The Bluetooth Radio Ball Interface (BRBI): A Wireless Interface for Music/Sound Control And Motion Sonification

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Abstract

The Bluetooth Radio Ball Interface (BRBI) is a wireless interface for motion tracking and sonification. The device is embedded in a palm sized foam ball. A 3-dimensional sensor with a Bluetooth module seated in the center of the ball transmits acceleration/tilt measurement data to a computer. Data is then converted into Open Sound Control messages for use with other applications.

This paper presents the design concept and implementation of BRBI. Details of its hardware and data handling software are also discussed. Applications include gesture control in music performance as well as sonification of athletics.

1 Introduction

A ball is among the simplest, and most ubiquitous and familiar recreational devices. It has been used for millennia and across virtually all cultures in a wide variety of games and sports. However, with the exception of some idiophones, the use of handheld balls for creating music is relatively rare. More recently, studies in motion tracked controllers for creating or shaping music have been the subject of increasing interest. Wireless technology has eliminated one of the main barriers in developing useful hand held gesture controllers.

In this paper, we describe the *Bluetooth Radio Ball Interface* (BRBI, pronounced “Barbie”) - a novel wireless ball interface for sound control and motion sonification. Inside a soft, easily grasped palm-size foam ball is a circuit board containing a 3-dimensional accelerometer/tilt sensor and a Bluetooth transmitter to send out measurement data to a Macintosh computer. Data is processed by the *WiTilt to OSC* (W_2O) - a program to decode binary inputs and re-format them as *Open Sound Control* (OSC) messages, and then transmitted over a UDP connection to any OSC-compatible application.

1.1 Review of Comparable Works

Sound controlled by spatial hand coordinates has been of interest since the theremin. With the development of motion- and gesture-tracking systems, numerous composers have explored the movement of a dancer as a means of creating, triggering, or processing musical sound. In addition, recent work in sonification of motion has been inspired by the expressive and gestural control produced in the physical-auditory feedback loop in traditional musical instrument performance including string instrument bowing and conducting.

In this paper we pay special attention to spherical ball shaped interfaces. Examples include the *StressBall* (Verplank 2001) by Heidema et. al., a rubber ball that contains an accelerometer inside and force sensors underneath its surface, thereby taking squeezing and shaking gestures as its control inputs. Sensor data from the StressBall is transmitted to a computer over a wired connection.

In (Hermann, Krause, and Ritter 2002), Hermann et. al. presented the *Audio-Haptic Ball*. This device consists of various sensors (i.e., force sensor, accelerometer, piezo sensor) and buttons/switches as well to provide higher dimension of control. In addition, it contains an actuator to generate haptic feedback. All these parts are integrated in a ball-shaped housing which fits into a human hand. Nevertheless, like StressBall, it is wired to a data processor, and therefore fails to give the freedom of motion.

In contrast, *Muggle* (Verplank 2002), is an RF-based wireless controller incorporating accelerometers and LEDs (for visual feedback) housed in a translucent plastic ball. Being wireless, Muggle offers much more freedom of control. However, its fragile translucent housing prevents it from being handleable as an ordinary ball for sonification of various ball movements. In addition, an extra RF receiver is required for a computer to communicate with it.

Prior work on the use of Bluetooth in wireless control includes *Soundstone* (Bowen 2005) which senses 3-dimensional acceleration and provides both visual and haptic feedback.

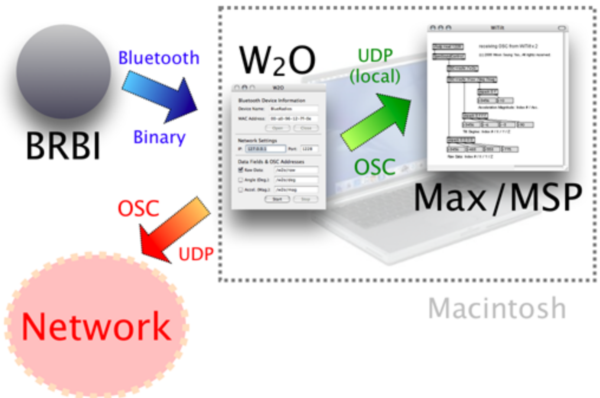

Figure 1: System diagram for BRBI.

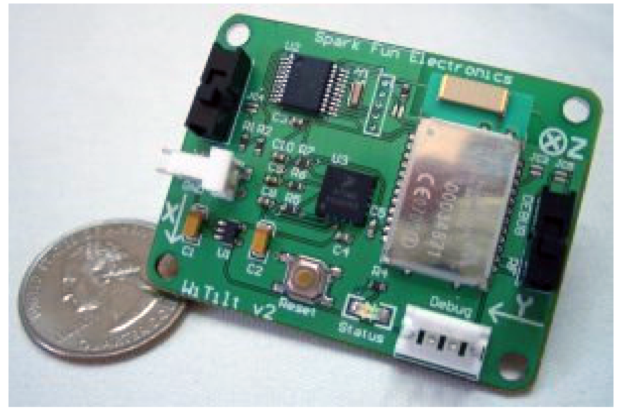

Figure 2: Wireless Accelerometer/Tilt Controller (version 2.0) by Sparkfun Electronics.

