Bela-Based Augmented Acoustic Guitars for Inverse Sonic Microinteraction

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ABSTRACT

This article describes the design and construction of a collection of digitally-controlled augmented acoustic guitars, and the use of these guitars in the installation *Sverm–Resonans*. The installation was built around the idea of exploring 'inverse' sonic microinteraction, that is, controlling sounds through the micromotion observed when trying not to move. The setup consisted of six acoustic guitars, each equipped with a Bela embedded computer, an infrared distance sensor, an actuator attached to the guitar body, and a battery pack. The result was a set of completely autonomous instruments that were easy to hang in a gallery space. The installation encouraged explorations on the boundary between the tactile and the kinesthetic, the body and the mind, and between motion and sound. The use of guitars, albeit with a nontraditional 'performance' technique, made the experience both familiar and unfamiliar at the same time. Many users reported heightened sensations of stillness, sound, and vibration, and that the 'inverse' control of the instruments was both challenging and pleasant.

Figure 1: A performance with the installation *Sverm–Resonans*. Each guitar is an independent instrument controlled by the microinteractions of a still-standing human.

Author Keywords

microinteraction, micromotion, standstill, installation, performance, Pure Data, Bela, BeagleBone, sensors

CCS Concepts

•**Applied computing** → **Sound and music computing;** •**Computer systems organization** → *Embedded and cyber-physical systems;* •**Human-centered computing** → *Field studies;*

1. INTRODUCTION

Is it possible to play an acoustic instrument by not moving? The project reported on in this paper is the merging of several different trends we have seen in the NIME community in recent years. One is that of focusing on finer control of digital musical instruments, or what may be called *sonic microinteraction* [4]. Another is that of investigating such microinteraction from the point of creating an 'inverse' instrument, in which the absence of motion is what is used to control the performance [5]. A third is that of exploring augmentation of acoustic instruments with various types of digital techniques [6, 7].

This paper describes the setup for the installation *Sverm–Resonans*, consisting of six actively augmented acoustic guitars (Figure 1). We present some design considerations and challenges with the implementation, and discuss some user experiences of the installation.

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2. BACKGROUND

2.1 Inverse control

The use of 'inverse' control has been suggested as an alternative control technique for NIMEs [5]. In normal instruments, particularly acoustic ones, there is a clear connection between the energy of the performer's sound-producing actions and the resultant sounds. Such connections are based on the mechanical properties of the actions, and the acoustic properties of the objects, involved in the interaction. In digital musical instruments, on the other hand, there are no such limitations, and the designer is free to create other types of mappings between action and sound. The majority of digital musical instruments are still based on some kind of action-oriented control paradigm. We therefore think it is interesting—conceptually, cognitively and technologically—to further investigate inverse control as an alternative control paradigm. We are not starting from scratch here, there are several examples of previous work, perhaps most notably Alvin Lucier's *Music For Solo Performer*, in which the performer's brain waves were controlling the sound. There are also examples of using other types of physiological measurements in performance, of which muscle control seems to be particularly popular [12, 2].

2.2 Augmented acoustic instruments

There has been a growing interest in the augmentation of acoustic instruments in recent years. These range from augmentation helping beginners to learn to play instruments [3, 1] to tools for expert performers [11, 7]. There are also examples of enhancing acoustic performance through digital sensing and sound manipulation [6]. One reason for this trend may be a wish to exploit the richness and non-linearities of acoustic sound generation, while at the same time utilizing the power of digital sensing and control.

2.3 Embedded computing

Digital musical instruments have for some time been built with computers as a core component, moving from desktop workstations to laptops, and more recently to single-board computers (SBCs) and embedded systems. There are many reasons why embedded musical systems are interesting, of which portability and stability are some of the most important ones from our perspective. One such embedded system that has caught our attention is the Bela platform [8]. This integrated hardware and software system makes use of the BeagleBone Black embedded computer, which runs a lightweight and real-time focused Linux operating system [13]. The Bela "cape" expansion board provides multiple channels of analog input and output, allowing for working with sensors and actuators at full audio rate, and with 'ultra-low' latency [9]. The integrated 1W speaker amplifiers allow for connecting a pair of speakers directly, simplifying the creation of a complete Bela-based instrument.

3. ARTISTIC GOALS

The artistic idea of the installation *Sverm–Resonans* was to invite people to relax, connect with their own breathing, and give them a soothing sonic and haptic experience. It was conceived of as a meeting point between a living body (the observer) interacting with an electronic sound system (the Bela) played through a vibrating acoustic instrument (the guitar). As such, *Sverm–Resonans* explores the meeting points between the tactile and the kinesthetic, the body and the mind, and between motion and sound.

