A design process of musical interface “PocoPoco”: An interactive art work case study

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We developed original solenoid actuator units with several built-in sensors, and produced a box-shaped musical interface named “PocoPoco” using 16 units of them as a universal input / output. From the beginning to the time when a professional artist used it for live performance, we experienced many problems and had to solve them. In this paper we present a design process of PocoPoco, explaining solutions for problems we faced. Then we discuss the process of problem-solving to design an interface for practical use.

1. Introduction

In this paper, we describe a design process of PocoPoco, an interface we researched and developed. It was developed as an interface to provide dynamic affordance with movable parts. Through various processes, now it is being used in a live performance of a professional artist.

We study about interaction design[1][2]. At the beginning this research started as an investigation of possibility of kinetic interface. We experienced various trial and error to implement this interface. At the same time we received so much feedbacks thorough demonstrations and live performances.

In this paper, we explain how we solved actual problems and discuss a design process to develop practical interfaces.

1.1 Abstract of PocoPoco

PocoPoco is an interface that can provide dynamic tangible information using movement of its movable parts. It has original solenoid devices for output and several optical sensors for input. The original solenoid unit consists of a base-parts and movable-parts, and they can move up and down by control from a build-in computer.

The units have built-in tactile switches to detect user’s push and built-in optical sensors to detect each unit’s height and rotations. Then this system can detect user’s “pushing”, “catching”, “turning” and “blocking” actions.

At the same time, there are two full color LEDs in each unit. The computer also controls the switching and the color of light.

This device has one set of MIDI IN / MIDI OUT terminal. It sends MIDI note messages to the outside sound source. At the same time other MIDI devices can control PocoPoco via MIDI control change messages.

Users can (1) edit sound loops, (2) play notes like keyboards and (3) manipulate sound effects by intuitive actions such as “pushing”, “catching”, “turning” and “blocking” with PocoPoco.

Hardware system, software system and processing for I/O is minutely described in [3].

Here we show our PocoPoco’s development process at figure 1.

