PocoPoco: A Kinetic Musical Interface With Electro-Magnetic Levitation Units

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ABSTRACT

We developed original solenoid actuator units with several built-in sensors, and produced a box-shaped musical interface "PocoPoco" using 16 units of them as a universal input/output device. We applied up-and-down movement of the solenoid-units and user's intuitive input to musical interface. Using transformation of the physical interface, we can apply movement of the units to new interaction design. At the same time we intend to suggest a new interface whose movement itself can attract the user.

Keywords

musical interface, interaction design, tactile, moving, kinetic

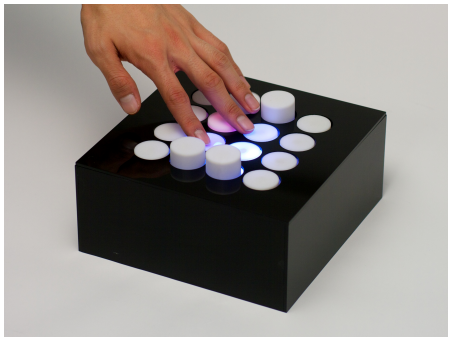

Figure 1: Appearance of PocoPoco

1. INTRODUCTION

Today a tremendous amount of audio and visual information is stuffed onto the flat displays of smart phones. It is no doubt a very convenient age, but a little bit uniform. Our research focuses on interfaces with dynamic movements and interfaces that can change their own shape dynamically [1][6][7]. Michelitsch suggests shape-changing interface called "haptic Chameleon"[9]. Parkes, et al. argued about kinetic interaction, as they called "Kinetic Organic Interface"[14]. They mentioned its specification and possibility for Human Computer Interaction. We have developed a box-shaped device called PocoPoco which controls the movement of columnar units with built-in solenoid actuators and utilizes them to give users dynamic tactile sensations. Figure 1 shows PocoPoco device. PocoPoco is an input/output device that can be used without visual information, because it can indicate all input/output information through tactile sensations. This device is a versatile interface that can be used in a wide range of applications including games, telecommunication, and musical performance. It was conceived as a new kind of interface which can be used by both people with visual impairments and people with normal vision.

In this paper we applied PocoPoco as a kinetic musical interface like a music sequencer. By "pushing", "catching", "turning" and "blocking" PocoPoco, users can play electronic music easily and intuitively. This simple interface attracts the interest of many people from children to adults, on the other hand this device 's various musical interaction attracts many people from musical beginners to professionals.

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2. RELATED WORKS

2.1 Musical Instrument

Tenori-on[12], a Product of Yamaha, is an instrument that enables users to play music visually. They suggest the way of playing musical instrument, like drawing. Its visual interaction is attractive, but doesn't have any kinetic elements like ours.

Here we focus on kinetic musical interface, which can move by itself. Haptic Drumstick by Berdahl et al. is a percussion instrument that applies feedback control to change drum-roll gestures[2]. It consists primarily of a drum pad attached to the cone of a woofer by a lightweight, cardboard cylinder. It assists user's drum play by adding energy to the drumstick vibrations.

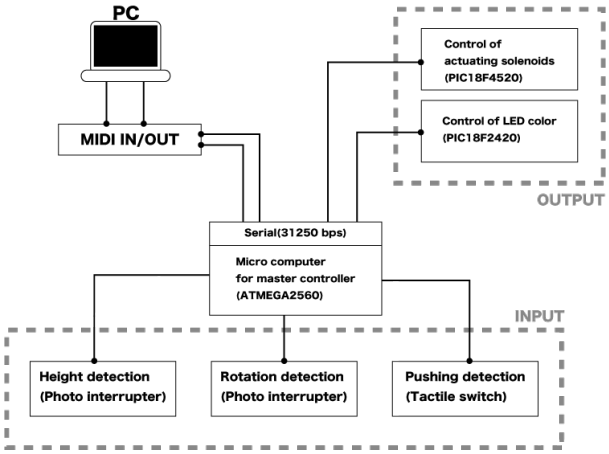

Figure 2: System of PocoPoco

Moog Guitar by Moog music Inc[10]. has almost infinite sustain. This guitar has a function to extend the sound tone using an oscillating current to a pick-up unit. E-bow by Heet Sound Products[4] and The Overtone Violin by Overholt[13] also use an oscillating current to extend its sound tone.

2.2 Tactile Display

There are several displays which can transform themselves. Iwata et al. made FEELEX [5], a kinetic display consisting of movable pin actuators using DC motors and Piston-crank mechanism. Relief[8] by Leithinger et al. and Recompose[3] by Blackshaw et al. are also kinetic displays using DC motors and faders. A kinetic display with a DC motor has speed and power. On the other hand, it's noisy.

Kinetic displays powered by a shape memory alloy can move quietly. Lumen[15] by Poupyrev et al. and PopUp![11] By Nakatani et al. are kinetic displays using a shape memory alloy. A shape memory alloy can move very quietly, but on the other hand it's not so powerful. And it takes relatively long time to transform, so it is not convenient to move rhythmically.

