Human-centered computing in Augmented Instruments. E-guitar interface case study

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ABSTRACT

This chapter combines the analysis of augmented instruments with the development of a prototype interface for the electric guitar as a case study. The research process assumes the principles of HCC (Human Centered Computer) to create user-oriented interfaces. In this case, it seeks a model of augmentation integrated into the instrument that harnesses the full potential of the computer while reducing its dependency on stage. The goal is to provide more freedom to the musician by using a telematic device and applying SMI (Smart Musical Instruments) technology. Furthermore, it aims to be minimally invasive to the instrument through reduced augmentation. The project focuses on "analogizing" the computer, turning it into a module in the sound chain, and bringing its control to the developed interface. This approach connects with the post-digital thinking framework and the ubiquity of computers in art. Finally, it opens the way to reinterpret works from the contemporary repertoire of the electric guitar, taking advantage of the electronic flexibility due to this integration and addressing technological transfer, i.e., the shift in technological framework used in contemporary works.

I

The evolution of musical instruments is the result of a historical process related to social, scientific, and technological advancements. In electronic music, the arrival of computers brought about a paradigm shift that quickly took hold. From the 1980s with the evolution of personal computers and the development of the MIDI (Musical Instrument Digital Interface)[1] language to the present day, the use of digital devices has exponentially expanded in electronic music.

> *1983 was an important landmark (...) establishing the credibility of digital rather than analog methods of synthesizer design at the very heart of the industry. (...) By the dawn of the MIDI era, however, the design and development of such computers was proceeding more rationally. Manufacturers had started to concentrate on generic approaches to the production of new models, in many instances designed specifically to accommodate applications developed for earlier technologies* (Manning, 2013).

1 In spite that the 1980s mark a turning point, 1963 is considered the foundational year for computers as musical instruments according to “Getting Out of the Black Box: analogising the use of computers in electronic music and sound art”(Charrieras and Mouillot, 2015).

> *The 1983 publication of the MIDI standard was another major step in the development of electronic instruments, allowing new ways to design interfaces connecting the performance and computer (Diegert & Artacho, 2018).*

Before the 1980s, analog electronics were used, and instruments took advantage of the technological advancements of the time. Their use was aimed at fulfilling certain needs or deficiencies (especially in the case of amplification) and also at highlighting aesthetic features, such as in the Moog synthesizer.

> *In the early twentieth century, we get electric amplification of instruments that previously were too low in amplitude (such as the guitar in a jazz band setting), and new electronic instruments in the form of synthesizers and tape* (Magnusson, 2021).

In this organological development of the 20th century, existing instruments were used as a basis for construction, in some cases to be improved through an additive modification process:

> *In the case of the electric guitar, the question of coexistence between the acoustic and electric levels of the instrument has been addressed with a cumulative model of augmentation* (Lähdeoja, 2008).

In other cases, instruments were transformed with notable acoustic modifications. In these cases, the resulting instrument is not a continuation of the model it is based on, but rather utilizes certain aspects of it. An example is the keyboard family, where the keyboard interface persists but gives rise to very different instruments. This transformation is closely linked to the difference between electric and electronic. Electric instruments use the same acoustic source and amplify it electrically, while electronic instruments rely on other components such as vacuum tubes, oscillators, modulators, filters, etc. Additionally, new instruments were created in the 20th century, such as the Theremin.

In all of these discussed cases, the core of the process is an analog transformation of the audio signal. The sound source of the instrument is separated from its physical body.[2] This procedure anticipates the idea that the augmented instrument should be arranged in a network, forming a sound chain. “A network of sound production and processing units, spatially extended and configurable by the player” (Lähdeoja & Navarret, 2010).

With the improvement of computers, new sound interfaces begin to shape this sonic universe that machines propose. From an engineering perspective, the primary practice is the use of sensors that send information to the computer, which then transforms it.

> *Today there is a wide (if not to say wild) variety of sensors available. Virtually any real-world action can be translated into electrical energy and therefore serve as a control signal for an electronic (analog or*

[2] This characteristic will be more prevalent in augmented instruments where sound processing will be separated from the instrument.

digital) sound source (...) the distance between controller and that which is controlled became even bigger (Bongers, 2000).