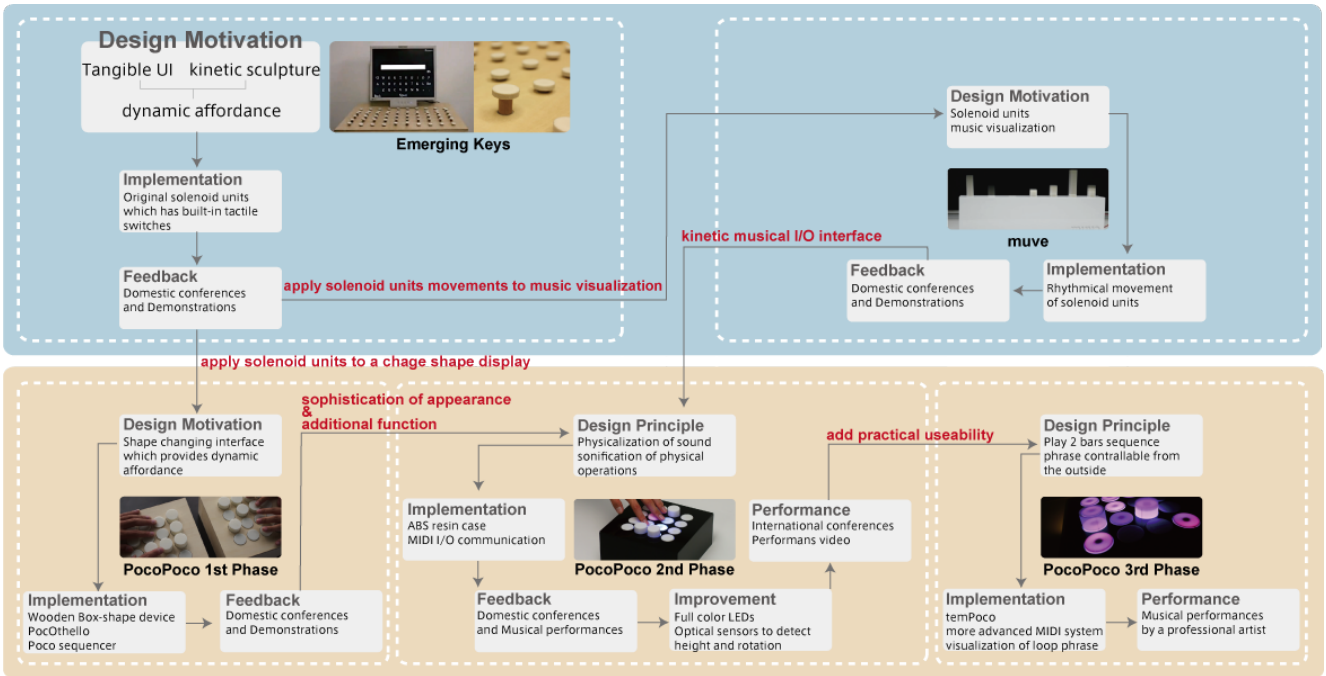

Figure 1 Abstract of a design process of PocoPoco

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2. Pre Implementation

Before we planed PocoPoco, we made two preceding works. “Emerging Keys” became basis of PocoPoco I/O system. “muve” showed a possibility of visualization of sound by up-and-down movements of solenoid units.

2.1 Emerging Keys

Emerging keys is a device that changes their interface in accordance with the purpose of use [7]. For the purpose of typing, they transfer to a keyboard, for the purpose of game, they float and user can use it as a controller.

2.2 Muve

Muve is a tangible music visualizer with seven original solenoid units [8]. It decomposes audio data to seven frequency ranges using Fast Fourier transform. And seven solenoid units move up-and-down corresponding to the sound level of each frequency level.

3. PROTOTYPE IMPLEMENTATION

In this chapter, we describe a development process and two applications we made in the prototype implementation phase.

3.1 Conception

When we investigated previous studies of haptic interfaces, we discovered that most of games or electronic musical instruments are hard for users to control without visual information. Study of interfaces that can be used without visual information would lead to a development of universal interfaces useful for visually impaired people.

In the case of Emerging keys, our previous work, our concept was making an interface that can change the shape of a controller dynamically. Then the role of solenoid units was just forming various shapes, so the movements of them were not being focused seriously. Emerging keys was designed as a device that outputs image and sound. Accordingly, it had a display and a set of speakers.

We turned attention to movement of solenoid units itself and started considering a new interface that can provide visual and haptic effect for interactive system. The interface provides advanced interactions by integration of input parts and output parts. To present the tactile sensations of all solenoid units, the device was considered to be large enough to fit both hands of the user. Then we changed the number of solenoid units, from vertical and horizontal 6×10 of Emerging keys to 4×4, and designed the size of device vertical and horizontal 205 × 205mm, it is suitable to feel all of the solenoid units’ movements when a user covers the device with both hands.

3.2 Hardware

The prototype was designed as shape changing display, to be used for a multiplicity of uses such as a communication tool, game and musical instrument.

Original cylindrical units that can move up-and-down by solenoid actuators, named “Poco”, are mapped into a 4x4 matrix. A tactile switch is embedded in each of the unit. So this unit can work as button input device.

A micro controller board, Arduino Mega, processes all the input-output control system.

In addition, we installed two speakers and a sound generation module, to realize sound output. And we installed one USB terminal to communicate with the outside computers. The casing consists of plywood.

3.3 PocOthello

PocOthello is a game application of PocoPoco inspired by board

Figure2 playing appearance of pocOthello

game, Othello. PocOthello uses concavo-convex shape of Solenoid units to tell the condition of pieces meanwhile ordinary Othello uses black and white color of the surface (Figure 2). When user pushes Solenoid units, PocOthello builds the concavo-convex shape by computerized control in each case and PocOthello expresses a passage of pieces by the motion of Solenoid units. The feature of this application is that when users put their hand on the device user can recognize the condition of pieces haptically. Therefore, visually impaired people who cannot play ordinary Othello can play this game.

3.4 Poco Sequencer

Poco sequencer is an application developed to use PocoPoco as a musical interface. Using this application, users can make loop music easily. Through the survey of sequencer type musical interfaces, we found most of them are making music by playing some musical phrases every bar or multiple bars. As seen in most of rhythm machines and music sequencers like Tenori-on, time progress in the sequence is expressed by a shift of timeline from left to right.