We planned the installation with six guitars hung from the ceiling, giving a visually striking appearance in the space. Interacting with hanging guitars also proposes a different user experience than the normal way of playing a guitar either in your lap while sitting or hung over the shoulder when standing. The idea was that one would interact with a guitar by standing in front of it, touching its body, and feeling its vibrations (Figure 1). People were informed that they would have to stand still in front of a guitar for the sound to appear. It was also important that the guitars should be 'alive', hence produce some sound also when idle to encourage interaction from passersby.

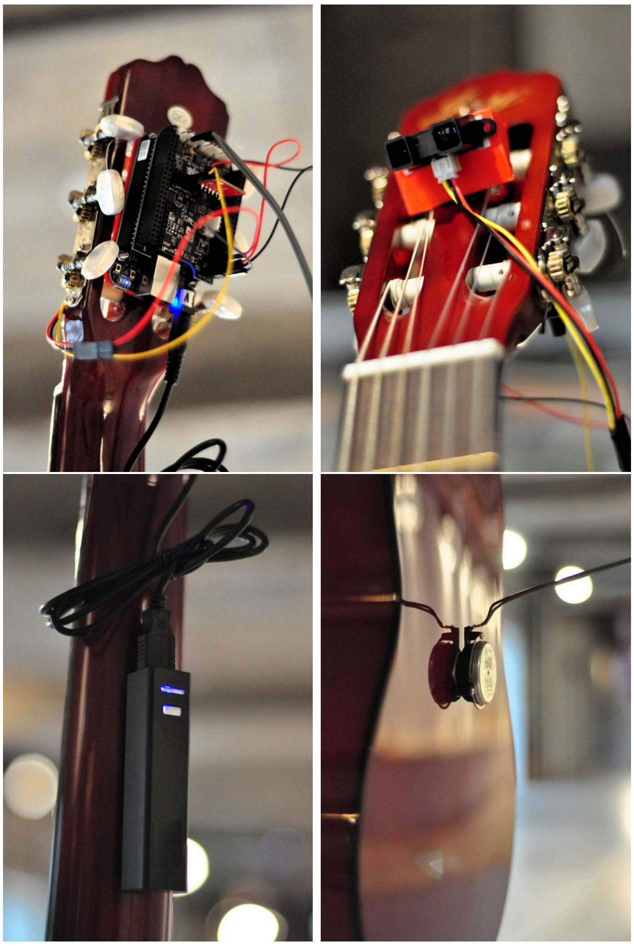

Figure 2: From top left: (a) Bela micro-computer, (b) IR-sensor attached to the headstock, (c) USB power source attached to the neck, (d) An actuator placed on the back plate of a guitar,

4. DESIGN AND IMPLEMENTATION

A design goal was to construct each guitar as an independent and self-contained system, and robust enough to be deployed in various installation situations. This was achieved by equipping each guitar with a Bela embedded system, an infrared distance sensor, an actuator, and a battery pack (Figures 2, 3). There were no external speakers, all the sound was generated by the vibrations of the acoustic guitar made by the actuator.

4.1 Sensing

For the detection of a user interacting with the system, we settled on a Sharp GP2Y0A02YK0F distance measuring sensor mounted on each guitar's headstock. This sensor incorporates position sensitive detection (PSD), an infrared emitting diode (IRED), and a signal processing circuit to yield the voltage corresponding to the detection distance. Similar sensors have previously been used at NIME to detect hand position over an interface [10]. We chose this particular proximity sensor as it has a fairly long range (15–150 cm), making it suitable for use in an installation environment in which participants may be up to a meter away from the instrument.

The sensor was attached to the headstock of each guitar (see Figure 2b) with a 3D-printed spacer used to provide a consistent downwards angle. When the guitar was suspended from the ceiling, the sensor was able to detect the

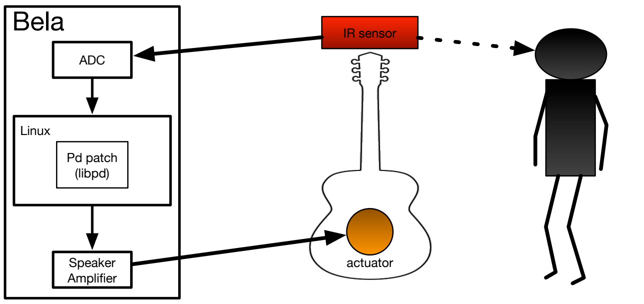

Figure 3: Diagram of our augmented guitar system. Each battery-powered system was self-contained on the guitar and the guitars were suspended from the ceiling of the exhibition space.

presence of a human in an area around 1 m in front of the guitar, but was not able to detect other guitars or the walls of the exhibition space.