Associated with this architecture, the idea of the Hyperinstrument emerged in 1986, associated with MIT and Tod Machover (Tod Machover, n.d.), which other authors refer to as Hybrid instruments (Bongers, 2000), and the majority as Augmented instruments: Wanderley (Wanderley 2004), Turchet (Turchet 2018), Lähdeoja (Lähdeoja and Navarret 2010), Furniss (Furniss 2017).

The family of the so-called "augmented-instruments" or "hyper-instruments" is composed by acoustic instruments that are enhanced at hardware level with sensor and/or actuator technology, and at software level with digital signal processing techniques.(Turchet, 2017).

Miranda and Wanderley (Miranda and Wanderley, 2006) define four types of DMIs [3] (Digital Music Instruments): Alternate controller, Instrument-Like controller, Instrument-Inspired controller, and Extended instruments. These categories encompass new instruments, instruments that take the form of existing ones, instruments that are inspired by others, and expanded instruments. We can see that the strategies for modifying instruments are quite similar in DMIs and acoustic instruments. A distinction is made between the practice of creating new instruments that do not aim to reconcile with the historical process of the instrument and its interpretive technique, and the idea of adapting existing instruments to varying degrees. The new organological and musical need that arises now is to express the potential of the computer.

To achieve this, it is important to understand how the performer's human body generates musical expression through gesture and musical technique. The emergence of computational sound possibilities requires the organicity that performers have developed in their traditional instruments to be applied to these new interfaces.

The communication between a musician and the instrument is often intimate and precise. This has been the case with traditional (acoustic) instruments, and developers of electronic instruments often strive for the same level of intimacy and precision (Bongers, 2000).

Most acoustic instruments are played through a close, physical connection between the body of the performer and the body of the instrument, what I will call an "action–sound coupling." In comparison, electro-acoustic instruments are based on "action–sound mappings" that can be more or less "disembodied".(Jensenius, 2022).

Initially, music with computers was better suited for music production and composition than for live performance. The created interfaces aimed to achieve the level of receptiveness and sensitivity found in traditional instruments. This quest to enhance the computer-performer communication also led to the study of performer movement

[3] A clarification regarding the diversity of instruments based on electronics: Musical electronics can be analog, digital or mixed. According to some definitions (Lähdeoja 2008), not all augmented instruments have to be DMIs, even other definitions presuppose the existence of a computer/software (Bongers 2000) (Turchet 2018). This study focuses on augmented instruments as DMIs.

characterization and the programming of related computer models. This allowed for the creation of more intuitive interfaces adapted to the musical expressions and gestures of performers, thereby facilitating real-time performance with computers.

II

The previous paragraphs describe the construction and evolution of instruments in relation to technology and computers. This chapter focuses on the relationship with the instruments from the performer's point of view. In terms of music interpretation, this entire process of instruments evolution and musical sounds generates a vast set of issues, especially nowadays when, in mixed music it is common to use a computer on stage as a module of the technological process.

> *Computers have become ubiquitous in all kinds of music production and performance (...) Computers have also taken on a major role in the realm of contemporary classical music, where many musicians are looking to computers as a means of expanding the palette of sounds available to them* (Diegert and Artacho, 2018).

> *In the post digital era the computer is integral to the arts. Computers are at the core of contemporary electronic music and are fundamental in performance practice.*(Vasilakos, 2016).

The key point is how this use affects to the performance with instruments, either on classical instruments or on more modern instruments that have their own electronification processes like synthesizers or electric guitars. The chapter focuses on the analysis of the binomial computer-instrument (which is already an augmentation mechanism)[4] that leads to categorizing the typology in interpretation with computers. It is a graduation that goes from approaches in which the performer does not control the elements of the electronic, to processes where the management of augmentation and electronics completely absorbs the performer losing concentration on the music, passing through those where there is a balanced relationship between the augmentation and the instrument technique.[5]

Within this scale, it is convenient that the performer uses the electronic potential of the computer, without unnecessary distractions, and without assistance of the electronic part. These characteristics configure the design of the augmented instrument leading towards developing new instruments that integrate computer parameters in a more organic way, harnessing the full digital potential added to an existing instrument while still preserving its previous identity prior to augmentation.