This system seems to be attributed by the fact that in general musical score time progress is expressed by a shift of timeline from left to right. In the case of Tenori-on, the device has 16×16 IO units and each row means one bar of a musical instrument. In the case of PocoPoco, to express sequence by 4×4 units, we applied a method to shift left top to right bottom, 16 units expresses one bar of a rhythm sequence (Figure 3). In the

general musical score, time progress is expressed by a shift of timeline from one row to lower row, so this method seems to be easy to understand.
When a user pushes the top of a cylinder, its switch is flipped to the "on" position causing the cylinder to rise and a sound to play at regular intervals. When a Poco turned on is pushed down, its

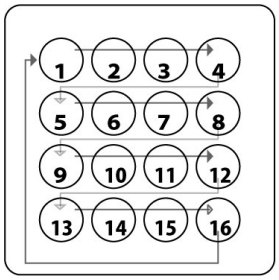

Figure3 order of the timeline shift

switch is moved to the "off" position and movements and the sound stops. Each Poco means a sixteenth notes, users can make loop phrase by selecting and pushing them freely. These tones are arranged so that a pleasant harmony results no matter which combination of notes is used.

Layers

PocoPoco has relatively few IO units and it can't express loops for multiple instruments at the same time. So we applied layers. Poco sequencer manages multiple layers in the program. Each layer keeps the sequence of one instrument. So users can pile up different musical phrases by changing layers. And each layer has a characteristic sound tone. Users can change layers by pushing specific 4 units at the same time.

3.5 Exhibitions and feedbacks

After the first implementation, we presented PocoPoco to some domestic study groups and displayed to some exhibitions.
The automatic movements of cylindrical units seemed to attract audience, from children to researchers.
Poco sequencer was praised in particular. The rhythmical movements of units seemed to attract audience. Thus we decided to concentrate to developing a musical interface using this device.

4. Improvement For Musical Performance

In this section, we describe about the phase when PocoPoco progresses from the first implementation to an especial interface for musical performances.
We explain the progress about hardware, software, and a musical performance by ourselves.
In the prototyping phase, it looked that the concept of shape display formed by solenoid actuators has some evolvability. Especially, Poco Sequencer, a musical application we made got positive feedbacks in some demonstrations and presentations.
Therefore we decided to improve PocoPoco as a practical interface for playing music.

4.1 Hardware

To make PocoPoco practical musical interface, we improved hardware systems. We implemented MIDI IN / OUT on the device, and we developed musical performance system through MIDI communication.
And we took away the wooden case and made a black ABS resin case alternatively. From the feedbacks we got by exhibitions of the first implementation, some new ideas for more intuitive interactions occurred to us. We witnessed many user tried to catch the popping units, or rotate or press cylindrical units. Despite they didn't receive any explanations about playing methods, but they tried "holding ","blocking" and "turning" actions as if they were granted actions. Then we considered these actions were quite intuitive for users, and we tried to map these actions to musical manipulations. To realize it, we implemented additional sensing system using multiple optical sensors. We installed three photo-interrupters in each solenoid unit, to detect units' rotation and up-and-down movements.
Through some demonstrations and live performances, the idea to install full color LEDs in solenoid units was occurred to us. This full-color-light is controlled by the computer, so its color and timing can be corresponding to up-and-down movements. After this implementation, up-and-down movements with flash became more impressive and attractive for audience.

Detection of height and rotation

To detect the height of movable parts, we fixed a photo-interrupter on the base parts. This sensor tells the distance between base parts and the top of movable parts.
In addition, we installed two photo-interrupters to detect the rotation of the unit. The movable parts were rotatable around the axle of the unit. We made slits in the movable parts. Using these two photo-interrupters' data, the program detects rotation like rotary encoder (About these sensing system, please see [3] for details.).

4.2 Implementation of MIDI system

To enable standard live performances, we took away built-in speakers and a sound generator module, then implemented MIDI IN / OUT terminals on the device, and developed MIDI communication system.
By using general MIDI communication, users can use any sound generators, workstations and speakers with PocoPoco, easily.
PocoPoco's importance as an interface is not generating sound but haptic manipulation of sound. So we chose to concentrate on designing a haptic MIDI interface.

