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 by the micromotion observed when attempting to stand still. It consisted of six acoustic guitars, each equipped with a Bela embedded computer for sound processing (in Pure Data), an infrared distance sensor to detect the presence of users, and an actuator attached to the guitar body to produce sound. With an attached 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 an untraditional '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 instrument was both challenging and pleasant.

Author Keywords

microinteraction, micromotion, installation, 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

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

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 [3]. Another is that of investigating how it may be possible to think of such microinteraction from the point of view of creating an 'inverse' instrument [4], in which the absence of motion is what is used to control the performance. Finally, the third is that of exploring augmentation of acoustic instruments with various types of digital techniques [5].

This paper describes the technical 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.

2. BACKGROUND

2.1 Inverse control

The use of 'inverse' control has been suggested as an alternative control technique of NIMEs [4]. 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. In acoustical musical instruments 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, as there are some examples of previous work, most notably Alvin Lucier's *Music For Solo Performer*, in which the performer's brain waves were controlling the sound. More recently, it has been explored in performances using signals from the micromotion of people trying to stand still [4].

2.2 Augmented acoustic instruments

There has been a growing interest in the augmentation of acoustic instruments in recent years. These range from augmentation aimed at helping beginners to learn to play instruments [2, 1], to tools for expert performers [9]. There are also examples of enhancing acoustic performance through digital sensing and sound manipulation [5]. One reason for this recent trend — which is, interestingly, happen in parallel with a renewed interest in analog synthesizers — 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. This is also the motivation in our project.

2.3 Embedded computing

Digital musical instruments have for some time been built with computers as a core component, moving from desktop stations to laptops, and more recently to mini/micro-computers and so-called embedded systems. There are many reasons why embedded systems are interesting from a musical perspective, of which portability and stability are some of the most important ones from our perspective. While there are numerous embedded computing platforms available, one that has caught our attention is the Bela platform [6]. The Bela project started with the aim to provide artists, researchers, and enthusiasts with an accessible tool for the development of digital musical instruments [10]. This integrated hardware and software system makes use of the Beaglebone black embedded computer, which runs a lightweight and real-time focused Linux version. The Bela "cape" expansion board provides multiple channels of analog input and output, allowing for working with sensors and actuators at full audio rate. Of particular interest from an interaction perspective is what the Bela developers call 'ultra-low' latency, based on the fact that the total round-trip latency is lower than any other computer-based solution [7]. The two integrated 1W speaker amplifiers also means that it is possible to connect directly to speakers, further 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, auditory and haptic experience. It was conceived of as a meeting point between a living body interacting with an electronic sound system played through a vibrating acoustic instrument. As such, *Sverm-Resonans* explores the meeting points between the tactile and the kinesthetic, the body and the mind, and between motion and sound.

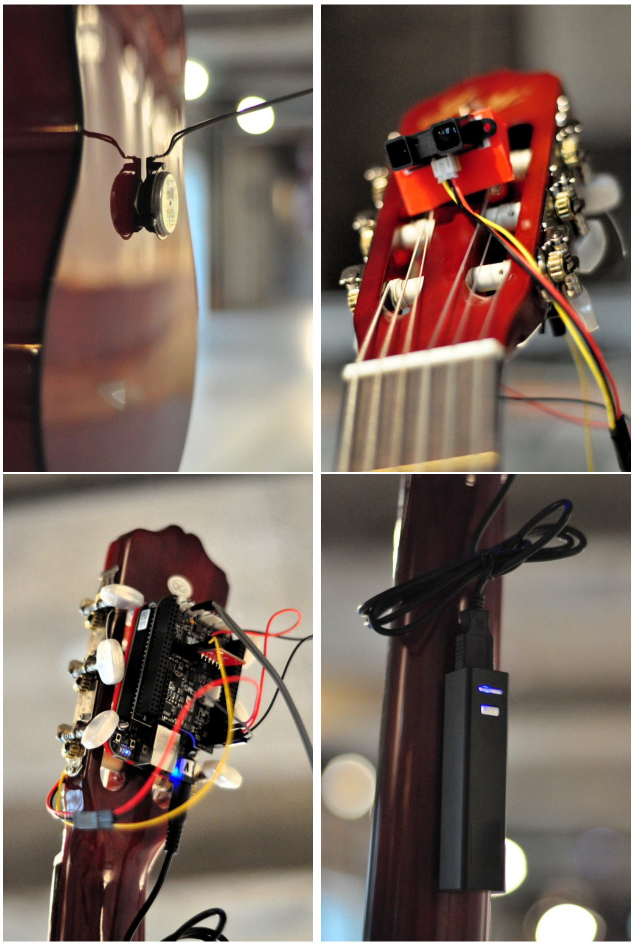

Figure 2: From top left: (a) An actuator placed on the back plate of a guitar, (b) IR-sensor attached to the headstock, (c) Bela computer, (d) USB power source attached to the neck.