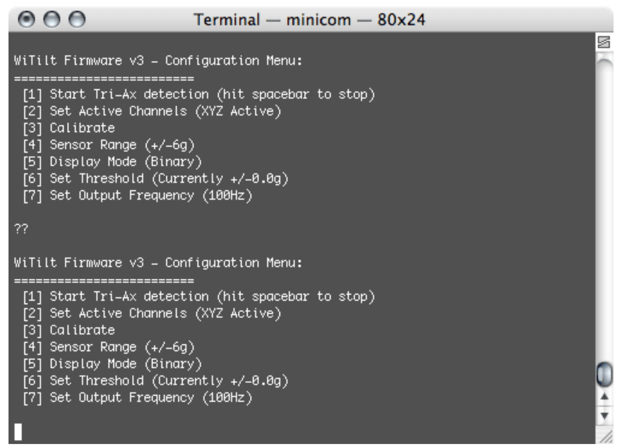

Figure 3: Sensor configuration using terminal.

1.2 Features of BRBI

BRBI has a number of advantages over the aforementioned examples. These include:

- Connection with data receiver is wireless based on Bluetooth: in addition to providing tether-free freedom of motion offered by wireless control, Bluetooth is compatible with most computers, easy to configure, and does not require any extra sensing device.
- Being housed in a small soft ball which is neither fragile nor heavy, BRBI is easy to grab and control. It is also quite robust to endure shocks caused by common ball-handling motions, and shows solid performance when transmitting sensor data. Therefore, BRBI can serve as a sound/music control interface and as a device for sonifying various ball-handling gestures and ball movements as well.

It should be emphasized that BRBI was designed for not only sound control with "active" ball-handling gestures, but also "passive" sonification of ball movements in mind.

2 System Overview

Figure 1 illustrates the data flow for BRBI and its supporting system. 3-dimensional tilt/acceleration data measured by BRBI is received by the data processor (W_2O). This processor then decodes and transmits the data as OSC messages to any compatible application: connection can be made within the same machine, or to a different machine on either LAN or WAN.

2.1 Sensor

To measure ball movements, a *Wireless Accelerometer/Tilt Controller (version 2)* (Sparkfun Electronics 2005) (figure 2) is used. This device contains an MMA7260Q - a 3-axis, low-g accelerometer (Freescale Semiconductor), and a class I Bluetooth module, on a single PCB board. In addition, it offers a built-in command line configuration utility that allows easy setup of sensor parameters, as shown in figure 3.

2.2 Ball

The sensor, together with batteries, is housed in a foam ball which is about 4 inches in diameter: components are shown in figure 4.

Based on the type of movement to be sonified, balls with different size and/or degree of firmness might be desirable.

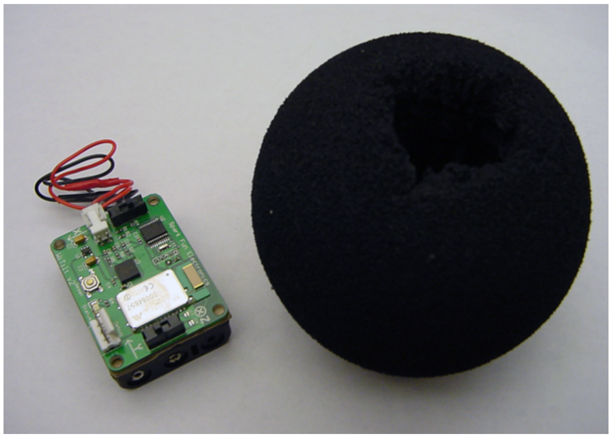

Figure 4: Components of the BRBI. A WiTilt sensor and a battery pack are inserted in the center of the foam ball.

2.3 Data Processor: W_2O

W_2O is a Mac OS X-based data processor, written by the author of this paper, for use with the Wireless Accelerometer/Tilt Controller. More specifically, W_2O consists of a Bluetooth data server, a binary-to-OSC data converter, and an OSC client.

Binary data transmitted from the sensor is processed by W_2O to provide a) raw measurement values from 10-bit ADC (0$\sim$1023), b) tilt angles (-90$\sim$90 degrees), and c) ratio of acceleration magnitude to the acceleration of gravity (per cent), as OSC messages with customizable target information and OSC address.

Figure 5 shows the user interface of W_2O, in which OSC output options can be determined.

Messages from W_2O can be utilized by any OSC supporting applications, such as Max/MSP and Pd. An example of a Max/MSP patch that receives sensor data from W_2O is depicted in 6.

W_2O is compatible not only with BRBI but also with any other interface incorporating the same Wireless Accelerometer/Tilt Controller. Moreover, the program can be easily customized to work with other Bluetooth devices. Detailed information on W_2O can be found in (Yeo 2006).