MIDI OUT

PocoPoco sends MIDI note messages from MIDI OUT, to play sound in the sound source. MIDI messages are sent to DAW (Digital Audio Workstation) software, Logic Pro in the computer, through a MIDI interface. Logic Pro play sounds, corresponding to the MIDI note messages.

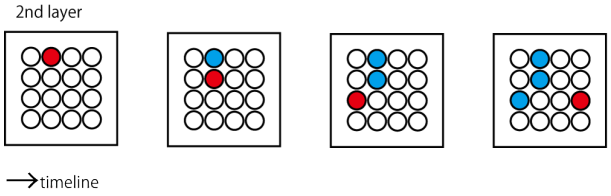

Figure4 example of the original scoring for PocoPoco

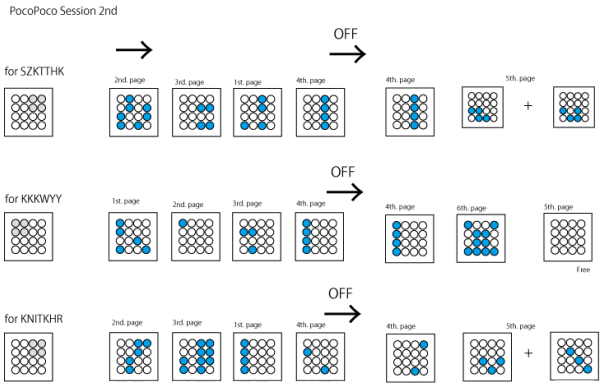

Figure5 score we used for the performance

Figure6 performance using PocoPoco as a vocoder

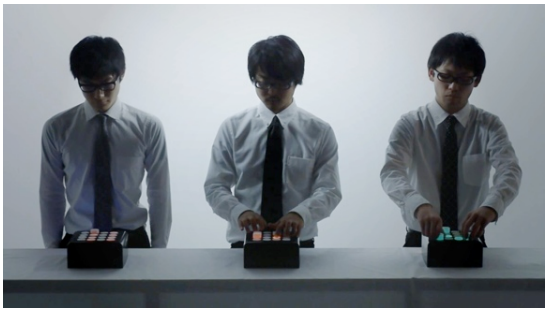

Figure7 a screen shot of the published movie

MIDI IN

PocoPoco can be controlled by MIDI messages sent to MIDI IN. START, STOP, RESTART of sequence is controlled by general MIDI control messages. Users can send the control messages using DAW or MIDI controllers.

And users can control PocoPoco's rhythm by sending MIDI clock messages. Users can synchronize multiple devices by sending same MIDI clock message to them. For example, we were using MAX / MSP to synchronize 3 devices for 3 performers' ensemble.

4.3 Implementation of Real-time mode

Through demonstrations in study groups and exhibitions, we found that most of musical beginners were supposing all the instruments generate sound after input gesture immediately.

In addition, PocoPoco's sequence function is suitable to compose some rhythm sequences like a drum set, but it is not suitable to play a melody. Then we implemented "Real-time mode" additionally. In this mode a sound note is played once the unit is pushed immediately.

4.4 Designing original score

As mentioned previously, this interface is optimized to play sequence phrases, and the playing method is not similar to the one of acoustic instruments like piano and guitar.

During making performance systems, we found ordinary musical score is not suitable for PocoPoco's play. So we designed original musical score (figure 4,5). In this score, the timeline moves left to right, and the units to be pushed is expressed visually.

4.5 Performances and feedbacks

Until now, we performed 8 musical performances and 11 demonstrations including ACM SIGGRAPH 2011 Emerging Technologies, and we estimate thousands of visitors played PocoPoco and watched our musical performances. Every time we get some feedbacks from visitors, we have been making many improvements to PocoPoco. Below we introduce some actual performances and feedbacks.

At the intercollege computer music concert 2010 on December 5, 2010, three of us performed the first ensemble concert. In this performance the synchronization of multiple PocoPoco with MIDI communication, the sound synthesis using external sound source, the Real-time mode to play the melodies, and an original score for the original composition were realized. From the fact that this performance has gained the support of audience and researchers, an ensemble format for three performers has been the basic form of our musical performances. Also, at that time we got the first idea of "catching" and "turning" operations, from the feedbacks of other researchers.

