POWDER BOX: An Interactive Device with Sensor Based Replaceable Interface For Musical Session

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ABSTRACT
In this paper, the authors introduce an interactive device, "POWDER BOX" for use by novices in musical sessions. "POWDER BOX" is equipped with sensor-based replaceable interfaces, which enable participants to discover and select their favorite playing styles of musical instruments during a musical session. In addition, it has a wireless communication function that synchronizes musical scale and BPM between multiple devices. "POWDER BOX" provides novice participants with opportunities to experience a cooperative music performance. Here, the interaction design and configuration of the device is presented.

Keywords
Musical instrument, synthesizer, replaceable interface, sensors

1. INTRODUCTION

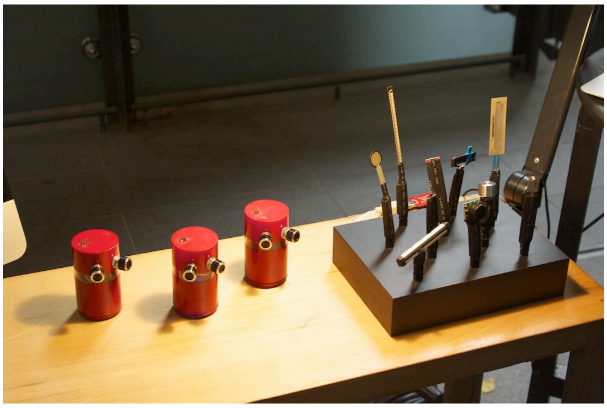

Figure 1: "POWDER BOX" with sensors

To date, various kinds of "inventive" electronic musical instruments have been created in the field of Computer Music field. The authors are interested in formations of musical sessions, aiming for a balance between simple interaction and musical expression. This study focuses on the development of performance playing styles.

Musicians occasionally change their playing styles (e.g., guitar plucking style) during a musical session. Generally, it is difficult for nonmusicians to achieve this kind of smooth changing depends on levels of their skill acquisition. However, it is essentially important for enjoying musical sessions whether people could acquire these skills. Here, the authors attempted to develop the device that supports nonmusicians to conquer this point using replaceable interfaces. The authors expected that changing interfaces would bring similar effect as changing playing style by the skillful player. This research aims to establish an environment in which nonmusicians and musicians share their individual musical ideas easily.
Generally speaking, a balance between simplicity of interaction and advanced musical expression is difficult to attain on a single device or system. Indeed, balancing ease and expressiveness is a recognized key concern for interface designers [1].
Focusing on these issues, here the authors specify three important requirements of the simplicity/expressiveness balance, implemented on the device. They are as follows:
(1) **Interfaces**: Interface that enables novices to control three sound elements (pitch, tone, and amplitude) with replaceable sensors.
(2) **Synchronization**: System that supports ensembles by automatically synchronizing tempo (BPM) and tonality between multiple devices.
(3) **Portability**: System that runs stand-alone (with sound generator, built-in speakers, and butteries).
In this paper, the authors introduce "POWDER BOX". "POWDER BOX" is equipped with a replaceable interface, which is based on various sensors enabling nonmusician to create multiple playing styles.

2. RELATED WORKS
2.1 Replaceable Interfaces/Sensors
Previously, Tinker-it! has developed "TinkerKit" [2], a simplified prototyping platform with sensors and actuators shielded on an Arduino board. The latter is a handheld microprocessor designed for simple integration of electronic projects. Similarly, LittleBits Electronics has developed a prototyping and playing system named "LittleBits," This is an open source library of electronic modules that snap together by tiny magnets [3][4]. However, these platforms are not designed for electronic musical instruments. Sound output and musical instruments constitutes a different type of research. "MaKeyMaKey" (Jay Silver et al.) is a new platform for improvising tangible user interfaces. The platform enables users to create natural interfaces, is compatible with all software, and requires no programming or electronic assembly by users. Participants can also use the platform for sound control [5][6].

