# Playful Audio-Visual Interaction with Spheroids

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## ABSTRACT
This paper presents a novel interactive system for creating audio-visual expressions on tabletop display by dynamically manipulating solids of revolution called spheroids. The four types of basic spinning and rolling movements of spheroids are recognized from the physical conditions such as the contact area, the location of the centroid, the (angular) velocity, and the curvature of the locus all obtained from sensor data on the display. They are then used for interactively generating audio-visual effects that match each of the movements. We developed a digital content that integrated these functionalities and enabled composition and live performance through manipulation of spheroids.

## Author Keywords
tangible interface, musical instruments, spheroids, spinning, rolling, audio-visual, live performance

## CCS Concepts
• **Applied computing → Sound and music computing**; • **Human-centered computing → Interactive systems and tools**.

## 1. INTRODUCTION
Tangible objects have been used in various ways by making effective use of their physical and geometric characteristics. In the case they are manipulated by humans, the controllability plays an important role to skillfully manipulate and achieve a variety of expressions. In this regard, classical musical instruments, some types of toys, and sports equipments are these with excellent controllability and functionalities. In the research of interfaces and displays, tangibility and interactivity have been emphasized for new types of interfaces and interactive systems, e.g. [1]. As for music, novel tangible musical instruments such as Tenori-On, Lemur, and the Reactable [2] are presented; however, kinematic physicality incorporating with digitality has not been fully utilized and it should be worth exploring.

In this paper, we focus on dynamically manipulating the geometric object called the *spheroid,* which is a symmetric round type of an ellipsoid which spins and rolls on a surface in various ways in a smooth manner. We utilize spheroids as playful interface manipulated on tabletop display for creating and making novel audio-visual interaction. Their spinning and rolling movements are accurately detected through the physical parameters such as the contact area, the (angular) velocity, and the curvature of locus and are effectively used for audio-visual expressions. We develop a digital content, with emphasis on the musical functionalities such as creating rhythms, loops, and sound effects that match each of the movements of spheroids, with which one can make composition and the corresponding live performance.

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## 2. BASIC MOVEMENTS OF A SPHEROID
A *spheroid* is a 3-dimensional object obtained by rotating an ellipse along an axis and is a special type of an ellipsoid. Since two of the three radii are the same, it spins and rolls smoothly in various ways on a surface. More precisely, a spheroid has two types of rolling: (a) rolling with the longer side of the body laid horizontally, which we call *Horizontal Roll*; and (b) rolling with the sectional ellipse to stand perpendicular to the surface, which we call *Vertical Roll*. Both are shown in the first row of Figure 1. There are also two types of spinning: (c) spinning executed horizontally on the surface, called *Horizontal Spin*; and (d) spinning executed vertically, called *Vertical Spin*. Since these four movements have their own physical characteristics, we extract their parameters and utilize them to make a new type of audio-visual interaction.

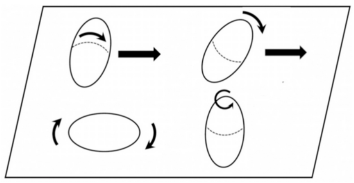

**Figure 1. Basic movements of spheroids:(a) Horizontal Roll; (b) Vertical Roll; (c) Horizontal Spin; and (d) Vertical Spin**

## 3. INTERACTIVE SYSTEM
### 3.1 System Description
We describe the interactive system that uses spheroids as interface. Figure 2 illustrates the overview of the system that consists of a sensor sheet on which a screen is set, spheroids manipulated on the surface, a computer, and a projection system with a projector and a sputtering mirror. The sensor sheet we use is the LL sensor shown in Figure 3(a), which is based on electromagnetic induction and reacts to metal. The size of the screen is 60 × 60 [cm], and the coefficients of electromagnetic induction range from 0 to $2^{16} - 1 = 65{,}535$ and are obtained at all of the cells of size 1 × 1 [cm] and sent to the computer as matrix data with 100 [Hz]. When aluminum or copper touches the sensor sheet, coefficients of around 19,000-20,000 are obtained. The matrix data are first utilized to recognize the physical conditions of the spheroid such as the contact area, centroid, and (angular) velocity. Then, they are used to create audio-visual effects.

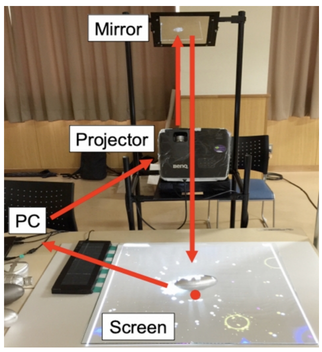


**Figure 2. System overview**

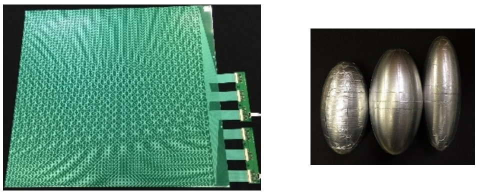

**Figure 3. (a) Sensor sheet based on electromagnetic induction; (b) Spheroids of three sizes**

We designed and fabricated spheroids of various sizes using PLA and nylon resins. Some of the fabricated objects of sizes (diameter, height) = (6, 12), (6.75, 13.5), and (5, 15) [cm] are shown in Figure 3(b). They are all covered with aluminum tape.