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[4] The difference between augmented instrument and augmentation mechanism is that in the augmented instrument the augmentation mechanisms can be controlled from the performer's technique, that is, without external assistance.

[5] Several authors have treated the relationship of the performer with electronics from different angles, MacDonald writes about the experience of the performer when the electronics are intervened by an external agent (MacDonald 2021) Diegert and Artacho (Diegert and Artacho 2018) seek to bring the electronic process closer to the performer and Stroppa (Stroppa 1999) talks about the nuances playing with fixed electronics. In Fennesz's performance (Boiler Room 2015) we see the computer used as a module alongside the electric guitar, in this case it would be an augmentation mechanism rather than an augmented instrument.

Human-Computer Interaction (HCI) is a field of study, not exclusive to music, focused in the use of computers. When emphasis is placed on the feasibility of computer use, it is referred to as Human-Centered Computing (HCC). HCC is “a software design process that results in interfaces that are really user-friendly” (Jaimes et al., 2006).

Considering this, there are two important features for augmented instruments design: to be able to control computers so that the focus of performance can stay in the music and to attend to HCC theories for a natural integration with the performer musical skills. In fact, several instruments of this kind have already been developed,[6] and a crucial study was done in the case of the electric guitar, highly focused in HCC and designed in collaboration with the performers (Newton and Marshall 2011). The ideal scenario is that the possibilities offered by the computer be embedded into the instrument and used in a straightforward and remote manner while making music. This entails an embodiment of the computer. Various research approaches address the need for computer embodiment and the non-material element, which was already acknowledged as early as 1994: “A good tool is an invisible tool**”** (Weiser, 1994).

> *The omnipresence of digital content and its systematic reduction and integration into the physical world makes it disappear in our perception, making it an integral part of our lives* (Schubert, 2021).

One of the goals chased by the current research is an interface that possesses the sensitivity of traditional instruments and can easily and even intuitively control computer parameters. This development process pursuits telematics over cabling and the transition towards less material elements replacing physical devices. The definition of SMI (Smart Musical Instruments) captures this concern:

> *Augmented musical instruments (AMIs) consist of the augmentation of conventional instruments by means of sensor or actuator technologies. Smart musical instruments (SMIs) are instruments embedding not only sensor and actuator technology, but also wireless connectivity, on-board processing, and possibly systems delivering electronically produced sounds, haptic stimuli, and visuals* (Turchet, 2018).

At a specific and technical level, the objective is for the computer to become an additional module whose control is integrated in the instrument and carried by the musician while performing.

> *computers, regardless of their technical specifications, are not only ‘black boxes’ or ‘meta-tools’ that serve to control music software, but are also material objects that are increasingly being used in a wide range of musical and sound art practices according to an ‘analog’ rather than ‘digital’ logic* (Charrieras and Mouillot, 2015).

In the specific case of the electric guitar, it is important to explain in detail how this objective is achieved.

III

[6] Some examples are: Augmented Violin (Frédéric et al. 2006), Hyper-flûte (Palacio-Quintin 2011) or Hyper-Mandolin (Turchet 2017).

A key conclusion from the previous section is the importance of effective communication between the computer and the instrument when considering augmentation. Building upon this point, the current research aims to design an interface that functions as a controller for the software processes and is integrated into the electric guitar. The goal is to expand the capabilities of the electric guitar and simplify its digital electronic operations, reducing the reliance on the computer and technical assistance, and instead empowering the performer to have control.