2.2 Unitized Musical Instruments

Many researchers have attempted to construct simple musical instruments from functional units. “Molecule Synth” (Travis Feldman) is a unitized analog modular synthesizer comprising three elements; speaker/amp, sound generator, and pitch control. “Molecule Synth” combines LEGO-like interchangeability with Synthesizers with Physical Electronics [7]. “UnitInstrument” is a musical instrument system (Maruyama et al.) in which multiple units are connected to construct different types of musical instruments [8]. However, these platforms or systems are too complex for use by nonmusicians.

2.3 B.O.M.B. –Beat Of Magic Box-

Figure 2: “B.O.M.B. —Beat Of Magic Box—”

Previously, the authors have attempted to create a device satisfying the above requirements using grasping as an intuitive, simple interaction.

The “B.O.M.B. —Beat Of Magic Box—” (Figure 2), allows participants to control the pitch, tone, and volume by a “grasping” interaction (satisfying requirement (1)). This is achieved by assigning position and pressure sensor values to pitch control, such that the musical score is grasped in one hand [9]. A wireless communication system provides an experience of cooperative music performance without recourse to musical theory (fulfilling requirement (2)). “B.O.M.B.” has three musical instrument modes, Rhythm, Solo (melody) and Bass (harmony), which participants can alter by a “shaking” interaction. This device includes sound generator using Arduino (fulfilling requirement (3)). However, “B.O.M.B.” had not mounted replaceable interfaces, because the authors had focused on grasping interaction.

Emphasizing simplicity, general versatility, and uniqueness of sensors, the authors have developed a replaceable sensor-based interface.

3. DESIGN

3.1 Design Concept

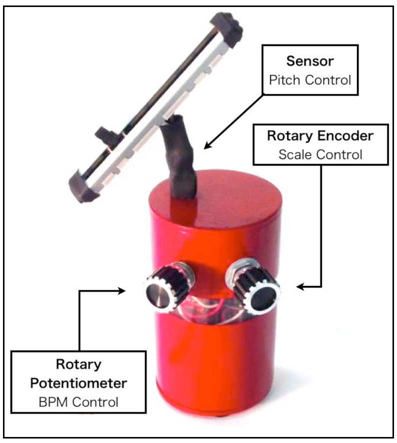

Figure 3: Appearance of “POWDER BOX”

3.1.1 Advantages of Replaceable Interface using sensors

As mentioned above, nonmusicians experience difficulty in changing their playing styles. Therefore, the proposed interface responds to multiple playing styles. Generated sounds and playing styles will differ despite use of same sound generator.

3.2 Hardware

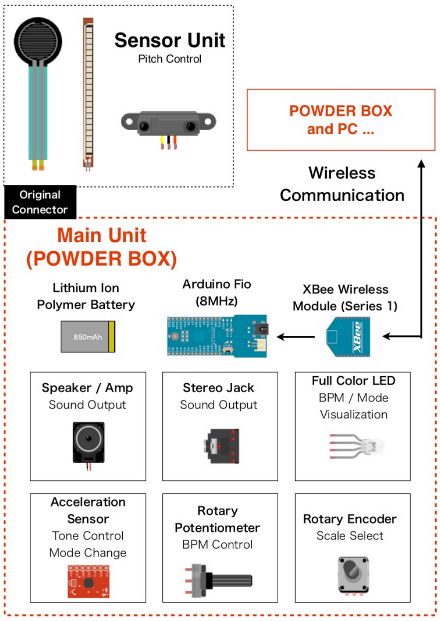

Figure 4: System of “POWDER BOX”

3.2.1 Portable Musical Instrument

Because musical sessions can be improvised at any place and time, the authors consider that portability is essential in designing musical instruments for sessions. The Arduino Fio (microcontroller board based on the ATmega328P, operating at 3.3V and 8 MHz with XBee wireless module socket) was included in the proposed device because of its portability and wireless communication function. In addition, “POWDER BOX” requires no external power supply, but is powered by a lithium ion polymer battery (850 mAh). A charged single battery guarantees approximately 10 hours running time (Figure 4).

