Ubiquitous Drums: a Tangible, Wearable Musical Interface

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Abstract
Drummers and non-drummers alike can often be seen making percussive gestures on their chests, knees and feet. Ubiquitous Drums enhances this experience by providing musical feedback for these and other gestures. This paper describes the implementation and evolution of this tangible, wearable musical instrument.

Keywords
Tangible interfaces, musical instrument, percussion, interaction techniques.

ACM Classification Keywords
H5.2. Haptic I/O

General Terms
Design

Introduction
Love of rhythm is universal. People everywhere can often be seen tapping their knees and feet to the music in their ears and in their heads. Unfortunately, traditional rock drums are loud, large, expensive and difficult to transport. As a result, very few rhythm lovers ever become drummers, and their passion sees no outlet. In this paper, we present Ubiquitous Drums, a tangible, wearable musical instrument built directly into clothing. This system allows aspiring drummers to have a drum kit wherever they go.

Ubiquitous Drums consists of a set of adhesive force-sensing pads that connect to a central dispatcher. This dispatcher communicates to a synthesizer that finally plays back the appropriate drum sample. The drum pads are designed to be attached to a wide variety of clothing types. We have so far built several such pads into the knee areas of a pair of jeans, the soles of running shoes and the upper abdominal area of a wool sweater.

The Ubiquitous Drums system yields various interesting applications. In addition to embedding pads into clothes, they can also be used in a variety of other contexts. Pads can be placed on a table, overlaid over a practice drum kit, or attached to the top of a pair of bongos or other hand drums. In addition to using the Ubiquitous Drums system to play their own beats, users can also play along to music that they listen to through their computer or mobile music player. Though it does not involve drum sticks, Ubiquitous Drums can still be used to effectively teach new drummers important concepts like limb independence and polyrhythm.

Implementation

Based on A. R. Tindale's work on sensor strategies for capturing percussive gestures[1], the Ubiquitous Drum system uses wired drum pads, each built out of a force-sensitive resistor (FSR) and a pull-down resistor circuit. Two pads are taped into the inside of a pair of jeans (see Figure 1).

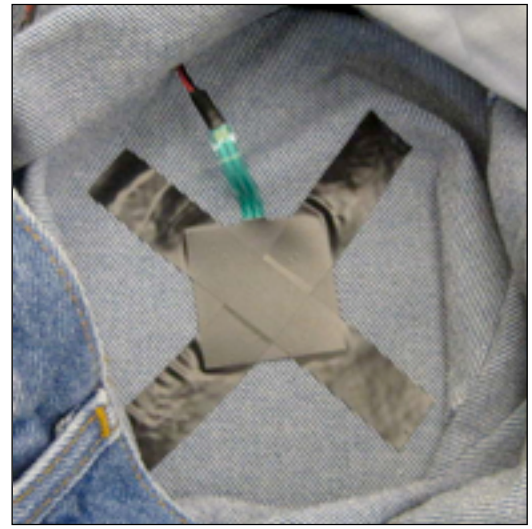

Figure 1. A FSR is attached to the knee area of a pair of jeans using electrical tape.

A circuit board is concealed in the left jeans pocket. Wires connecting each pad and the circuit board run up through the each pant leg, attached to denim using electrical tape. The jeans have a four-pin header interface which allows the user to easily plug and unplug the jeans from the system. The shoes and sweater are wired like the jeans and feature a similar header interface (see Figure 2).

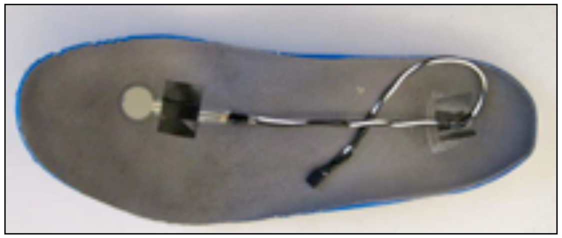

Figure 2. A FSR is attached to the sole of a shoe

Figure 3 shows the overall structure of the system.

The main Arduino-based system connects with wires to all of the peripheral clothing. When a pad is hit, the Arduino program detects how much force was applied to the pad and transmits that data to the computer over a serial port. Data sent to the computer includes the pad's unique string identifier and a value from 0 to 1023, representing how hard the FSR was hit. The FSR sometimes generates noise due to pressure caused by natural folds in the clothing, so the Arduino program filters them out.

A Python program running on Mac OS X listens over the serial port for strings representing drum hits. Using the pygame[2] library it then plays back drum samples at a volume corresponding to the intensity of impact. This program is flexible enough to easily allow the user to configure what sound sample is played for each pad in the Ubiquitous Drums system.

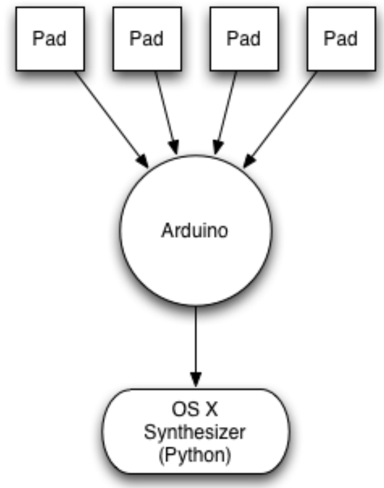

Figure 3. System architecture

The need for a computer-based synthesizer forces the user to be near a computer, which prevents drumming on the go. Instead of relying on a Mac, we connected the wearable drum kit to the iPhone. To avoid relying on proprietary accessory protocols, we attached a WiFi shield to the Arduino to communicate wirelessly with a program running on the iPhone through a TCP/IP socket. However, this is slow. Work is still ongoing to sufficiently reduce the latency of this communication to provide a good enough drumming experience.

