UnitKeyboard: An Easily Configurable Compact Clavier

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ABSTRACT

Musical keyboard instruments have a long history, which resulted in many kinds of keyboards (claviers) today. Since the hardware of conventional musical keyboards cannot be changed, such as the number of keys, musicians have to carry these large keyboards for playing music that requires only a small diapason. To solve this problem, the goal of our study is to construct UnitKeyboard, which has only 12 keys (7 white keys and 5 black keys) and connectors for docking with other UnitKeyboards. We can build various kinds of musical keyboard configurations by connecting one UnitKeyboard to others, since they have automatic settings for multiple keyboard instruments. We discuss the usability of the UnitKeyboard from reviews by several amateur and professional pianists who used the UnitKeyboard.

Keywords

Portable keyboard instruments, block interface, Automatic settings

1. INTRODUCTION

Musical keyboard instrument has a long history, resulting in many kinds of keyboards today (ex. piano, choir organ, and accordion). Moreover, there are many kinds of musical forms in classical piano performance: *solo*, which is played by one performer, *piano duet*, which is a performance by two performers with a single piano, *piano duo*, which is a performance by two performers with two pianos, and *ensemble*, which is a performance by multiple groups that consist of two or more musicians.

At the same time, various kinds of electronic musical instruments have been developed. These instruments have many kinds of functions, such as diapason change and tone change. Since conventional musical keyboards cannot change their hardware configuration, such as the number of keys, musicians have to carry large keyboards for playing music that requires only a small diapason. Moreover, it is difficult to adjust to various kinds of keyboard instruments. For example, musicians cannot play music for the organ with a digital piano with 88 keys.

The goal of our study is to construct UnitKeyboard, which has only 12 keys (7 white keys and 5 black keys) and 4 connectors for docking with other UnitKeyboards. With these keyboards, we can build various kinds of keyboard configurations by connecting a UnitKeyboard to other UnitKeyboards. Since they have automatic settings considering the relationship among UnitKeyboards, and intuitive controls using sensors and actuators. Because of these special functions, UnitKeyboard is a flexibly instrument for playing music.

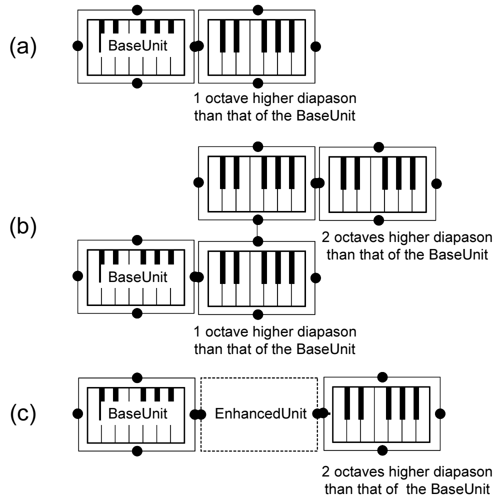

Figure 1: Combination examples of UnitKeyboard

2. DESIGN

A UnitKeyboard is a keyboard equipped with 12 keys and also 4 connectors for connecting to other UnitKeyboards. Also various kinds of keyboards can be simulated with them. For example, we can construct a keyboard of two octaves by connecting two UnitKeyboards horizontally, as shown in Figure 1-(a). Moreover, we can construct an organ that has two manuals by connecting two UnitKeyboards vertically as shown in Figure 1-(b). We can also increase the diapason by connecting an EnhancedUnit, which has various kinds of functions, between UnitKeyboards as shown in Figure 1-(c).

2.1 Characteristics of UnitKeyboard

2.1.1 Automatic Settings

We can build various kinds of keyboard instruments by docking multiple UnitKeyboards. However, users need to configure various kinds of settings for each UnitKeyboard. To reduce the setting time, we propose an automatic setting algorithm.