At the 89th IPSJ Special Interest Group on music and computer (SIGMUS) conference on February 11, 2011, we added one microphone to three PocoPoco, and we played songs including vocal performance. The vocal sound was processed like robot voice, and at that time one PocoPoco was working as a vocoder. The player could decide the vocoder's pitch by pushing PocoPoco's solenoid units, like real-time mode. This playing method was developed to expand PocoPoco's playability, but from the feedbacks we found the interaction between actions and sound was not clear for audience, then we abandoned this

method as a result.
In June 2012 we published a movie of 3 performers' ensemble on the web. As of February 2013, this movie has been played more than 30 thousands times, and commented more than 35 times. Possibly this fact prove the potential of the musical performance with PoccoPoco.

5. Collaboration With a Professional Artist

In this capture we describe a development process of PocoPoco's third implementation. In this phase we did a collaborative research with a professional artist LITTLE BOOTS, based in London. Through this collaboration, we improved PocoPoco to achieve her requests, and then this interface became more practically useful and attractive. We explain the process from the beginning of this collaboration to the live performance she used PocoPoco in public.

5.1 LITTLE BOOTS

Victoria Christina Hesketh, well known as LITTLE BOOTS, is electro pop singer songwriter born in U.K. She is a versatile player and she plays piano, keyboard, synthesizer, Tenori-on, and etc. on the stage. She performed in Japan SUMMER SONIC 2009 at first. Including solo performance in Japan, she continues to perform actively at home and abroad.

She found our research through the Internet, and offered the collaboration with us. At that time PocoPoco had never been played on commercial music stages.

By complying request from a professional artist, we could improve the interface efficiently. Thus we decided to collaborate with her. For this collaboration we had one meeting and exchanged emails about 150 times so far.

5.2 Process of collaboration

This collaboration started from a meeting at Tokyo. As her artistic characteristic, he takes a lot of electronic instruments and synthesizers in musical performance. She says she demands for her musical interface to be as visual as possible for a live performance so the audience can see what is happening and understand how the sound is created. And she says if the audience can make a connection between what they are seeing and what they are hearing then that is the ultimate achievement for her for a live show. From this point of view, PocoPoco, an interface that physicalizes sound by object's movements and light, seems to be suitable interface for her live show. Also, because she mainly plays dance music, she often plays on the dark stage and light of PocoPoco fits to the music. Through meetings and exchanges of e-mail, we reached one conclusion that the new PocoPoco she would use should be able to play two bars long phrases, to play a motif phrase of her representative song "Shake". At the same time, the sequencer had to be controlled by an outside interface (For example other instrument players can stop and restart the sequence using a MIDI interface). To achieve this we had to develop a more advanced MIDI system. In addition, for the audience, she hoped more impressive visualization of sound.

5.3 TEMPoco

PocoPoco's 4x4 matrix units are suitable to express 16 beats phrases. On the other hand it is not good at expressing long bars phrases. To enable PocoPoco to play 2 bars phrases, we had to remedy a defect. Then we developed a new gadget named "TEMPoco". This device relays MIDI messages between the outside interfaces and PocoPoco.
It has 3 sets of MIDI I/O terminals. One is connected to the outside interface and others are connected to two PocoPoco (Figure 8). TEMPoco receives MIDI clock messages from the outside, and sends one bar's MIDI clock messages to one PocoPoco alternately. Each PocoPoco play one bar phrase one by one, then two of them can consist 2 bars loop phrases.
TEMPoco bypasses all MIDI note messages from two PocoPoco to the outside interface. In addition, control messages such as "stop", "restart" and "reset" are sent from the outside interface and relayed to two PocoPoco at a time. A program in PocoPoco receives these control messages and controls its sequence. Using TEMPoco, we could enable PocoPoco to "play 2 bars long phrases" and make it "controllable from the outside".

