of pedals and their mis-selection. The timing of pedals with Mobile Clavier is different to the pedalling of an acoustic piano, because pianists generally only use two pedals (damper and soft pedal). He concentrated on operating the pedals and neglected his keying to avoid making mistakes while getting used to operating the pedal.

When he had familiarized himself with the prototype, he could improvise and calculate the amount of shift in pitch in real-time.

4.2 Objective Evaluation

We did an experiment where pianists evaluated Mobile Clavier. We examined the ease of use in the early stages and the changes in the degree of progress in operating the Key Transpose of Mobile Clavier compared with a conventional portable keyboard.

4.2.1 Experimental Procedure

[1]You can see a demonstration video at http://www-nishio.ise.eng.osaka-u.ac.jp/~takegawa/DownLoad/MobileClavier/top.html

Pedal number and diapason variation	
1 Down1	6 Down 4
2 Down 2	7 Down 6
3 Down 3	8 Up 13
4 Up 2	9 Up 6
5 Up 1	10 Up 4

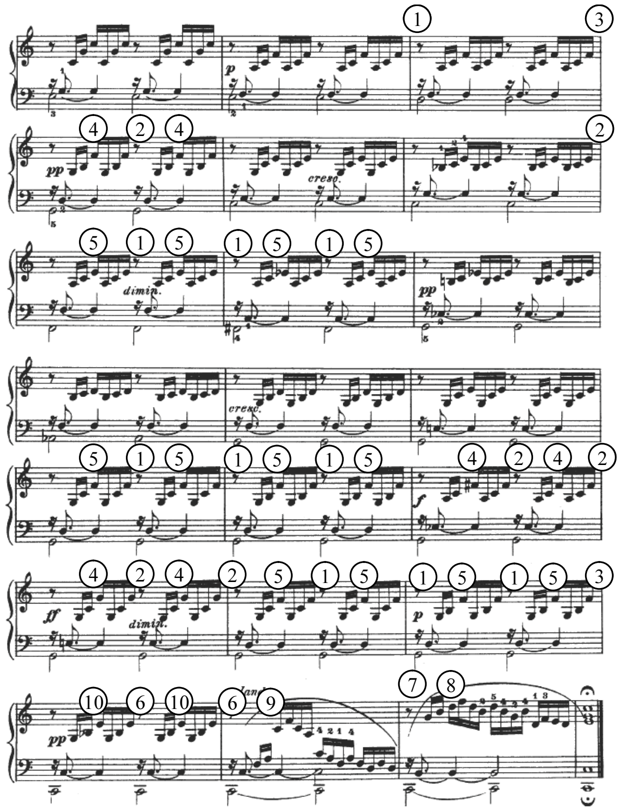

Figure 6: Sscore for BWV846

The trial piece was the First half of BWV846 (left of Figure 6). Six people who could play the trial music well took part in this experiment. They belonged to a college of music, their major was piano playing, and they always practiced with acoustic pianos. They were not familiar with conventional portable keyboards or Key Transpose. None of them had any experience with the prototype. We used Roland's SP-1 as a foot controller in this experiment to change the diapason, which has only one pedal. The pianists could easily change the diapason with using the foot pedal and this did not interfere with their playing. We used IBM's ThinkPad X30 whose platform was Windows XP as the PC, Roland's SC-8820 as the MIDI sound generator, Bose's MM-1 as the speaker, OXYGEN8 as the conventional portable keyboard, and the prototype. Additionally, two white keys and one black key were cut into the far right of the conventional keyboard to make the diapason width uniform between the conventional keyboard and the prototype, we also constructed an application (Figure 7) to support this evaluation experiment. The left of Figure 7 indicates the BWV846 score, the timing for diapason changes, and the note set in the left most key. The top right of Figure 7 indicates the present diapason number. Since we preset diapason variations to simplify diapason changes for the pianists, they did not need to pay attention to the position but only the timing. When a pianist pushed the SP-1 button, the diapason change number increased by one.

All participants played a piece with both instruments to evaluate ease of use in the early stages. They next selected one of two instruments and practiced with it to evaluate changes in the degree of advancement. We first allowed pianists to play with both instruments for five minutes to practice Key Transpose. We then allocated main/sub instruments to all pianists. The pianists then did their evaluations following the procedure in Table 1.