3.2.2 Controllers

3.2.2.1 Sensor (Pitch Control)

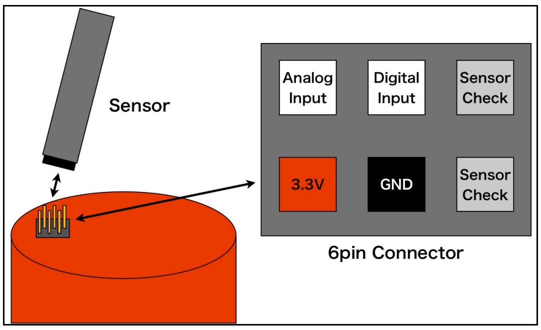

Figure 5: Structure of original common connector

Sensor values are input to the proposed device via a 6-pin original common connector. The sensor values are assigned to pitch control; thus participants can select various sensors for their performance without knowledge of the electronic circuit. Because the device requires three inputs, two GNDs (ground) and 3.3V input for sensor inputs and a mute function; (Figure 5), the connector fits only one way. However, if the sensor is connected in the reverse direction, the connector can avert circuit failures. A planned future project is to improve this design.

3.2.2.2 Rotary Potentiometer and Encoder (BPM and Scale Control)

Two controllers are attached to the side the device (Figure 3). The rotary encoder, on the left side, assigns sensor values to the BPM value, while the rotary potentiometer, on the right side, assigns values to the select-function scale. Electronic parts are used in these controls, since BPM and Scale are infrequently changed.

3.2.2.3 Acceleration Sensor (Mode Change and Filter Control)

The proposed device is equipped with an acceleration sensor for Mode Change and Filter Control. This achieves an intuitive interaction that controls the filter effect with one hand and the control pitch with the other. Together, the connected and acceleration sensors allow simple control of all sound elements.

3.3 Sound Synthesis

"POWDER BOX" uses the Arduino based PWM synthesizer "Auduino" developed by Tinker-it! [9]. This device assigns sensor values to a MIDI notes number according to scale setting, and generates sound from a built-in speaker or a Φ3.5 mm stereo jack. The jack is compatible with audio interfaces or general speakers. The eight musical scales generated by the device are shown in Table 1. The authors selected general scales for performing.

Table 1: Musical Scales

No.	Scale
1	Minor Pentatonic
2	Major Pentatonic
3	Minor
4	Major
5	Lydian
6	Ryukyu
7	Octave
8	Chromatic

3.4 Wireless Communication

Wireless communication is achieved using a XBee wireless module (Digi International: Series1). This function automatically synchronizes the musical scale and BPM between multiple devices, thereby supporting musical sessions for nonmusicians.

4. HOW TO PLAY

4.1.1 Choose Sensor

Figure 6: Sensor units (From the left: Infrared range sensor, Strain gauge sensor, Membrane potentiometer, FSR Pressure sensor, Rotary potentiometer, Ultrasonic Distance Sensor)

The authors have designed a number of sensors (Figure 6). Participants with little knowledge of electronic circuitry could easily design sensors for other playing styles if desired.

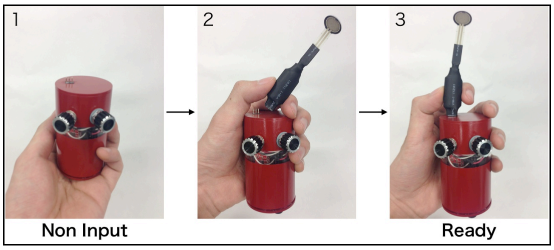

Figure 7: Example of a sensor setting (FSR Pressure Sensor)

The common connector allows attachment and detachment of different sensors (Figure 7).

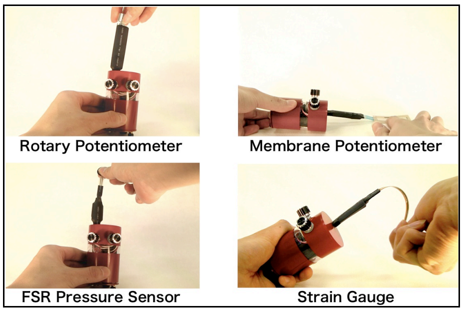

Figure 8: Playing style variations on "POWDER BOX"

The different features of expression and interaction provided by the sensors allow participants to create novel playing styles (Figure 8).