Drum pads and their wires are fixed in place on every augmented article of clothing, preventing the user from easily moving the sensors to another location in the same article of clothing. When putting on or removing drum-augmented clothing, the wires can be annoying. Furthermore, having electronics built into clothing discourages washing. To resolve these problems, we devised a system with wireless pads, relying on XBee modules in pass-through mode. The new pads consisted of a FSR, an XBee module and a coin battery to power the system. Each pad's XBee chip communicated to a central XBee receiver module attached to the Arduino.

Related Work

Ubiquitous Drums is both an embedded, wearable, tangible user interface (TUI) and an electronic drum. TUIs and electronic musical instruments are each large areas of research in their own right, but surprisingly little work has been done at the intersection of these two fields.

Our system relies heavily on embedding electronics into clothing. Holleis et al[3] discuss the details of embedding capacitive touch sensors into clothing. To address issues of comfort associated with wearable interfaces, Gemperle et al[4] provide guidelines for how to optimally design such systems for wearability.

Much work has been done on augmenting musical instruments with electronics. Many projects aim to improve the realism of electronic drums, such as the Augmented Djembe[5]. Others, like Jam-o-Drum[6] attempt to make drumming more social. Both approaches are interesting, but remain constrained to interaction with traditional musical instruments.

Baba et al proposed a new kind of drumming interface [7] that uses Electro Dermal Activity (EDA) to detect the intensity of human skin contact. In spirit this is similar to Ubiquitous Drums, but EDA technology works through bare skin and not through clothing, greatly reducing the practical utility of such a system. In addition, there is no way to tell where on the skin the impact occurred, so only one drum sample can be played back.

Evaluation

We have not yet attempted a formal evaluation of Ubiquitous Drums. We have, however, received a large amount of positive feedback, both online (Figure 4) and in person (Figure 5).

Figure 4. Ubiquitous Drums video on YouTube

Even drummers, the most discerning users of Ubiquitous Drums, don't seem to have issues interacting with it. Several people have even offered to buy Ubiquitous Drums if and when such a system becomes commercially available.


Figure 5. Making Things Interact final demos at CMU

Fundamentally, Ubiquitous Drums' success depends on whether or not people enjoy the interactive experience that it provides. Although our informal findings have been encouraging, we intend to conduct a thorough study to get a detailed profile of the system's prospective users. On one hand, we want to learn how long non-drummers interact with Ubiquitous Drums before losing interest. On the other hand, we want to investigate whether skilled drummers are able to play complex rhythms and get an acceptable response.

Future Work

To make Ubiquitous Drums a more compelling experience for a wider audience, it must be fully wireless and independent of a computer. A natural direction is to leverage the ubiquity of cellular phones and integrate with an existing platform like iPhone or Android. Ideally, each drum pad could communicate directly with the phone through Bluetooth, eliminating the need for a central Arduino unit. As illustrated earlier, latency remains a problem for wireless communication. It is not clear whether Bluetooth can provide a short term solution, especially considering the incomplete implementations of the Bluetooth stack on both the iPhone 3.1 and Android 2.0 platforms.

Real drums have a subtle response depending on *how* the drum is hit, not just the hit's intensity. For example, a snare drum has a rim, which when struck creates a sound entirely different from the drum head. Hand drums like the bongos have similar properties, where impacts near the edge typically create a different, higher pitched noise. The current Ubiquitous Drums implementation does not sense where on the pad the user hit because it uses one sensor per pad. By embedding multiple sensors in the same pad similar to the Augmented Djembe[5], real drums can be simulated more accurately.

The Ubiquitous Drums system can also be enhanced to play back naturally occurring sounds from the world around us. A concept similar to Merrill's idea of capturing sound from the environment[8] could be applied to the context of percussion. A glove might be retrofitted with a microphone to capture the sound of one's hand hitting an object. Perhaps by simultaneously striking one of the pads, the pad would take on this sound. Thus it would become possible to dynamically program each pad to sound like real drums or something more fantastic.

References

[1] A. R. Tindale, A. Kapur, G. Tzanetakis, P. Driessen, A. Schloss. A Comparison of Sensor Strategies for Capturing Percussive Gestures. Proceedings of the International Symposium on Music Information Retrieval, 2005.

[2] Pygame, a set of Python modules designed for writing games. http://www.pygame.org

[3] P. Holleis, A. Schmidt, S. Paasovaara, A. Puikkonen, J. Häkkilä. Evaluating capacitive touch input on clothes. Proceedings of the Conference on Human Computer Interaction with Mobile Devices and Services, 2008

[4] F. Gemperle, C. Kasabach, J. Stivoric, M. Bauer, R. Martin, Design for Wearability. Proceedings of the International Symposium on Wearable Computers, 1998

[5] T. Maki-Patola, P. Hämäläinen, A. Kanerva. The augmented djembe drum: sculpting rhythms. Proceedings of the Conference on New Interfaces for Musical Expression, 2006

[6] T. Blaine, T. Perkins. The Jam-O-Drum Interactive Music System: A study in interaction design. Proceedings of the Conference on Designing Interactive Systems, 2000.

[7] T. Baba, T. Ushiama, K. Tomimatsu. Freqtric drums: a musical instrument that uses skin contact as an interface. Proceedings of the Conference on New Interfaces for Musical Expression, 2007

[8] D. Merrill, H. Raffle, R. Aimi. The sound of touch: physical manipulation of digital sound. Proceedings of the Conference on Computer-Human Interaction, 2008