3 Gesture Mappings and Motion Sonification

Any movement of BRBI can be considered as combinations of linear and angular components. Based on the output of W_2O, although not perfectly distinguishable from each other, linear and angular motions can be characterized by relatively bigger changes in overall acceleration magnitude and

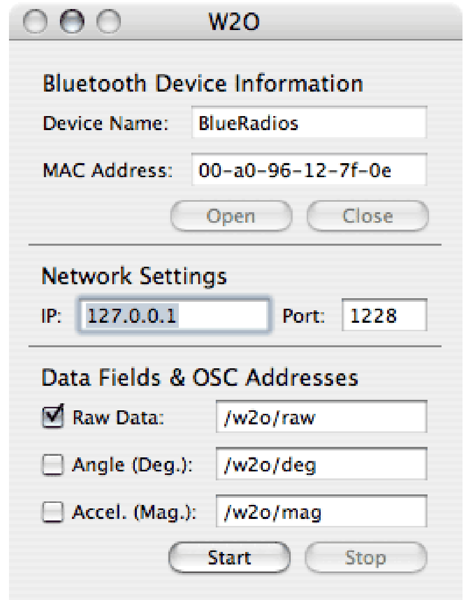

Figure 5: User interface of W_2O.

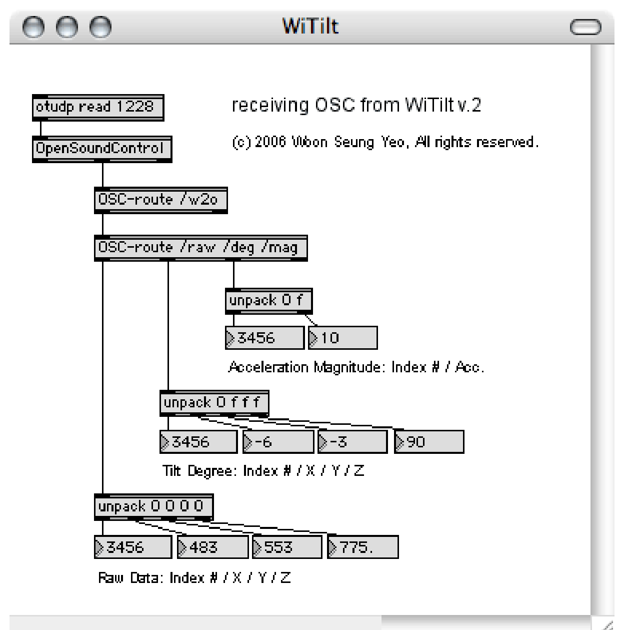

Figure 6: A Max/MSP patch to receive sensor measurement data from W_2O as OSC messages.

tilt-angle values, respectively.

3.1 Gesture Mappings for Sound/Music Control

Different ball-handling gestures show different patterns of variation in measurement data. Examples include:

- Rotation. By slowly rotating BRBI, it is possible to control three tilt angles with high precision while keeping the acceleration magnitude very small. I used this to control the parameters of an FM instrument, which proved to be an excellent example of timbre control by fine hand motions.

- Spin. Like any ball, BRBI can be spun. Compared to rotation, this makes the tilt angle(s) change more rapidly, and the acceleration magnitude somewhat high.

- Shake. This involves fast, repetitive gestures that introduce frequent high jumps in acceleration with less tilt angle variations. As an emulation of real percussion instrument, acceleration magnitude could be mapped to the "shake energy" parameter of a *Physically Informed Stochastic Event Model* (PhISEM), such as the **Shakers** class (Cook and Scavone 2005) of the *Synthesis Tool Kit* (STK), to synthesize a shaker sound.

- Toss/throw. These are mostly linear motions, resulting in changes of acceleration both at the beginning and at the end. Angular motion, however, can be introduced together to make them more complex.

Since BRBI is a sphere, there's no absolute external reference in terms of direction, whereas the sensor inside the ball has its own coordinate system. Therefore, depending on the mapping and the initial tilt angles of the sensor, similar movements of BRBI could produce quite different results.

Although BRBI's performance is robust, it currently is prone to instability when exposed to excessive shocks: for example, the sensor "freezes" in case of collision against a hard object. In fact, this limits its use for acquiring bouncing gestures.

3.2 Sonification of Ball Movements

BRBI can also be used for sonifications of ball movements in a *passive* way: instead of being held and controlled by hand, it could be put into an environment in which only indirect access (or no access) to the ball is possible (i.e., a big container, or the cargo space of a moving van) to convert its movements into sound.

4 Conclusion

I have proposed BRBI as a wireless ball interface. Together with W_2O, it provides a convenient and flexible method for sound control by gestures and sonification of ball movements.

Future works will include:

- Enhanced physical implementation. This means not only using better material for the housing, but also adopting a new sensor which is more robust and precise.

- Software upgrade. W_2O will be able to filter sensor data, and support more flexible network configurations (i.e., multiple target, TCP connection, etc.)

- Various gesture and sonification mappings. Especially, more reliable physical implementation of BRBI will allow it to be used for sonification of ball-sports activities.

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