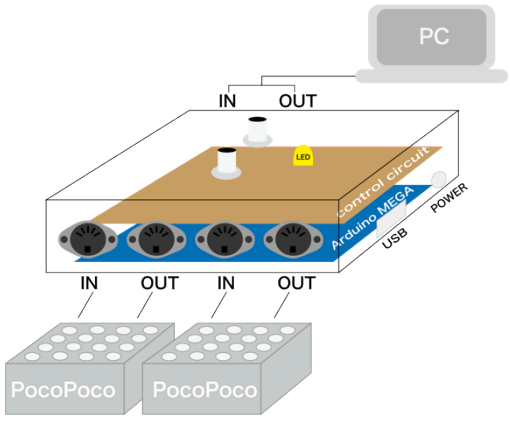

Figure8 communication system of TEMPoco

5.4 Visualization of the timeline

For more impressive interaction, we visualized sequence timeline by LEDs' flash. The flash pointed the timing of 16 beats. In addition, we set up respective light color for each layer. When some unit's switch is turned on, the unit continues to turn on the light. Using this system, users could compose rhythm sequence like drawing (figure 9).

5.5 Performance and feedback

May 4, 2012, at XOYO London, LITTLE BOOTS used PocoPoco for her public live performance at first. In this performance two PocoPoco were connected to TEMPoco, and could play her song "shake" without mishap.
After that we performed a questionnaire by e-mail to her about evaluation of PocoPoco as a musical interface. As good points, she mentioned

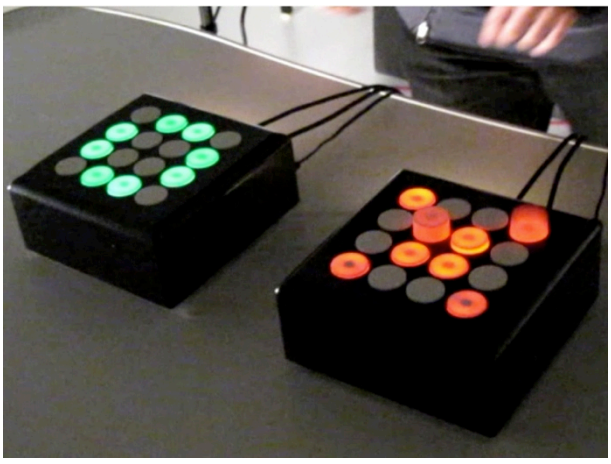

Figure9 Playing appearance of PocoPoco, the third phase

·a music novice or beginner could easily play with PocoPoco and start making music and begin to understand the connection between what they are playing and how the sound is reacting.
·a trained musician like herself can use it and get to a very advanced level of programming and performing with it quickly

In fact she says that she witnessed large audience was gazing on and fascinated by PocoPoco's movements.
On the other hand, she mentioned bad points below

·The main difficulty for her with PocoPoco is it is not stable enough to be moved around for live performance and touring travel

·She had many problems with the solenoid units not reacting or getting stuck and having to open up the inside but repairing them was too hard for herself.

We consider that these problems are due to the fact that many of the current manufacturing steps of PocoPoco is dependent on the handwork. Changing the course of production, such as outsourcing some modules, may solve these problems.
Even though it has a difficult point about stability, she is highly approving the potential of PocoPoco as a musical interface for full-fledged musical performances. This collaboration will continue and additional improvements will be implemented. PocoPoco will be more stable and practical to be used for various performances.

6. Conclusions

In this paper we described a design process of PocoPoco. Through various design processes such as planning, implementation and evaluation, PocoPoco made refined as a practical interface. Especially, collaboration with a professional artist seemed to be an efficient process to improve the interface. PocoPoco can provide advanced interactions by integration of input parts, such as a tactile switch and photo-interrupters, and output parts, such as a solenoid actuator and full color LEDs into a small unit. This unit is just a cylinder as long as it has stopped, but once it starts to move and flash, it can provide various impressions such as Whac-A-Mole or a knob. More precise control of these movement and light may create other impressions. We will keep studying affordance that an interface provides to a user, and pursuing intuitive interactions with that a user can control the interface without any explanations. While we abandoned some applications such as "pocOthello" in the design process, shape-changing interface has possibility to be used for various applications. We would like to continue designing new interfaces, referring to PocoPoco's design process. PocoPoco is a so simple and intuitive interface that music novice or beginner could easily play with it. At the same time its physicalization of sound is valuable for full-fledged musical performances. But this interface is immature, for example about the stability or preciseness of control. We will keep refining them and pursuing artistic value, for example original sound or playing methods that only this interface can realize.

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