Connection position A UnitKeyboard is equipped with one connector on each side, left, right, top, and bottom, for connecting to other UnitKeyboards. Assignments of the

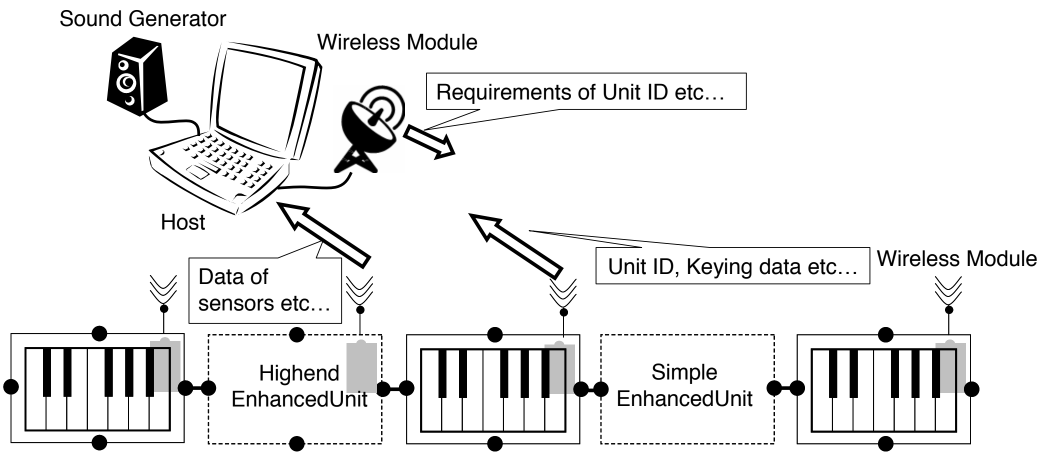

Figure 2: System structure

tone and the diapason for each UnitKeyboard depend on the configuration of the connections. Generally, single manual keyboards like the piano, have characteristics that the more left/right the position of a key, the lower/higher its pitch, and all of the keys have the same tone. Therefore, a UnitKeyboard horizontally connected to a BaseUnit, which controls the base settings such as the tone and the diapason, inherits the tone of the BaseUnit, and a diapason of the UnitKeyboard increases one octave based on the diapason of the BaseUnit as shown in Figure 1. On the other hand, a UnitKeyboard vertically connected to the BaseUnit has the same diapason as that of the BaseUnit, and the tone of the UnitKeyboard is independent from that of the BaseUnit.

Priority Between a BaseUnit and a non-BaseUnit, there is a hierarchical relationship, that is, the settings of the non-BaseUnit inherit those of the BaseUnit. We define this as priority. This is similar to an ensemble, where the multiple sections have section leaders or there is a conductor of the entire ensemble. Our system automatically assigns UnitKeyboard as low priority based on settings of a high priority UnitKeyboard.

2.1.2 Real-Time reconfiguration

Since there may be cases where the configurations and connection statuses of the UnitKeyboards should be changed during the performance, the system needs to detect them and reconfigures the settings of the UnitKeyboards in real-time.

We discuss the system design for fast real-time processing from the views points of data management.

Data management In a UnitKeyboard system, there are various kinds of system data: connection data to manage the connection relationships among UnitKeyboards, setting data for setting the diapason and the tone of each UnitKeyboard, and keying data that is generated when keys of a UnitKeyboard are pressed/released.

If each UnitKeyboard manages its own settings, each UnitKeyboard sends a connection change message to all the UnitKeyboards. Because the CPU and memory in a UnitKeyboard is limited, it is difficult to do this in real-time.

Therefore, we use a computer as the "host" to calculate the connection statuses, setting statuses for all UnitKeyboards in the system.

3. PROTOTYPE SYSTEM

Figure 2 shows the structure of the prototype system. It consists of a host, UnitKeyboards, and EnhancedUnits.

Figure 3: A snapshot of UnitKeyboard

Figure 3 shows a snapshot of a UnitKeyboard. We implemented the system using Microsoft Visual C++ .NET 2003, and we use a Sony Vaio VGN-S92PS, with the Windows XP platform as the host, Allow7 UM-100 as a wireless module, Roland SC-8820 as a MIDI sound generator, and M-audio OXYGEN8 as the keyboard. OXYGEN8 has 25 keys but we cut one in half to make the 12-keys. We use a programmable integrated circuit (PIC) microcomputer (PIC16F873) to control the UnitKeyboard and EnhancedUnit. The software on the PIC is programmed in C language on Microchip Technology's MPLAB.