We planned the installation so that six guitars would hang from the ceiling, which in itself would create a different experience of an instrument that otherwise is played through holding. The idea was that one would interact with a guitar by standing in front of it. Participants were invited to touch the guitars, to feel the vibrations, and they 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' when not interacting with them, encouraging interaction from passersby.

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 micro-computer, an infrared distance sensor, an actuator, and a battery pack (Figure 2). There are 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 measur-

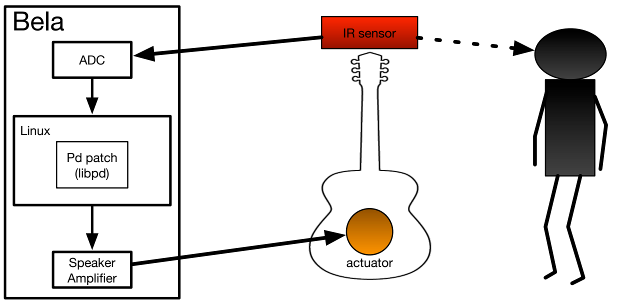

Figure 3: Diagram of our augmented guitar system. Each battery-powered system was self-contained on the guitar and the guitars were suspended from the ceiling of the exhibition space.

ing 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 [8].

We chose this particular proximity sensor as it has a fairly long range — the analog output varies from 2.8 V at 15 cm to 0.4 V at 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 requires a supply voltage between 4.5 and 5.5 VDC, provided by the Bela through its P9-7 pin; the sensor output was connected to analog input 3 of the Bela cape (Figures 2, 3).

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 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 2c). 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 an acoustic actuator glued to the back plate of each guitar's body (see Figure 2a). 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 2d). 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. This workflow allowed us to quickly prototype sounds on a laptop and deploy to multiple guitars via the Bela's USB network interface to update the patch.

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.

The installation patch had two layers of sound, one pulsating 'drone' that was present all the time and an inversely controlled 'breathing' sound that the users would interact with. The 'drone' was programmed with a simple additive synthesis, a sine tone with a few 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 that the sound from the individual guitars went in and out phase with each other.

The second layer of sound was programmed with a noise generator modulated with a low frequency oscillator resembling breathing. This sound was controlled inversely with an amplitude ramp that started when the sensor detected a person standing still. 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.

5. DISCUSSION

The installation was running for a week during a contemporary music festival. 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 several participants. Many of them suggested that the standstill and relaxed soundscape was meditative:

> I really enjoyed it. This was meditational, and the sounds hit me in different parts of my body.

We were satisfied that our aim to create sounds that resembled pulse and breathing was picked up by the participants. It was also 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.

And although some people were confused — some even irritated — by the inverse control paradigm, there were also many positive comments:

> 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 thing we were satisfied with ourselves was the placement of the guitars in the space. During the development phase we experimented with a number of different placements of the guitars, standing, lying, holding, and hanging. Finally, we settled on hanging the guitars from the ceiling using a strong and 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, and efficient setup made possible through the Bela platform. 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 Bela into the augmented instrument system provides opportunities for improved interaction features, allowing for more precise motion detection and, thus, more realistic response.

Audience feedback on the installation 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.

7. ACKNOWLEDGMENTS

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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. Int. Conf. NIME*, volume 16 of *2220-4806*, pages 14–19, Brisbane, Australia, 2016. URL: `http://www.nime.org/proceedings/2016/nime2016_paper0004.pdf`.

[2] F. Heller, I. M. C. Ruiz, and J. Borchers. An augmented flute for beginners. In *Proc. Int. Conf. NIME*, pages 34–37, Copenhagen, Denmark, 2017. URL: `http://www.nime.org/proceedings/2017/nime2017_paper0007.pdf`.

[3] 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, New York, 2017.

[4] 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`.

[5] 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. Int. Conf. NIME*, Ann Arbor, Michigan, 2012. URL: `http://www.nime.org/proceedings/2012/nime2012_279.pdf`.

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

[7] A. McPherson, R. Jack, and G. Moro. Action-sound latency: Are our tools fast enough? In *Proc. Int. Conf. NIME*, volume 16, pages 20–25, Brisbane, Australia, 2016. URL: `http://www.nime.org/proceedings/2016/nime2016_paper0005.pdf`.

[8] C. Miyama. Peacock : A non-haptic 3D performance interface. In *Proc. Int. Conf. NIME*, pages 380–382, Sydney, Australia, 2010. URL: `http://www.nime.org/proceedings/2010/nime2010_380.pdf`.

[9] 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. Int. Conf. NIME*, pages 415–418, Sydney, Australia, 2010. URL: `http://www.nime.org/proceedings/2010/nime2010_415.pdf`.

[10] V. Zappi and A. McPherson. Design and use of a hackable digital instrument. In *Proc. Live Interfaces*, 2014.