### 3.2 Physical Parameters

In order to distinguish the types of movements of a spheroid, physical parameters such as contact area on the display, the centroid, the (angular) velocity, and curvature of locus are obtained as follows.

The *contact area* of a spheroid is defined to be the number of cells with coefficients of values more than 2,000. It is almost constant at Horizontal Roll and Horizontal Spin, while at Vertical Roll, it oscillates between the value in the vertical case (the smallest case) to the value in the horizontal case (largest). At Vertical Spin, it is the smallest in the beginning and gradually increases as a spheroid declines. The *centroid* of the contact area is used as the location of the spheroid. Its $x$ and $y$ coordinates are obtained by computing the weighted sum of each of the coordinates of the coefficients over the contact area. The *velocity* of the centroid is defined to be the one for the spheroid. The *angular velocity* of the spheroid is computed by the velocity of the angle of the vector connecting two ends of the spheroid, which plays an important role at Horizontal Spin.

Since the locus of the centroid gives main impression on the movement of the spheroid, we extract the following information related to the *curvature* of the locus. We represent the curvature by the angle between the vectors connecting the centroids of the spheroid in the neighboring time frames. If it is close to zero, so is the curvature and the curve turns to be locally a straight line. If it is much larger than zero, so is the curvature.

### 3.3 Recognition of Basic Movements

The four basic movements of a spheroid are recognized using the physical parameters explained in Section 3.2. The results are then utilized to distinguish the movements of spheroids on the display. The outline of the recognition method is described as follows.

In the cases of Horizontal Roll and Spin, the initial contact area is the one the spheroid is laid horizontally to the surface, so the area is almost the maximum. On the other hand, in the cases of Vertical Roll and Spin, the contact area is the one the spheroid stands vertically, so the area turns to be almost the minimum. We distinguish the horizontal and vertical cases using this criterion. In order to distinguish Horizontal Roll and Spin, we use the angular velocity. At Horizontal Spin, the angular velocity is the maximum in the beginning of the movement and is locally almost unchanged, while at Horizontal Roll, it is frequently oscillating, so they can be stably distinguished. Finally, to distinguish Vertical Roll and Spin, we use the value related to the curvature. Since a spheroid moves straightly at Vertical Roll, there is almost no change in its direction, while at Vertical Spin, the angle of the direction changes.

## 4. AUDIO-VISUAL EXPRESSIONS

### 4.1 Basic Audio-Visual Assignments

Visual effects of our system are rather simple at this point. Namely, we plot the contact points of the spheroid and additionally visualize shapes such as circles and particles around the contact points for some movements. Sound effects are assigned thoroughly as follows. First, since Horizontal Roll is characterized by the change of the velocity of a spheroid and the curvature of the locus, given sound sources that we created beforehand as Wav files, we assign the volume proportional to the velocity and also oscillate the pitch according to the curvature. Next, Horizontal Spin is characterized by the angular velocity, so we assign the volume and pitch proportional to it. Vertical Roll is characterized by the change of the contact area and the velocity, so we assign the volume and pitch proportional to the velocity and the contact area, respectively. Finally, Vertical Spin is characterized by the velocity, curvature, and the angular velocity, so this time we assigned the volume and pitch proportional to the velocity and the curvature, respectively (here we note that the angular velocity is not used this time because the shape of the contact area is a mere circle in the beginning and the sensor data can not tell the revolution of the spheroid itself).

### 4.2 Integrated Audio-Visual Content

We developed an audio-visual content with emphasis on interactive sound generation, composition, and live performance. The system was developed using Unity 2017.1.0f3 and the graphical interface is shown in Figure 4. In the bottom part of the display, there are three square area for rhythm tracks. A player first executes Horizontal Spin in one of them and determines the basic speed of the loops through the angular velocity. Then, one plots several points of different sizes in the circles that reflect on the volumes of the drum sounds. In the upper part of the display, one manipulates spheroids rather freely, obtaining audio-visual effects explained in Section 4.1. In the figure, for example, the white fluctuating curve on the right side is drawn by Horizontal Roll, which is accompanied with a high tone matching the movement whose pitch oscillates according to the curvature. The blue circles are drawn by Vertical Roll, which is accompanied with a tone of the rolling movement with the changing radii and pitch according to the contact area. The system is intended for one or two players.

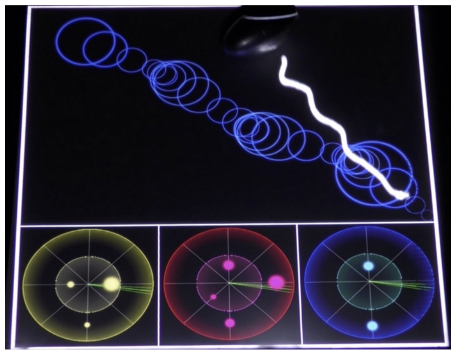

**Figure 4. The graphical interface of the audio-visual content**

Future work includes making a richer set of sound sources and effects, evaluating the relationship between the sensor data and the movements of spheroids, and creating original music, visual, and choreography worth presenting in live performance.

## 5. ACKNOWLEDGMENTS

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