NoiseBear: A Wireless Malleable Instrument Designed In Participation with Disabled Children

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ABSTRACT

NoiseBear is a wireless malleable controller designed for, and in participation with, physically and cognitively disabled children. The aim of the project was to produce a musical controller that was robust, and flexible enough to be used in a wide range of interactive scenarios in participatory design workshops. NoiseBear demonstrates an open ended system for designing wireless malleable controllers in different shapes. It uses pressure sensitive material made from conductive thread and polyester cushion stuffing, to give the feel of a soft toy. The sensor networks with other devices using the Bluetooth Low Energy protocol, running on a BlueGiga BLE112 chip. This contains an embedded 8051 processor which manages the sensor. NoiseBear has undergone an initial formative evaluation in workshop sessions with four autistic children, and continues to evolve in series of participatory design workshops. The evaluation showed that controller could be engaging for the children to use, and highlighted some technical limitations of the design. Solutions to these limitations are discussed, along with plans for future design iterations.

Keywords

malleable controllers, assistive technology, multiparametric mapping

1. INTRODUCTION

We present a wireless, malleable controller designed to facilitate complex interaction and control specifically in sonic and musical interaction contexts. The controller has been developed through an inclusive, interactive design method that features engagement with end users and those around them, with the aim of creating an object that can be integrated into the users daily experience. In particular, it has been developed specifically for, and in participation with, physically and cognitively disabled children at Whitefield Schools and Centre, Walthamstow. This process involves a number of challenges, as understanding the needs of these users requires an often slow process of observation, review, and consultation with teachers and therapists. The project rises out of a continuing development process exploring mobile music software development in assistive technology contexts. This work was done in collaboration with a number of schools and community organisations in the UK.

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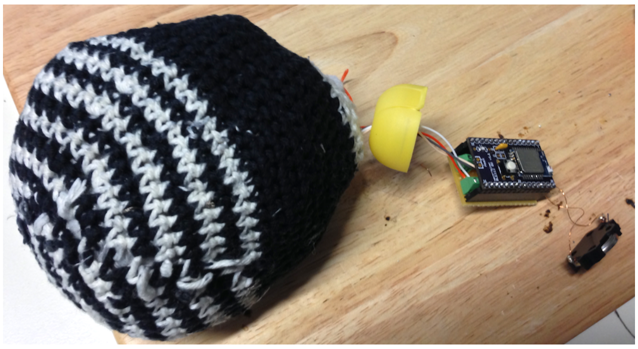

Figure 1: The sensor and internal electronics

It was initially observed that some participants struggled with the fine motor control requirements of portable touchscreens. In addition, we noticed that some users were not interested in the touchscreen at all, preferring a more tactile interaction. With this in mind, we decided to develop a tangible interaction device to complement other objects that users engaged with as part of their development, including tactile objects used by the users teachers as learning and interaction aids, with the purpose of developing a controller that was easy for teachers to use without expert assistance, and that would be easily integrated into everyday learning so as to incorporate sonic and musical interaction firmly within the learning context of the users.

2. RELATED WORK

Several projects have explored the cross-over between assistive technology design and NIME. Commercially produced instruments include the Skoog and the Soundbeam [2]. Machover's [10] HyperScore focused on individuals with mental health impairment. More recently, Grierson explored music creation with brain computer interfaces [5], and Luhtala et. al. [9] developed the DIYSE tool for individuals with learning disabilities.

Our participatory design approach follows from previous work in this area with children with disabilities, such as Frauenburger et. al's ECHOES project [4], Benton et. al's IDEAs project [1] and Hirano et. al's vSked [6]. Falcão and Price demonstrate the potential value of tangible interfaces for children with intellectual disabilities [3].

A range of approaches to the design of malleable controllers can be seen in Smith et. al's 3D modelling controllers [14], Sato et. al's *PhotoelasticTouch* [13], Marier's *The Sponge* [11] and Weinberg and Gan's *Squeezables* [15].