4.1.2 Choose Performance Mode

The proposed device includes a Mode Change Control with a "shaking" interaction. This function is achieved by an acceleration sensor (MMA7361). Participants can select from one of two performance modes providing the experience of a band performance. The modes are distinguished by the color of an internal Full-color LED, visible through a slit in the device body (Figure 9). Solo and Arpeggiator Modes are identified by blue and green LED light, respectively.

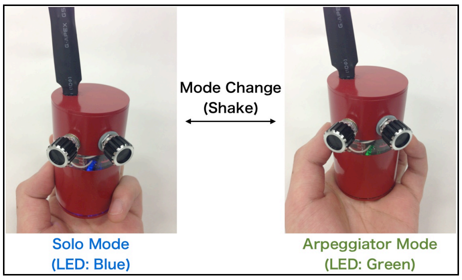

Figure 9: Mode Change

4.1.2.1 Solo Mode (LED Color: Blue)

With sensors attached, Solo Mode provides melodic phrase performance. In this mode, the value of a connected sensor is assigned to pitch. If the pressure sensor is used, a pressure value is converted to a MIDI note number and sounds are generated on a real-time scale. Participants can control the filter effect by change in slope with the acceleration sensor.

4.1.2.2 Arpeggiator Mode (LED Color: Green)

Arpeggiator Mode provides BPM-based pitch sequence performance. Sensor values input to Arduino are mapped to pitch in time-synchrony with BPM. BPM speed is confirmable, because the embedded Full-color LED blinks in time with BPM. BPM Control is assigned to the Rotary potentiometer on the side of the device (Figure 3). The Arpeggiator Mode operates identically to the Solo Mode.

4.1.3 Synchronization

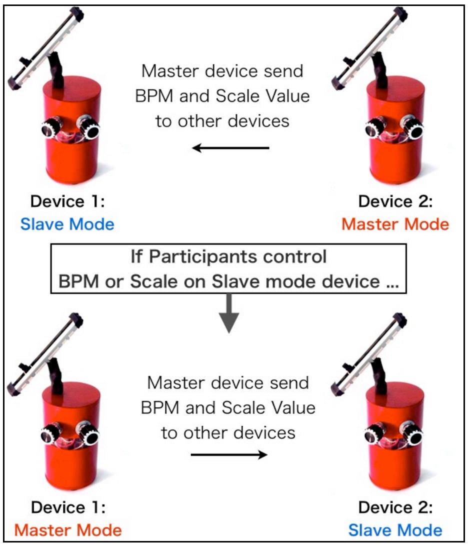

Figure 10: Master and Slave Mode control

This device requires no special settings for synchronization. If a participant desires to alter the BPM or Scale controller, the device sends the controller values to other wireless devices. Simultaneously, the sending device is automatically set to master mode while the receiving devices are set to slave mode.

5. EXHIBITION

The authors exhibited this device twice and gave several live performances using the device.

During the exhibitions, the authors observed the participants experiences and reaction toward the device. Several participants spent around three minutes playing with the device and offered their feedback. Children, in particular, enjoyed replacing sensors and frequently played for over five minutes (Figure 11).

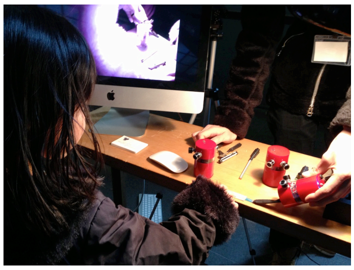

Figure 11: Experience of participants

6. FUTURE WORK

Having obtained participant feedback, the authors will attempt to develop a more sophisticated sensor connector and synchronization system on "POWDER BOX". In addition, the authors are considering incorporating "Mozzi", a sound synthesis library for Arduino [11]. In future, the authors will evaluate the device in terms of its interaction simplicity and expressiveness for nonmusicians.

The purpose of the proposed device is to enable nonmusicians to participate in music sessions. The authors consider that many people, not just musicians, enjoy sharing their musical ideas.

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