3.1 Host

In the prototype, we used a PC as the host. The functions of the host are as follows.

Management of setting data The host manages the setting data of each Unit. Note that a Unit includes teh UnitKeyboard and the EnhancedUnit.

Management of connection statuses The host directly manages the connection statuses of all the Units. Moreover, the host calculates the setting data of each Unit's configuration from the connection data of all the Units.

Process of sound generation The host generates a MIDI Note On/Off messages based on the setting data of the Units and keying data sent from a UnitKeyboard.

3.2 UnitKeyboard

The hardware structure of a Unit is shown in Figure 4. A UnitKeyboard consists of a PIC, a 12-key keyboard connectors on all four sides, and a wireless module to communicate to the host. A UnitKeyboard has the following functions.

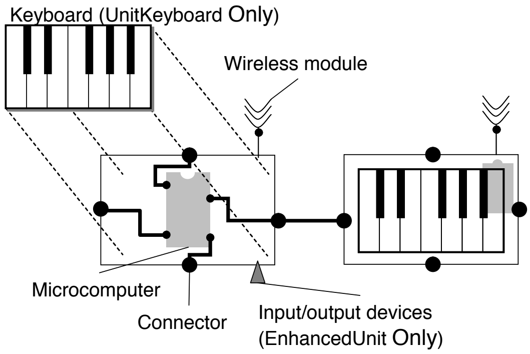

Figure 4: The hardware of Unit

Establishing connection to the host A UnitKeyboard broadcasts a "New Entry" command after it is turned on, and when the UnitKeyboard receives acknowledgement from the host, it sends an "ID" and "connector data", such as the number of connectors, to the host.

Sending keying data A UnitKeyboard sends keying data to the host, when the status of the UnitKeyboard keys is changed.

Sending connection data A UnitKeyboard sends a "Connection Status" command to the host, when the status of its connectors is changed.

3.3 EnhancedUnit

The EnhancedUnit has two models: a simple model that only controls the diapason of a UnitKeyboard and a high-end model that is equipped with sensors, actuators, and a wireless module to operate settings of the UnitKeyboards. The former is inserted between UnitKeyboards to increase the diapason. It has a simple structure that consists of two connectors and a variable electric resistance.Since the connectors of a UnitKeyboard can measure the change of voltage that works with the number of the variable resistance, UnitKeyboards that interleave with simple EnhancedUnits convert the amount of voltage to changing the diapason.

Figure 4 shows hardware of the high-end EnhancedUnit. The main differences between the EnhancedUnit and the UnitKeyboard are that the EnhancedUnit does not have a keyboard and has various input/output devices. The high-end EnhancedUnit has the following functions.

Connection to the host The enhancedUnit broadcasts a "New Entry" command after the power is turned-on and establishes connections with the host just like a UnitKeyboard.

Sending connection data The EnhancedUnit monitors the status of its own connectors, and it sends a "Connection Status" command to the host when it detects a change of connection just like the UnitKeyboard.

Sending of input data from input devices The EnhancedUnit collects data from input devices, and informs the host of this according to the requirements of the host.

Control of output devices The EnhancedUnit controls output devices according to commands sent from the host.

3.3.1 *Input/Output devices*

We developed a high-end EnhancedUnit prototype equipped with various kinds of input/output devices.

Distance sensor Users can control diapasons of a UnitKeyboard neighboring an EnhancedUnit equipped with distance sensors. For example, the longer the distance between the UnitKeyboard and the EnhancedUnit, the higher the diapason of the UnitKeyboarda.

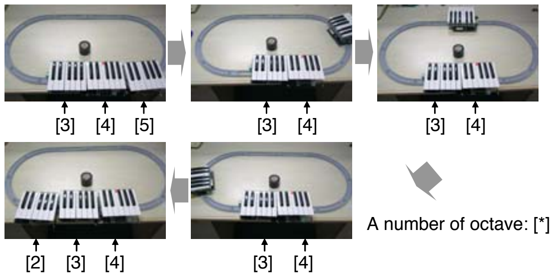

Figure 5: An EnhancedUnit with electric motor

Acceleration sensor Users control the tone of UnitKeyboards with the users' posture that is calculated and detected from data of the acceleration sensor.