3. HARDWARE DESIGN

The project's aim of building a controller for use by children led to some challenging design requirements. Overall, a controller was required that would be flexible enough for the children to explore in a variety of scenarios in participatory design workshops. It also needed to have a look and feel that could be engaging to children. A key requirement was robustness; the controller needed to be able to survive pressure and shock damage, and it needed to be wireless as cables would be too fragile. Further to this, the controller needed to be able to network to our existing software which had been developed in previous workshops, and runs on iOS. Ideally, the controller needed to be cheap to produce, enabling multiple controllers to be built for group work, collaborative scenarios being particularly important for individuals with Autism Spectrum Conditions (ASC) where communication and social skills need to be developed. Finally, we observed how a class of children with ASC carried out daily exercises using a range of small objects in personalised work boxes. One aim of NoiseBear is to fit into this paradigm, by creating a tangible interface that could be embedded into the children's daily learning practice, offering new interactive possibilities.

3.1 Sensor Design

NoiseBear is based on Kiefer's *EchoFoam* system [8], a multiparametric malleable controller made with conductive foam. It offers some significant design improvements over EchoFoam: improved responsiveness, wireless communication, and increased robustness. Following from EchoFoam's design, the controller uses a set of electrical contacts connected around a mass of pressure sensitive material. Half of these contacts are for output, and half for input. A micro-controller in turn sets each output contact to high voltage, and then reads all the voltages on the input contacts. Each set of readings gives a deterministic description of the current shape of the controller. NoiseBear is designed in four and sixteen channel versions.

It was decided that the form factor of the controller would be a small woollen teddy bear. Currently, NoiseBear is the woollen ball that forms the main body of the bear, and will be extended with limbs and a head later. To build the controller, electrical contacts were attached to inside of a woollen ball, and the ball was filled with pressure sensitive stuffing. For the contacts, some EEG electrode connectors were sewn into to the wool using conductive thread. For stability in use, the area of the contact was increased by sewing the conductive thread in a wider circle around the contact centre (see figure 3). Several types of pressure sensitive stuffing were trialled. Thse included small conductive foam pieces and shredded conductive thread felted with cushion stuffing. Eventually, a simple but effective design of cushion stuffing balls wrapped with conductive thread was used (see figure 2). This created an arbitrary network of paths for current to flow through. As the ball was manipulated, the network changed, changing the resistance of the path between contact points. This approach was highly flexible, allowing many shapes of pressure sensor to be made. It also preserved the springy feel of cushion stuffing, making a realistic soft toy, and improving on the latency of conductive foam as the material expands to its default state more quickly.

3.2 Sensor Controller Design

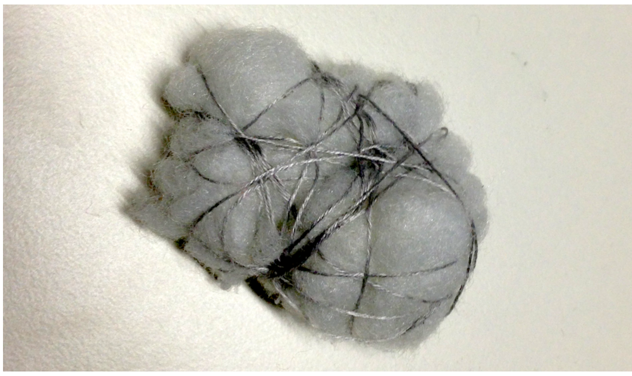

Figure 2: A Ball of Pressure Sensitive Stuffing

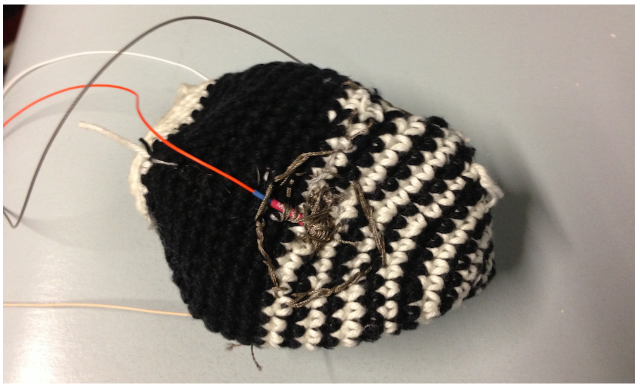

Figure 3: The inside of the ball, showing one of the contacts

The circuit is based around a Bluetooth Low Energy (BLE) chip, the BlueGiga BLE112[1], housed on a breakout board[2]. BLE was chosen for its connectivity with recent iOS devices, and because it gave some interesting possibilities for inter-controller networking. The BLE112 not only provides bluetooth functionality, it has a set of analog inputs and digital outputs and an embedded 8051 microprocessor. The 8051 is programmable, and provides all the functionality needed to operate and monitor the sensor. The chip is programmed in *BGScript*, and compiled binaries are flashed onto the chip using a Texas Instruments *CC debugger*.