In developing this augmentation, consideration is given to the aforementioned divided relationship between the interface and the computer, as well as the musical adaptation to the existing sonic universe. The divided relationship establishes a foundational dichotomy in digital interfaces, allowing an instrument to remain identical as an object while its sonic palette can be radically different. This is evident in MIDI keyboard controllers, which simply send messages that are transformed into sound through computer processing. In contrast, analog setups require individual modules for each effect. This difference is significant because it enables the reconfiguration of electronic components in digital instruments. As a result, the interface can adapt to various instrument forms and different technical and physical approaches.

Regarding the adaptation to the existing sonic universe, it pertains to the desired musical outcome. A question that often arises in HCI research and the development of new instruments is whether the interface-performer-computer relationship should create new sounds independent of control gestures or instead emphasize expressive gestures or non-causal and even chaotic relationships between gesture and sound.

> *We hypothesize that a generation of coders and engineers is emerging, composed of ... artists who are more interested in developing instruments which leave a space for the machinic to express itself and respond to us in novel unpredictable ways* (Oreggia and White, 2018).

> *I envisioned to create a disorientating musical environment in which the relation between the act of playing the guitar and the resulted sound is blurred in different levels* (Prins, 2007).

The question at hand is whether the objective is to create new techniques and sounds or to be able to manipulate existing ones, or both. Ideas of non-causality, or chaotic or creative systems, while attracting a significant portion of research due to their artistic and technological appeal, diverge from a more pragmatic view in which digital setups seek to recover the uses of electronics that were already made in analogic or hybrid past sets. The latter view is the one in which this study is focused.

In the case of the electric guitar, in an analog setup, actions are performed directly on the modules themselves, rather than on a controller that affects the module. This allows for significant expansion of the setup. In contrast, digital setups may offer a simplified approach to achieving similar outcomes.