3. HARDWARE

3.1 Outline

Figure 2 indicates the system of PocoPoco based on micro controllers. This device consists of 16 I/O units "Poco" and a circuit to control it. Output are MIDI messages, up-and-down motion of movable units powered by solenoid actuators and full color LED light. Up-and-down motion and LED light are controlled by two micro controller (PIC, Microchip) individually.

3.2 Poco : original I/O unit

We developed Poco, an original I/O unit consisting of push-type DC solenoid actuator and several sensor input parts to realize original interactions of PocoPoco. Poco consists of a base part and a moving part. Poco can detect "pushing" using a tactile switch, height of a moving part using a photo interrupter, and rotation of a moving part using two photo interrupters. Table 1 indicates the specification of the device (PocoPoco), table 2 indicates the specification of the original I/O unit (Poco).

3.2.1 Solenoid Actuator

As can be seen on Figure 3, there is a built-in Neodymium magnet at bottom of the moving part. There is also an

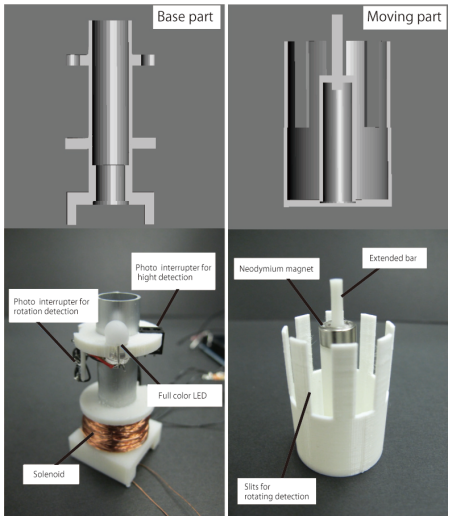

Figure 3: Appearance of the solenoid unit

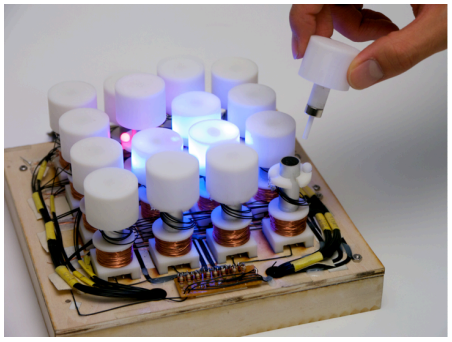

Figure 4: Solenoid units which have LEDs

enameled wire in base part. Current passed through conductive coils can generate a magnetic field. So conductive coils can be used as electromagnets. When the solenoid unit is connected to electricity, magnetic force comes up, the neodymium magnet is pushed by repulsion of the force, and the moving part float up.

PocoPoco uses a micro controller to control the electric current. Electric current flowing to the electromagnets causes individual cylinders with built-in magnets to be raised and lowered. The bottom of this solenoid actuator also contains a tactile switch that is activated when a user presses down on the cylinders and a photo interrupter that detects the position of the solenoid actuator. So users can play the applications of PocoPoco by simple pushing, holding, and turning up the solenoid actuators.

3.2.2 Full Color LEDs

There is a full color LED on the top of the base part. This LED can change its color controlled by the micro controller, such as Red, Green, Blue, Cyan, Magenta, Yellow, White. Each RGB channel's lights are turned on via matrix control. A controller for LED control and a master controller communicate with serial communication. We applied this LED light to indicate timeline, and particular Poco's situation (Figure 4), such as holding. Each layer has color, so color assists users to find which layer the user is editing at that time.

3.3 Sensing

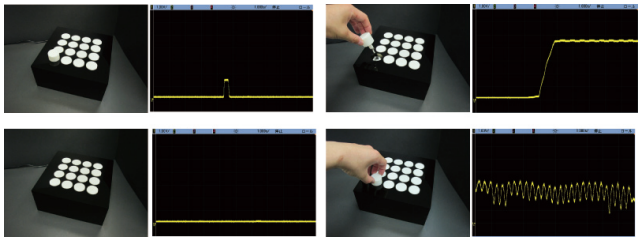

Figure 5: Relation of height of moving part and output voltage(Upper left : normal actuation, Left below : no actuation, Upper right : holding, Right below : up and down)

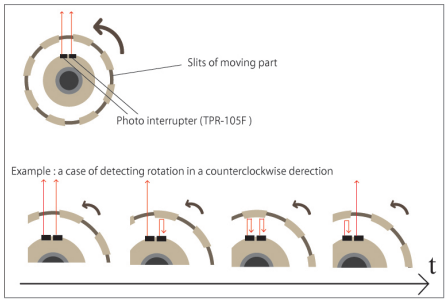

Figure 6: The mechanism to detect direction of rotation

3.3.1 *Matrix Switch*

16 tactile switches are located under solenoid units on matrix to detect pushing interaction. To push the surface of the moving part, an extended bar (shown in Figure 3) pushes the tactile switch through the solenoid coil.