It was important for the electronics to have a small footprint so they could be hidden within the controller while minimising any effect on the feel of using it. With the BLE112 chip managing the sensor, this footprint could be kept to a minimum. The extra circuity and connectors for the contacts are housed on a small stripboard with pin headers that the BLE112 breakout board could plug into as a shield. The whole unit measures 4 x 2.5 x 1.5cm, is powered by a 3V coin cell, and fits into a small plastic housing that sits in the stuffing inside the ball.

4. SOFTWARE DESIGN

The BLE112 was programmed to scan the pressure sensitive material at 25Hz, using the following algorithm:

iOS is limited to receiving 21 byte packets for each Bluetooth characteristic, so the data is sent as a block of 8 bit numbers. Connected devices are notified each time the

[1] `http://www.bluegiga.com/BLE112_Bluetooth_low_energy_module`
[2] `http://www.inmojo.com/store/jeff-rowberg/item/ble112-bluetooth-low-energy-breakout/`

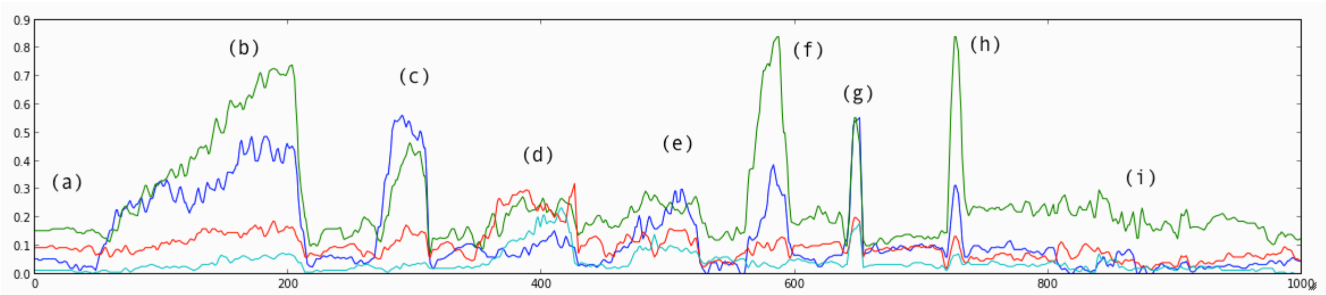

Figure 4: Sample output from a four channel controller

foreach *output* X **do**
  set the voltage at X to high;
  foreach *input* Y **do**
    read the voltage at Y;
  end
  set the voltage at X to 0V;
end

block is updated. The BLE112 can act as a server for up to four clients devices.

An iOS library was built, using the CoreBluetooth API to connect to the controller. The library applies an exponential mapping to the input streams to increase sensitivity, smoothes the signal with a three point moving average, and then passes the streams on to sound mapping processes.

5. MAPPINGS AND INTERACTIVE SCENARIOS

As a wireless malleable controller, NoiseBear offers a wide range of affordances. The player can use any type of deformation, for example squeezing, twisting or stretching. The controller can also be thrown, dropped or bounced against surfaces. In collaborative work, it can be passed or thrown between players. It can also used with other materials, for example it can be placed inside a larger toy or wrapped in other materials. It can also be used to augment other objects, for example it could be attached to a wheelchair.

There are a wide range of options for mapping the outputs. Typical uses include combining streams to create a binary switch or single continuous controller, or mapping the streams to separate continuous parameters. Post-processing of the streams can locate the area of the controller being manipulated, giving localised continuous or discrete mappings. The derivative can be taken to find the level of energy used in manipulating the sensor. Machine learning techniques have been employed to segment and classify gestures. Physically, the large sensor gives a many-to-one relationship between motions and output; there is always more than one way to achieve the same result.

Figure 4 shows an annotated example of the output from a four channel sensor. From rest state (a), (b) shows a gradual compression of the whole ball. (c), (d) and (e) show different sides of the ball being squeezed, and (f), (g) and (h) show the ball being poked with a finger. Note that the squeezes and pokes show different signals in different areas so they can be localised. (i) shows the ball being bounced against a table, unfortunately the bounce is not detected very well because the stuffing absorbs the impact.