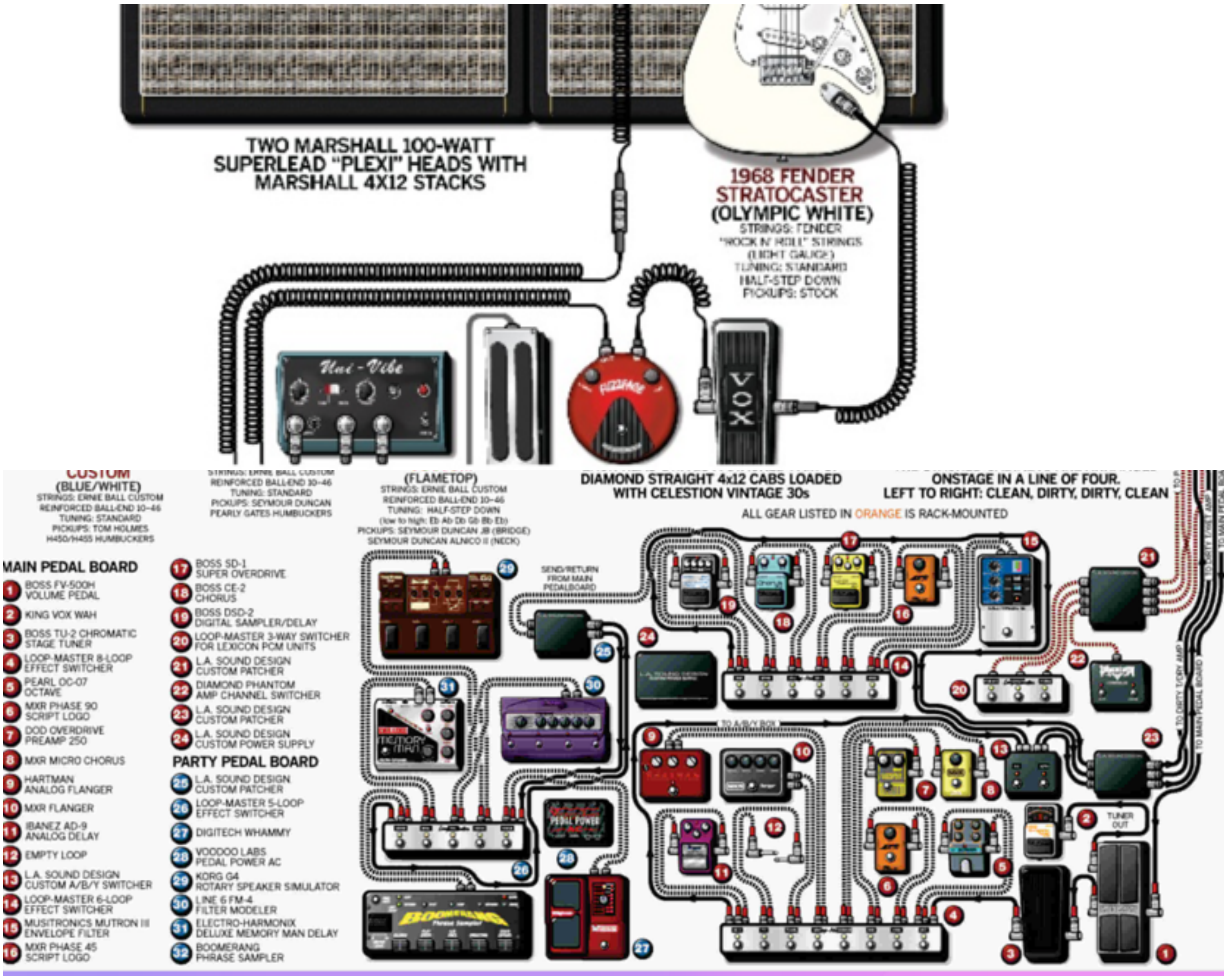

Figure 1: Comparison between Jimi Hendrix's setup (late 60s) and 2009 Tim Mahoney setup.

There are hybrid setups like Yaron Deutsch's, which include an ADA Amplitube preamplifier and a TC Electronics G-Force effects unit, connected to an amplifier and controlled via MIDI using a Roland FC-300 pedalboard. Here, we can already observe a split augmentation setup: Although technically and gesturally everything is controlled from the pedalboard, there is actually nothing more than the sending of messages. All the processing happens in other modules, especially in the effects unit. It is essentially a remote control, but not yet telematic.

In Daniel Santos' digital setup for *Trash Tv Trance,* (Santos and Portovedo, 2023) the software program used becomes an integral part of the setup. In the proposed digital setup with a computer, significant importance is given to wireless data transmission networks with the computer. This facilitates the performer's freedom of movement on stage.

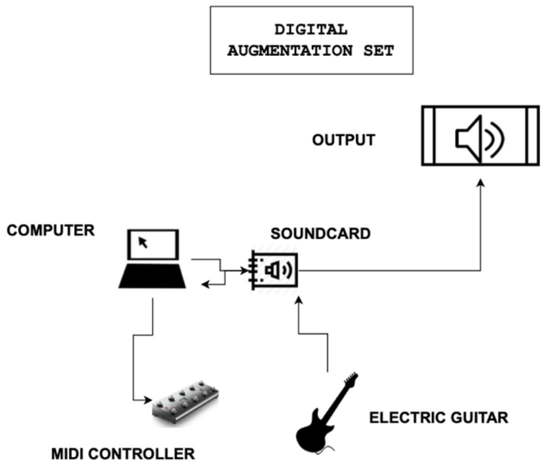

Figure 2: Daniel Santos' setup for *Trash TV Trance*. Extracted from *The Electric Guitar: Forms of Augmentation and their use in the Contemporary Repertoire.* (Santos and Portovedo, 2023).

With these models in mind, the problems of the electric guitar can be defined:

1. In many cases, the problem with the electric guitar lies in mobility and device adaptation, as well as the convenience of setup. This issue has been present in the field of contemporary music for some time. It is not the same to carry a computer and a pedalboard as it is to carry multiple individual pedals. The setup becomes more complicated, and the chances of failure increase.

   At first, I was led to the manna of software for purely practical reasons: I was tired of carrying gear. However, what was originally a practical decision soon became an aesthetic one when I realized the advantages presented by the open-ended nature of a modular software program, namely, that this software would enable me to go beyond the limitations of the pre-existing singular functionality built into the individual hardware-based audio processing devices (stomp boxes) I had been using for years (Kaiser, 2006).