3.3.2 *Detecting Height of Moving Part*

We implemented an optical sensor (photo interrupter) onto the base part in order to get height of the moving part. The moving part could levitate about 20[mm] from bottom to top. On the other hand, the photo interrupter could detect up to 40[mm]. Therefore, our unit can detect the case that the user pulls the moving part higher than the range of moving part can levitate. As a result, it can detect whether the user is pulling on the moving part or not.

Figure 5 shows relation voltage and height position of moving part. Upper left shows the situation that the beginning and end of levitation of moving part. Lower left shows the static situation of moving part. Upper right shows the situation that user catch and pull the moving part from the base part. Lower right shows the situation that the user moves moving part up and down.

3.3.3 *Detecting Rotation of Moving Part*

The user can rotate the moving part along the unit's vertical axis. In order to detect the rotation, we implemented 2 kinds of optical sensor onto the base part(see figure 3), then we made some slits around the moving part. After that, like a rotary encoder, the unit detects the user's rotation from which optical sensors detect slits first. Figure 6 shows how it detects. This is the same approach used by rotary encoders. In our device, PocoPoco, we have to detect rotation and up/down of moving part at the same time. Therefore, it is difficult to apply general kind of rotary encoders to our system. That's why we decided to make our original units.

Table 1: Specification of PocoPoco

Operating voltage	12 [V]
Max Electric Requirements	60 [W]
Dimension	205x205x90(WxDxH) [mm]
Weight	1500 [g]
Material of Chassis	ABS
Internal Communication	Serial(31,250 bps)
External Communication	MIDI in/out

Table 2: Specification of Unit

Distance between Each Solenoid	35[mm]
Range of Motion	20 [mm]
Average Speed of Motion	260 [mm/sec]
Maximum Speed of Motion	560 [mm/sec]
Weight	15 [g]
Total Coils	500
Wire Diameter of Coil	0.29 [mm]
Spec of magnet	Neodymium, 409[mT]
Photo Interrupter for Rotation	TPR-105F
Photo Interrupter for Height	RPR-220

4. APPLICATION

4.1 Outline

Kinetic movements of physical interface attracts human's mind, even little children. PocoPoco plays music with synchronized movement and light. It has a possibility to attract from children to adults. It is also a versatile musical interface that can play as a musical sequencer or keyboard, just by pushing, catching, and turning units. It has 16 sound layers. Users can choose a sound instrument just by pushing some buttons. It uses MIDI communication and it can be controlled by MIDI messages, including sequence rhythm.

4.2 Sequence Mode

Basically PocoPoco is used in sequence mode, with which users can play improvised loop music. By using this mode users can create fascinating loop music easily, just by pushing, catching, and turning cylindrical units (Poco). In this mode, LEDs always indicate 1 bar timeline continuously(Figure 7). 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 switch is moved to the "off" position and the sound stops.

Each Poco can be given its own sound tone and rhythm. These tones are arranged so that a pleasant harmony results no matter which combination of notes is used. By using this sequencer to play music we are able to create both aural and visual components of a performance at the same time, thereby linking these two senses for the audience in ways

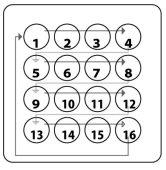

Figure 7: 16 beat time line of LED indicator

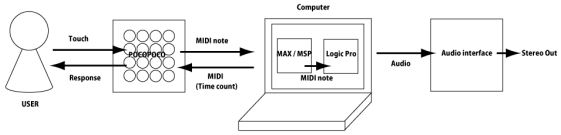

Figure 8: data communication flow

not normally experienced.

4.3 Real-time Mode

In Real-time mode, just like a MIDI keyboard, when a user pushes a Poco, particular sound tone comes out. Each of the 16 Poco is assigned a MIDI note. Users can use this mode to play melodies.

4.4 Layers

PocoPoco has 16 layers including 12 sequence mode layers and 4 real-time mode layers. A user can choose a layer by pushing an external button and particular Poco at the same time. Each layer uses respective MIDI channels. Users can assign each layer's note to sound source as users like.

4.5 MIDI Specification

PocoPoco has a MIDI I/O port and users can use it as a MIDI interface. Connecting to some sound source (basically we are supposing some Digital Audio Workstation, because they are convenient to map a particular MIDI message to a particular sound trigger) users can play PocoPoco with sound as users like. Users also may have to prepare some audio interface and speakers. Figure 8 indicates a data communication flow from a user to a speaker. Connecting multiple PocoPocos to a sound source, users can play ensemble by multiple players.

5. FUTURE WORK

Until now, we performed 8 musical performances and 9 demonstrations. Every time we get some feedbacks from audience and users, we have been making many improvements to PocoPoco.

We are now investigating the effect of the device's physical motion on users. We are experimenting about it using PocoPoco. We use eye mark recorder system (EMR-9, nac image technology), and compare the trace of gaze direction for instruments that have physical motion and those that do not. The interface is so simple that playing PocoPoco is very easy even for children and beginners with no musical experience. On the other hand, PocoPoco is also a sophisticated device which can be used to create compelling performances. Our goal is to make a new musical interface which takes kinetic affordance dynamically, and provide new musical interaction. We continue to design more intuitive and deep interaction.

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