4.2 Processing and actuating

The Bela system was mounted on a 3D-printed plate, which was attached to the rear of each guitar's headstock using velcro (see Figure 2a). This allowed for both a stable placement, but also the possibility to quickly remove the Bela for testing and maintenance.

One of the Bela's on-board amplifiers was used to drive a TEAX32C30-4/B structure-borne actuator glued to the back plate of each guitar (see Figure 2d). This compact, rubber-sealed actuator provides a robust, durable and portable solution for sound transduction [7]. After much testing, we settled on positioning the actuator in the middle of the back plate, to ensure maximum vibration. Despite the low-powered amplifier this setup was sufficient to produce a remarkably loud and rich sonic experience, particularly when the guitars were suspended in a resonant gallery space.

Each augmented guitar system was powered by a 3000 mAh USB battery pack attached to the neck (see Figure 2c). The battery was also attached with velcro, to allow for easily switching packs during the installation. In practice, we found that a battery could supply power for 3 hours, and we made a routine of switching every 2.5 hours to keep the installation running continuously.

4.3 Sound Design

Pure Data (Pd) was chosen as the environment for sound design in this project. The Bela environment facilitates working with Pd by automatically opening patches in a provided C++ program using the `libpd` library. The installation patch had two layers of sound: (a) pulsating 'drone' that was present all the time, and (b) an inversely controlled 'breathing' sound that the users would interact with.

The 'drone' was programmed with simple additive synthesis using sine oscillators to form a base tone and a few inharmonic partials. This was modulated through a low frequency oscillator, giving the drone a relaxed and pulsating feel. The frequencies and amplitudes of the sine tones were selected after much experimentation with the combination of actuators, actuator placement, and the acoustics of the space. Some randomness on all the synthesis parameters secured that the overall soundscape in the room changed slowly throughout the day, and also ensured a general sonic complexity with the sound from the individual guitars moving in and out of phase with each other.

The 'breathing' sound layer was programmed with a noise generator modulated with a low frequency oscillator so that it resembled the pace of human breathing. This sound was controlled inversely through an amplitude ramp that started when the sensor detected a person standing still. A threshold was set to ensure that people were actually standing still in front of the guitar, not just passing by. The maximum sound level would be reached after one minute of standstill, and if the user moved away from the guitar the sound would cut with a quick 1 s fade-out. The IR sensor's detection range was used to limit the participants' possibility to move, and to define the 'stillness' level. For performance setups we have been using continuous control, but for the installation we decided to use a single on/off interaction paradigm for both presence and stillness.

Figure 4: Connecting with the guitars through different holding strategies. By lightly touching the body of the instrument, participants can feel the sound of their guitar and at the same time find a focal point for standing still.

5. DISCUSSION

The installation ran for a week during the Ultima contemporary music festival in Oslo.[1] A number of people passed by, and approximately 200 people interacted with the guitars (Figure 4). We observed audience interaction from a distance, and also collected feedback through recorded interviews with some of the participants. Several of them commented on the meditative nature of the installation:

> I really enjoyed it. This was meditational, and

[1] `https://doi.org/10.5281/zenodo.1215947`

> the sounds hit me in different parts of my body.

It was interesting that people felt that the guitars were 'different,' because, in fact, they were running the same patches, albeit with randomly controlled settings:

> The sensations you have from different guitars are very interesting, and you can feel, like, a heartbeat. It's like they had different heartbeats with different grades.

Some people were confused—some even irritated—by the inverse control paradigm, but there were also several positive comments, such as:

> In the optimal scenario I would just stand with this guitar for a day or two, or three, and not move, and become a stone. And then after one week of standing, or one month, or even one year of standing here, the entire building would collapse from the sound.

One of the things we were most satisfied with ourselves, was the placement of the guitars in the space. During the development phase we experimented with many different setups, before we settled on hanging the guitars from the ceiling using a strong, invisible fishing line. This gave a strong visual appearance in the space, and made the guitars–a well-known instrument for most people–into an aesthetic object in itself. The hanging of the guitars at trunk height, also invited for a close contact between the vibrating guitar body and the hands of participants touching them (Figure 4). Finally, hanging the guitars also made them vibrate more than when we tested with guitar stands, so the built-in amplifiers of the Bela were more than strong enough for reaching the necessary sound level.

