TwinkleBall: A Wireless Musical Interface for Embodied Sound Media

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ABSTRACT
In this paper, we introduce a wireless musical interface driven by grasping forces and human motion. The sounds generated by the traditional digital musical instruments are dependent on the physical shape of the musical instruments. The freedom of the musical performance is restricted by its structure. Therefore, the sounds cannot be generated with the body expression like the dance. We developed a ball-shaped interface, *TwinkleBall*, to achieve the free-style performance. A photo sensor is embedded in the translucent rubber ball to detect the grasping force of the performer. The grasping force is translated into the luminance intensity for processing. Moreover, an accelerometer is also embedded in the interface for motion sensing. By using these sensors, a performer can control the *note* and *volume* by varying grasping force and motion respectively. The features of the proposed interface are ball-shaped, wireless, and handheld size. As a result, the proposed interface is able to generate the sound from the body expression such as dance.

Keywords
Musical Interface, Embodied Sound Media, Dance Performance.

1. INTRODUCTION
Music is created with human's body movement, and musical instrument is a device to translate human body motion to sound. In traditional digital musical instruments, the body motion to generate sound is limited to physical structures of the instruments. Therefore, the freedom of the musical performance (body movement) is limited. On the other hand, there have been a lot of researches on new musical systems using advanced information technology, which utilize haptic interface, video and motion capture devices to create music according to human gesture and body movement [1]-[13]. They introduce various types of sensing techniques to detect human motion, and the measured body movements are mapped to music or sound. One example is a magnetic based motion capture system [14]. These performance systems enable a performer to be free from the physical limitations and provide different abilities on music creation. However, the sound cannot be generated with the dance. It is necessary to generate sounds controlled by a different dimension from the gesture, because the combination pattern that associates the sound with the body movement does not only increase but also the gesture does not request an immediate relation to the sounds. Therefore, we have been proposed an interface that can control the *music scale* by detected the grasping motion [15][16].

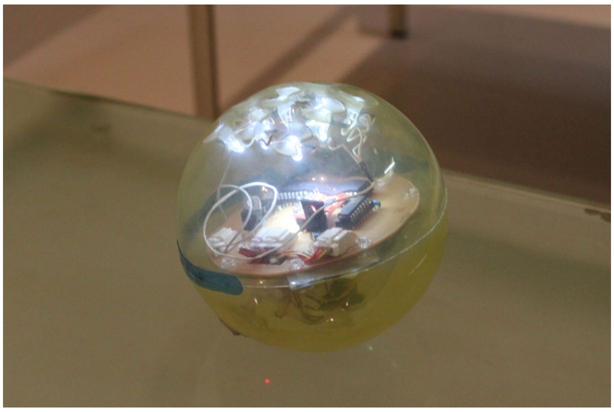


Figure 1. *TwinkleBall*.

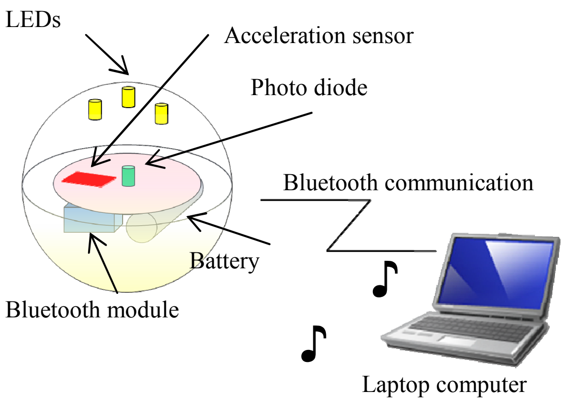


Figure 2. Overview of the proposed system.

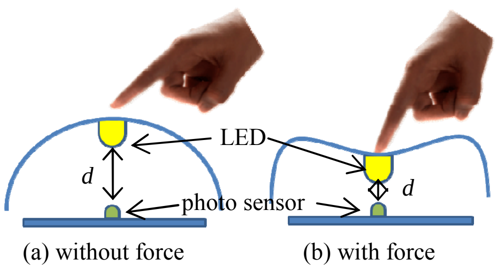


Figure 3. Difference between with or without force.

This paper presents a novel wireless musical interface, *TwinkleBall*, which controls the sound by using not only the grasping motion but also the human body motion. *TwinkleBall* has three features that is ball-shaped, wireless, handheld size. *TwinkleBall* can control the *note* and *volume* by varying grasping force and body motion respectively. As the interface can realize wireless communication and is of handheld size, it is possible to control the sound by using both small motion of their hand and the large motion such as dance performance. Moreover, the spherical shape of *TwinkleBall* enables musical performance to be carried out freely.