6. FORMATIVE EVALUATION

Figure 5: Evaluation

The controller has been tested in a series of sessions with four severely autistic children (as pictured in figure 5), and will continue to be evaluated in further workshops. In preparation for the sessions, the controller was integrated into music software that had previously been developed in participatory design workshops with disabled children. The application is called SonicTag, and runs on iOS platforms. It allows the user to navigate through a set of simple sound interaction scenarios, which incrementally introduce new features. Users can record their own sounds and manipulate them. SonicTag was modified so that the recording and playback scenarios were triggered by squeezing NoiseBear, and so that multiparametric effects patches could be manipulated by the controller.

During the evaluation, the children were introduced to the controller by their teacher, and encouraged to explore its use. The authors observed these sessions, and made modifications to the mappings during the sessions in reaction to feedback from the children and teacher. The teacher was interviewed after the sessions.

The evaluation highlighted some positive aspects of the controller. It was clear that the children were engaged in using the controller, compared to how they interacted with the iPad in prevision sessions. They we're interested to explore how the controller worked, and some children adapted very quickly to the motions needed to operate the scenarios. Of particular interest was that when two children were present, they shared the controller between them.

The flexibility of the controller meant that we could explore several types of control during the sessions, and observe the preferences of the individual participants, allowing us to focus on more specific areas in the next sessions. In the continuous control scenarios, some children had trouble making a connection between manipulating the controller and the sound output; with this type of interface it's easy to make very abstract mappings, and the feedback shows that in forthcoming sessions we will focus on very clear sound-motion correspondence (the importance of which is highlighted by Jensenius [7]). Sometimes the participants were occasionally more focused on the iPad than the controller, this highlights the potential problems of a dual-device setup, and hiding the computer could be beneficial in some scenarios, possible moving to a scenario where graphics are projected. Feedback from the teacher suggested that we build a *sensory cube* version of the controller, with different tactile materials on each face; this will be the next iteration of the design.

7. CONCLUSIONS

We have presented the design and formative evaluation of NoiseBear, a wireless malleable controller. With regard to technical development, the BLE112 board has shown itself to be a flexible tool for instrument design; it provides some of the functionality of an Arduino style prototyping board along with low-power wireless communication. There are some drawbacks in programming the unit with *BGSCript*; each line of code can take 1-3ms to run, so more complex programs could run slowly. Also, arithmetic is limited to using signed 32-bit integers. However, this functionality works well enough for simply reading and transmitting data. Any further processing can be carried out on the client.

NoiseBear demonstrates a flexible system for building malleable controllers; the stuffing design can be housed in any fabric container, opening up a large space of design options. The multiparametric output can be used in a wide range of interactive scenarios, involving control that is discrete or continuous, offering localised areas of interaction on the controller, and gesture recognition. The design improves on the use of conductive foam, offering a more responsive feel with lower latency. Wireless operation with BLE opens up many possibilities, including controller-to-controller networking. There are some areas that need improvement; it would be ideal if the controller could register an impact signal when bounced against surfaces. Also, the many-to-one nature of the sensor means that the space of possible gestures for using the controller may be too large or confusing in some scenarios. When designing interaction for cognitively disabled individuals, it is especially important to keep this in mind.

Overall, designing for disabled individuals can be a extremely challenging area, yet it is one that can be very valuable; in what Pullin calls the trickle-up effect [12], the challenging design requirements involved in developing and evaluating assistive technology may result in robust techniques which can be used in the wider field.

8. FUTURE WORK

NoiseBear continues to be developed and evaluated in series of participatory design workshops. The project has plenty of scope of future additions. In the case of hardware, an accelerometer will be added, allowing tilt control and enabling impacts can be detected if NoiseBear is thrown or dropped. BLE gives the potential for networking several controllers and iOS devices together, so group multi-device group collaboration will be explored. Of particular interest is to find ways to embed the controller into the children's daily learning practice. For example, they have a box of objects and daily tasks to perform with them, the controller could be included as a tangible interface in this collection. The authors are also exploring the potential of NoiseBear in musical performance.

9. ACKNOWLEDGMENTS

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