6. CONCLUSIONS

This project allowed the exploration of both technological and artistic concepts, with a clean, fast, efficient, and self-contained setup. Unlike our early prototypes that used laptops and amplifiers with wired connections, we were now able to assemble completely independent, lightweight, and battery-powered augmented guitars that worked flawlessly during a week in a professional installation context. The successful implementation of the Bela into an augmented instrument system provides opportunities for improved interaction features, allowing for more precise motion detection and, thus, more realistic sonic response.

Even though we have not carried out a formal user study or evaluation, the informal observation and audience feedback suggest that we reached our aim of giving people a space to relax and reflect on their own standstill and stillness. Although some people were confused, many also found the inverse control paradigm to be engaging and different, challenging their preconceived notions of sound generation and instrument interaction.

In future developments we will add more sensors, such as inertial measurement units (IMUs) to pick up more micromotion, and other range-finding sensors to detect people at a longer distance. We will also explore the addition of a second actuator to allow for more complex sound generation and rendition. Adding more guitars will also involve the need for a more efficient software deployment solution, preferably through a wireless connection to the Belas.

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8. REFERENCES

[1] A. Baldwin, T. Hammer, E. Pechiulis, P. Williams, D. Overholt, and S. Serafin. Tromba moderna: A digitally augmented medieval instrument. In *Proc. NIME*, volume 16 of *2220-4806*, Brisbane, Australia, 2016. URL: `http://www.nime.org/proceedings/2016/nime2016_paper0004.pdf`.

[2] M. Donnarumma, B. Caramiaux, and A. Tanaka. Muscular interactions. combining EMG and mmg sensing for musical practice. In *Proc. NIME*, Daejeon, Republic of Korea, 2013. Graduate School of Culture Technology, KAIST. URL: `http://nime.org/proceedings/2013/nime2013_90.pdf`.

[3] F. Heller, I. M. C. Ruiz, and J. Borchers. An augmented flute for beginners. In *Proc. NIME*, Copenhagen, Denmark, 2017. URL: `http://www.nime.org/proceedings/2017/nime2017_paper0007.pdf`.

[4] A. R. Jensenius. Sonic Microinteraction in "the Air". In M. Lesaffre, P.-J. Maes, and M. Leman, editors, *The Routledge Companion to Embodied Music Interaction*, pages 431–439. Routledge, NY, 2017.

[5] A. R. Jensenius, V. G. Sanchez, A. Zelechowska, and K. A. V. Bjerkestrand. Exploring the Myo controller for sonic microinteraction. In *Proc. Int. Conf. NIME*, pages 442–445, Copenhagen, Denmark, 2017. URL: `http://www.nime.org/proceedings/2017/nime2017_paper0083.pdf`.

[6] M. Kimura, N. Rasamimanana, F. Bevilacqua, N. Schnell, B. Zamborlin, and E. Fléty. Extracting human expression for interactive composition with the augmented violin. In *Proc. NIME*, Ann Arbor, Michigan, 2012. URL: `http://www.nime.org/proceedings/2012/nime2012_279.pdf`.

[7] O. Lahdeoja. An augmented guitar with active acoustics. In *Proceedings of the Sound and Music Computing Conference*, Maynooth, Ireland, 2015. URL: `https://doi.org/10.5281/zenodo.851048`.

[8] A. McPherson. Bela: An embedded platform for low-latency feedback control of sound. *J. Acoust. Soc. Am.*, 141(5):3618–3618, 2017.

[9] A. McPherson, R. Jack, and G. Moro. Action–sound latency: Are our tools fast enough? In *Proc. NIME*, Brisbane, Australia, 2016. URL: `http://www.nime.org/proceedings/2016/nime2016_paper0005.pdf`.

[10] C. Miyama. Peacock : A non-haptic 3D performance interface. In *Proc. NIME*, Sydney, Australia, 2010. URL: `http://www.nime.org/proceedings/2010/nime2010_380.pdf`.

[11] L. Reboursière, C. Frisson, O. Lähdeoja, J. A. Mills, C. Picard-Limpens, and T. Todoroff. Multimodal guitar : A toolbox for augmented guitar performances. In *Proc. NIME*, Sydney, Australia, 2010. URL: `http://www.nime.org/proceedings/2010/nime2010_415.pdf`.

[12] A. Tanaka and R. B. Knapp. Multimodal interaction in music using the electromyogram and relative position sensing. In *Proc. NIME*, Dublin, Ireland, 2002. URL: `http://www.nime.org/proceedings/2002/nime2002_171.pdf`.

[13] V. Zappi and A. McPherson. Design and use of a hackable digital instrument. In *Proc. Live Interfaces*, Lisbon, Portugal, 2014. URL: `https://www.eecs.qmul.ac.uk/~andrewm/zappi_icli14.pdf`.