2. SYSTEM OVERVIEW

2.1 Hardware Design

The design of the developed musical interface, *TwinkleBall*, is shown in Figure 1. The main body of the proposed interface consists of a rubber ball, a Bluetooth wireless module, a photo sensor, an 3-axis accelerometer, LEDs, a PIC (Peripheral Interface Controller) and a battery (9.0 V). All electronic devices are enclosed in the translucent and hollow rubber ball. The measurement range of the acceleration sensor is ±3.6g. The peak wavelength of the photo sensor is 560nm. The Bluetooth wireless module, the photo sensor, 3-axis sensor, the PIC, and the battery are place on an electronic circuit board inside the core, which is fixed to the rubber ball using rubber sheets. 10bit A/D conversion is used to convert analog signal of the sensors into digital signal. Moreover, LEDs are placed in the interior of the rubber ball. The specifications of the rubber ball are as follow: diameter 152 mm, weight 260 g, material PVC (Polyvinyl Chloride). As shown in Figure 2, the signal output from the photo sensor and the accelerometer are digitized and sent to an external computer via Bluetooth wireless module.

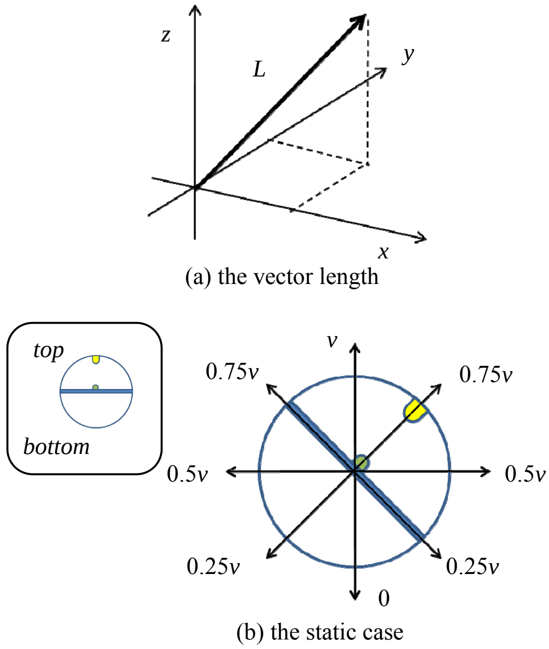


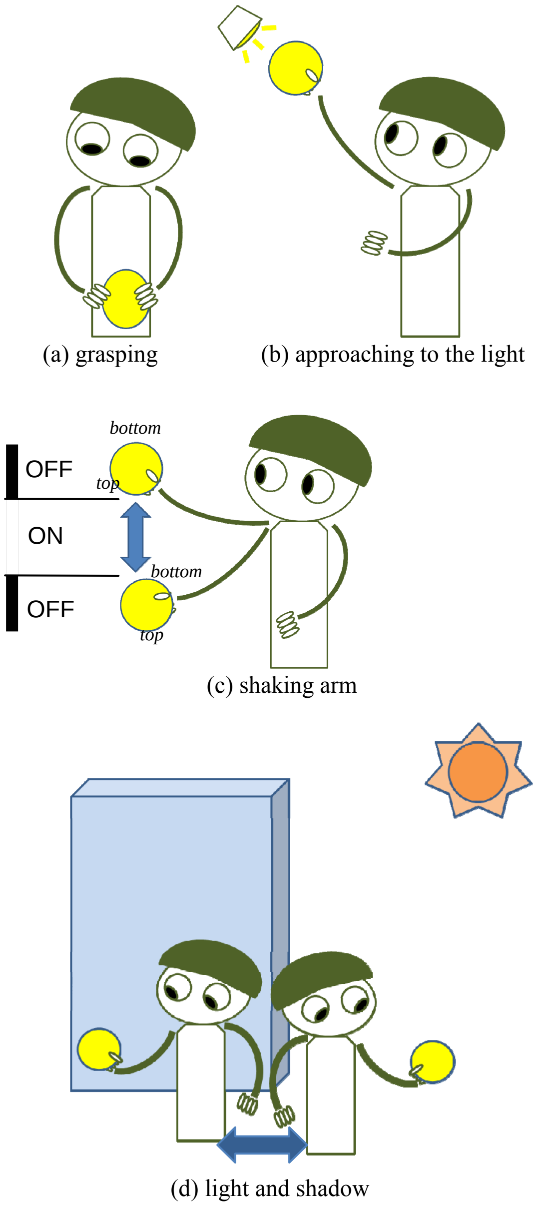
Figure 4. *Volume* control.

2.2 Sound Control

In order to apply the proposed interface to the digital musical instrument, the *note* is controlled by the grasping force and the *volume* is controlled by the moving interface. We use MIDI sounds for the output sounds.

In particular, when the shape of the rubber ball changes due to the grasping force by user, the distance *d* between the photo sensor which is embedded in the inside and LEDs varies as shown in Figure 3. As the illumination intensity is inversely proportional to the distance *d*, changes in grasping force will produce different signal output from the photo sensor. This output signal value is then sent to the computer via Bluetooth wireless module, and the *note* is calculated based on its value. As we use MIDI sounds, the range of the *note* is 7 bits. As a result, the 10-bit digital signal from the photo sensor is normalized before sending to the MIDI output.