   The article by Portovedo on HASGS (Augmented Saxophone) emphasizes the importance of remote control and reduced augmentation. "In this scenario, we mention the concept of Reduced Augmentation because, from the idea of having all the features of an EWI (Electronic Wind Instrument) (...)" (Portovedo, Lopes, and Mendes, 2018).

2. In other cases, the problem can be summarized as a lack of control over the gradations of effects and memory management (loops, samples, etc.). This is well reflected in Lähdeoja's article *"The electric guitar an augmented instrument and a tool for musical composition"* (Lähdeoja and Navarret, 2010). This point is crucial for developments and understanding the limitations of certain switch pedals. The concept of memory is central to electronic music, allowing the storage of audio fragments (whether generated live or pre-recorded). The computer serves as a highly flexible and powerful tool in this regard.

3. Additionally, there is another key element, which is the simplicity of electronic setup in some works compared to the complexity of others. This is important because both works may be part of the same concert repertoire. To address this issue in terms of setup, a more complex setup may be required. This leads to guitarists having different setups, one complete and another more simplified. However, in the digital realm, the setup can always remain identical. In other words, the size of the set does not physically increase depending on the repertoire.

4. Lastly, there are issues related to the concept of monitoring, specifically the mix of sounds that the performer hears during live performances, including monitors with their own sound, electronic parts, and metronome sounds. Having control over these outputs within the instrument is crucial for adjusting and monitoring one's own performance, whether through headphones or speakers. Even something as basic as the volume of a click track can have a significant impact on the outcome of a performance.

While advanced possibilities in interfaces and augmentation can be achieved, such as detailed gestural control or body movements, for most guitarists it would simply be useful to have a control system that doesn't require constantly going to the amplifier/pedals or the computer to adjust parameters.

Therefore, we arrive at the first synthesis of interface needs: reduced augmentation, telematic capabilities, gradations, simplified control, compatibility with other devices (integrable into an existing and broader set). Not specifically focused on creating new gesturality, effects or sounds, but rather standardizing the digital control of existing effects and improving monitoring preparation. In terms of design, the importance of volume and tone potentiometers is emphasized as the primary control mechanism for integrated outputs within the instrument, as well as the simplification of the number of elements in the setup. All of these aspects are reflected in a case study as a knowledge project and analysis of integration.

IV

Having analyzed the main issues and ideas related to augmentation in the electric guitar, the next step is to design an interface that enhances the experience of working with computer effects. The objective is to create a model that goes beyond a basic prototype and approaches a research product.

> *Previous authors have proposed 'research products' as a specific category of artefact distinct from both research prototypes and commercial products. The characteristics of research products are their holistic completeness as a design artefact, their situatedness in a specific cultural context, and the fact that they are evaluated for what they are, not what they will become* (Jack, Harrison, and Mcpherson, 2020).

Additionally, an effort has been made to utilize the wealth of DIY electronic culture and open-source resources. This includes both the microchip programming and the software development. The aim is to emulate the functionality of the volume and tone control potentiometers found on the instrument and use other potentiometers to control common effects such as reverb, delay, and distortion. [7]These effects require gradual control and fine adjustments depending on the performance space and artistic sensitivity. Therefore, the interface is integrated into the electric guitar, operating with a reduced and telematic augmentation. Initially, a prototype for both feet and hands was adapted. Secondly, only the manual action part was developed. The intention is to position the interface at different points on the guitar to affect the technique in various ways.

It is important to reflect on the transition from an interface designed to be activated by both the feet and hands to one that is solely associated with the hands. In the context of the electric guitar, the use of feet makes it possible to control effects and modulation of the electronics while continuing to play the instrument.

With the feet, effects can be turned on and off, and expression pedals can be used to adjust parameters. This pedal-based control serves as a combinational equivalent to potentiometer gradation. Yaron Deutsch discusses this in an interview where he explains how he utilizes pedals to regulate volume and gain.

> *And for that is what I'm using is this Roland FC-300 pedalboard, (...) has two panels. So, as I said, one is the volume, and one is the gain. Gain of a distortion or gain of a clean* (Santos, 2022).