They had two time periods, i.e., full execution and practice in this experiment. In the former, they played the trial piece from the beginning to the end and the system logged MIDI Note On/Off and the timing for diapason changes. We also instructed the pianists to "play a smooth tempo of more than 70 beats per minute." In the latter, we asked to them "practice freely for five minutes".

4.2.2 Results and Considerations

The pianists, who used the prototype, played it naturally with few errors at the requested tempo after the experiment. Those who used the conventional portable keyboard, on the other hand, made many fingering errors.

We will now discuss the details of this experiment.

Error: Figure 8 plots the number of errors during Full Execution time. The horizontal axis means the first, second, and third Full Execution times, and the vertical axis means the number of mean errors. The bar chart is the average number of errors and the line segment is the extent of the standard deviation. The first number of errors is the average for the six musicians, and the second and third numbers are the averages for three participants.

The prototype had far fewer errors than the conventional portable keyboard. Moreover, both keyboards decreased the number of errors when the pianists repeatedly practiced with their own instrument. The reason the conventional keyboard had so many errors is that the musicians could not recognize the note set in each key after the diapason changes. Moreover, the fewer the diapason variations, the fewer the errors.

Figure 7: Screen snapshot of application used for evaluation

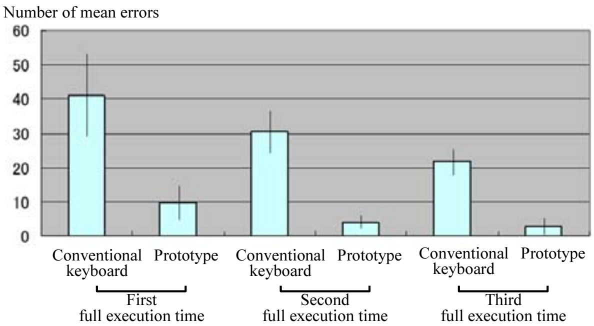

Figure 8: Evaluation results for errors

The reason for this is that they could easily anticipate a set note on each key with few diapason variations.

Because participants, who used the prototype, on the other hand, could visually recognize the note set on each key, there were fewer errors than that with the conventional keyboard. As a result of analyzing the errors for the prototype, we found few mistakes for interpreting the NULL keys and the main reason for them were large diapason variations and frequent diapason changes. These problems are dissolved as participants became more familiar with the prototype.

Velocity and Tempo: The constancy of tempo and the velocity were important factors in the evaluation. Our subject findings suggest that pianists, who used a conventional keyboard, played at unstable tempo and velocity. They especially could not control the tempo after diapason changes because they could not push the next key immediately. They could also not control the velocity because they concentrated on right keying and became frustrated. However, the velocity of musicians who used the prototype was stable. Their tempo was unstable at the beginning but they improved their constancy at the end.

Asymmetry vs Visual Assistance: Musicians can use the asymmetry of the black keys or visual/optical assistance to assess the position of their fingers and hand placement. However, Mobile Clavier has NULL keys and is not asymmetrical. Therefore, users have to assess the position of their fingers with the visual/optical assistance of Mobile Clavier.

We think that visual assistance is more important and intuitive for beginners because using asymmetry requires sufficient experience in playing and musicians then usually,