The proposed interface can change the *volume*. The measurement value of the acceleration sensor changes, when the user moves the interface. The accelerometer used can measure the acceleration in *x*-, *y*-, and *z*-axes. The acceleration values are sent to the computer via Bluetooth wireless module. The computer calculates 3-D acceleration vector length *L* by using these values, and the *volume* is determined by this length as shown in Figure 4(a). The range of the *volume* that is the MIDI velocity is also 7bits. Therefore, the calculated vector is normalized to suit this range. The *volume* does not depend on the direction of movement because we use the simple vector length *L*. *Volume* control is divided into two cases namely static and dynamic cases. In the dynamic case that performers move the interface by their motion, the volume is calculated linearly. In the static case that performers do not move but grasp the interface, the *volume* depends on the gradient angle of the interface. Although the shape of the interface is a sphere, it is divided into top and bottom directions. The *volume* is determined as shown in Figure 4(b). *v* is set as 60 in this paper.



(a) grasping (b) approaching to the light

(c) shaking arm

(d) light and shadow

Figure 5. Examples of musical performance.

Figure 4 shows the case of the 45 degree, and this volume is 0.75*v*.

3. FEATURES

During musical performance, a performer usually handles a musical instrument through direct physical contact. On the other hand, there are some musical instruments like *Theremin* that can be performed without physical contact. Although the proposed interface can control the *note* by detecting the grasping forces via the intensity of illumination, the proposed interface is also able to perform using the external illumination such as the lamp, because it is made of translucent rubber-ball. Therefore, users can achieve a musical performance like *Theremin* performance to extend the degree of freedom of the performance style. For examples, Figure 5 illustrates four different performance styles. Figure 5(a) shows the directly grasping performance. Figure 5(b) shows the case of using ambient light by approaching the interface to the light source. In this case, one can control the *note* by changing the distance between the light and interface. Figure 5(c) shows the shaking performance. The proposed interface cannot control the *tempo* of the sound. The system assumes that the *tempo* is constant. However, the *volume* is controlled by the acceleration, and the *volume* is also controlled its gradient angle. By setting the initial position as shown in Figure 5(c) (inverse the top and bottom as the initial position), the proposed interface can be used as a percussion instrument by controlling the *volume*. Figure 5(d) shows the performance in an outdoor environment. The *note* changes based on the light intensity, and then the performer can use the bright place and shadow place to control the *note*. Of course, the performer can also use own shadow.

4. PERFORMANCE EVALUATION

We examined the musical performance with body motion by using the developed musical interface, *TwinkleBall*. We use the electric lamp as an environmental light, and perform the experimental music in indoor room. As the proposed interface can control two features such as the *note* and *volume*, the *tempo* is set as constant.

Figure 6 shows appearances of the musical performance when the proposed interface is used. From Figure 6(a), the performer can vary the *volume* by moving with the large motion such as swinging. The proposed system is not dependent on the exact gesture, but the strength of the human movement influence the *volume* control. Therefore, the system responds the different motion. Moreover, the performer throws the interface to other performer to change the *volume*. In this case, as the volume depends on the acceleration, the volume becomes 0 when the interface does not rotate. The performer should perform a spinning throw if they want to change the *volume*. From Figure 6(b), the performer can change the *note* by varying the grasping force with single hand and both hands, and the distance between the light and the interface. Unlike traditional musical instruments where the relationship between the action and the generated sound is determined by the physical structure of the instrument, the relationship in the proposed interface as a musical instrument is able to be set freely. Through the experiment, the musical performance can be done with improvised manner in real-time.

Through the experiments, the performer points out the problem. The *tempo* is one of the important factors for the dance. The dance involves various movements during the performance. As shown in Figure 5(c), the proposed interface can change the *volume* by the shaking motion. It is a sort of the *tempo* control but it is difficult to perform these motions during the large or high-speed dance performance.

5. CONCLUSIONS

This paper describes a novel interface method to control sounds by using the human body motion. The developed interface, *TwinkleBall*, was used for the event of the banquet of Virtual Reality Society of Japan (VRSJ) the 14th annual conference which was held on September 2009 and confirmed the effectiveness and usability.

The future works remain the problems of the durability capacity and to control the *tempo*. The durability capacity is required for the usage of the practical scene because the children intensely

(a) *Volume* control

(b) *Music scale* control

Figure 6. Scenes of the musical performences.

throw out the proposed interface. In order to control the tempo, we are planning to equip other sensor or use the speed calculated by differentiating the acceleration.

6. ACKNOWLEDGMENTS

This study has been conducted as part of the humanoid project at the Humanoid Robotics Institute, Waseda University. This work was supported in part by the “Global Robot Academia,” Grant-in-Aid for Global COE Program by the Ministry of Education, Culture, Sports, Science and Technology, Japan; and CREST project “Foundation of technology supporting the creation of digital media contents” of JST; and Grant-in-Aid for Young Scientists (B), No.21700206, from 2009 to 2011.

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