Motor Users can move UnitKeyboards automatically by using an EnhancedUnit equipped with motors attached to a propeller and wheels. For example, if musicians use an EnhancedUnit equipped with a motor and wheels, they can add/subtract a diapason by automatically moving a UnitKeyboard as shown in Figure 5.

4. CONSIDERATIONS

We discuss the usability of proposed UnitKeyboard from the reviews by 5 amateur pianists and 5 professional pianists that actually used the UnitKeyboard. We have demonstrated UnitKeyboard in various kinds of events such as *Kobe Luminarie Live Stage* on December 8th and 9th, 2007. It began in 1995 and commemorates the Great Hanshin earthquake of that year about 4 million participants attended last year.

4.1 Performance Evaluation

Visibility We checked the function that automatically assigns the settings of the UnitKeyboard assuming the relationship among all the UnitKeyboards were working well. The host settled conflicting settings among the UnitKeyboards. Moreover, the proposed automatic-assignment algorithm was intuitive from participants' reviews.

Because he participants could see the connection relationships between the UnitKeyboards, it was easy to recognize the relative diapason of each UnitKeyboard. However, it was difficult to recognize the absolute diapason of each UnitKeyboard. In present implementation, participants could not see the BaseUnit and the diapason of the BaseUnit. Therefore, participants had to press the keys of each UnitKeyboard to check the diapason.

For future work, we plan to develop an EnhancedUnit with LEDs and a display for checking the settings of the UnitKeyboard.

Wireless vs. Wired connections We adopted a wireless connection for communication between the host and the Units.

In the wireless connection, although there was some delay between the keying to the output sound. The delay was not so noticeable in the music. However, the more UnitKeyboards were used, the higher the possibility was for packet loss and longer delays.

On the other hand, the delay produced using wired connection was less than that of the wireless connection.

Because both methods have advantages and disadvan-

Figure 6: Snapshots of collaborative performance

tages, we will conduct a more detailed evaluation for each method in future work.

One-octave UnitKeyboard In this study, a UnitKeyboard had only one octave from C to B. This diapason is effective in music of only C major or C minor.We can solve this problem by using the Mobile Clavier[7], which enables a smooth change in diapason.

4.2 New performance

We conducted performance with UnitKeyboards and EnhancedUnits.

As shown in Figure 6, when there was a lack of diapason during the performance, a musician solved it by borrowing a UnitKeyboard from another performer. Moreover, as shown in Figure 5, a keyboard moving automatically to a commanded location was visually interesting. These performances are not only musically entertaining but also visually attractive.

4.3 RELATED WORK

There has been a large amount of research whose main goal was improving a function by combining simple functional units. For example, users can control an object in a game by combining LEGO blocks[1], control website browsing by combining triangle boards[2], or control programming with combined blocks[3]. Moreover, there are block interface equipped input/output devices[4]. These targets were not musical like our study.

On the other hand, a system whose for music composition functions by combining blocks assigned for mood music[5]. Moreover, there are systems, DoublePad/Bass[6] and Mobile Clavier[7], which were developed to improve the portability of acoustic instruments. DoublePad/Bass is base instruments using two PDAs. Musicians who play an electric bass should be able to easily play it. Mobile Clavier enables the smooth change of diapason by allowing additional black keys to be inserted. These instruments were not designed with concept of combining units or for various kinds of keyboard/string instruments

5. CONCLUSIONS

We proposed the UnitKeyboard, which can apply various kinds of keyboard instruments by connecting one-octave keyboards together. Moreover, the UnitKeyboard has various functions such as the automatic settings considering the relationship among multiple UnitKeyboards, intuitive controls and new performance using an EnhancedUnit.

We intend to evaluate the hardware and the usability of the system in the future.

6. ACKNOWLEDGMENTS

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