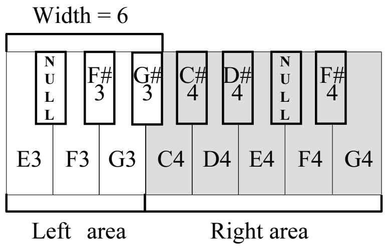

Figure 9: Example of split diapason

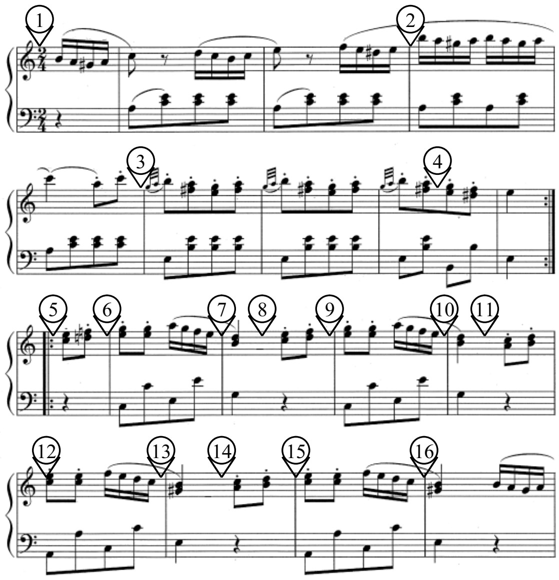

Figure 10: Score for Turkischer Marsch

frequently, and visually check the keyboard and the score. Therefore, beginners can assess the position of their fingers with our proposed mechanism. However, skillful players do not need visual assistance as much as beginners, because they can play without looking at the keyboard as much. However, this does not mean the asymmetry of the black keys is of direct tactile importance, but they enable multiple manipulations to assess hand placement, such as the relative position of the keys, of course, this includes visual assistance. Therefore, the tactility of asymmetry impacted by the black keys is not especially important even for skillful players.

However, since the asymmetry of the black keys helps players to assess hand placement, we plan to construct a physical approach to shade the NULL keys by pushing them physically into their keying state.

4.3 Splitting Diapason Function

Mobile Clavier can adapt problems with changing diapason functions by inserting black keys between any two side-by-side white keys. However, a problem still remains in that we cannot play keys that are located over the diapason of the keyboard at the same time. To resolve this problem we suggest splitting the diapason function. Figure 9 has an example of a split diapason function. The left-most key starts from E3 and the right-most area starts from C4. Width means the number of keys in one area. The left and right

Table 2: Map of diapason-setting information in Turkischer Marsch

Diapason setting	Left area		Right area
number	Left note	Width	Left note
1	A3	16	H4
2	A3	10	C5
3	E3	16	E5
4	H2	16	E5
5	C3	10	A4
6	C3	16	A4
7	C3	10	A4
8	C3	14	C5
9	C3	16	D5
10	C3	10	A4
11	A2	14	A4
12	A2	16	H4
13	A2	10	F4
14	A2	14	A4
15	A2	16	H4
16	A2	10	F4

areas played with the left and right hands.

We can play Chopin's Turkischer Marsch by using this function. Figure 10 shows the musical score for Turkischer Marsch. Each number in the score is the state for the diapason setting state as listed in Table 2, which indicates the left-most note for each area and the width of the area of left. The first author practiced and played the score, and used SP-1 with one pedal to change the diapason settings number[2].

4.4 Related Work

There has been little research whose main goal has been the simultaneous pursuit of playability and mobility at the keyboard.

Key Transpose and DTXPL's[2] multi-zone input are examples of functions that improve playability. Key Transpose is a function that shifts the diapason to cover the decrease in the number of keys. We expanded the concept of Key Transpose in our study. Moreover, DTXPL's snare pad assigns three sounds: head to the head, a rim shot to the up-rim, and a cross stick sound to the down-rim. It can therefore sound like a real snare pad.

There have been several studies on changing a diapason smoothly. CHROMA's CHROMATONE[3] does not has distinguish between white or black keys. It only has white keys and has 12-note scale white keys assigned. Moreover, Button Accordion[4] has the same concept as CHROMATONE. Moreover, there are different keyboard layouts that are used as electronic music controllers[5, 6, 7, 8].

These instruments are in fact designed to enable easy diapason changes. However, these instruments do not make good use of the techniques acquired through conventional keyboards and it is difficult to master them because of their differences to conventional instruments.

There are Rollup Piano[9] and Foldup Keyboard[10]. Rollup Piano is made of rubber. It is extremely portable because users can roll it up. However, it has flat embedded keys and zero tactile feedback making it difficult to use. Although Foldup Keyboard can be folded, it does not enable notes to be played when the diapason of the keyboard is protruding.

There are musical instruments whose underlying concept is to enable music to be played at any time and anywhere[11, 12, 13, 14]. They are not keyboard but percussion instruments, and do not have devices to improve playability.

[2]You can see a demonstration video at http://www-nishio.ise.eng.osaka-u.ac.jp/~takegawa/DownLoad/MobileClavier/top.html

5. CONCLUSIONS

We have proposed and implemented Mobile Clavier, which is aimed at increasing the playability of portable keyboards. It resolves the problems of Key Transpose by having additional black keys inserted. Using our system, musicians can smoothly play a wide range of music with Key Transpose. Moreover, we evaluated the availability of additional black keys.

We intend to evaluate a splitting function for the diapason and propose a smoother method of operating diapason changes in the future.

6. ACKNOWLEDGMENTS

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