Therefore, any adjustable effect can be controlled using the guitarist's feet. However, this presents a significant challenge: the number of adjustable effects is vast, and using traditional expression pedals for each effect can result in a massive collection of pedals on the floor. There is also a mnemonic difficulty in remembering the location of each effect. This makes it interesting to have an additional control option on the guitar body.

One of the reasons for discarding the implementation of a foot pedalboard, considered in the first prototype, was that there are already a variety of models available that fulfill this need. Nevertheless, the model developed in the first prototype led to considerations about the potential of foot pedalboards, as will be discussed in the description of the prototypes below.

First prototype: The initial idea was to use an existing device (a Novation Keypad 25) and repurpose its circuit board and controls in a more adapted configuration for the guitar's anatomy, without changing the controller itself but rather its arrangement. Based on insights from the HASGS (Portovedo, Lopes, and Mendes, 2018) and the tests conducted with guitarists and their augmentation ideas in the article *"Examining how musicians create augmented musical instruments"* (Newton and Marshall, 2011), the concept of incorporating a portion of the interface onto the guitar body emerged. The most interesting aspect of the Novation, which brought value to the generated pedalboard, was its foot-controlled illumination, providing information, particularly regarding sound memories (loops and samples). This is crucial since visual indicators or displays play a significant role in identifying the stored files in each channel, displaying effect labels, and so on. The main drawback of the Novation is that the portion relocated to the guitar body is connected to the part located at the feet by a cable, limiting mobility and complicating performance. As a result, the decision was made to independently develop

[7] Although these effects are the most common, the use can be extrapolated to more complex and creative effects and actions that require gradual control.

the interface component located on the guitar body. During the initial stages of development, this component was referred to as the "neuron," a name that has been retained throughout its subsequent development.

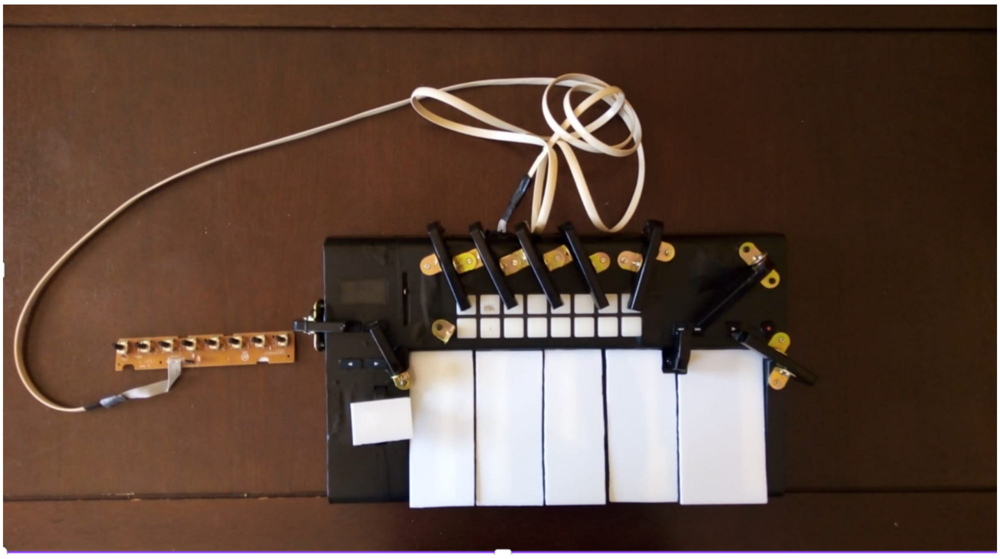

Figure 3: First prototype. Pedalboard and neuron.

Second prototype: Ultimately, the options for foot control were discarded despite their appealing illumination, and a standard pedalboard available on the market (Behringer FCB 1010) was used instead. The manual control of the interface was developed independently. One of the secondary learnings from the former design was the ability to connect independent controllers together using virtual MIDI ports. The idea was to link

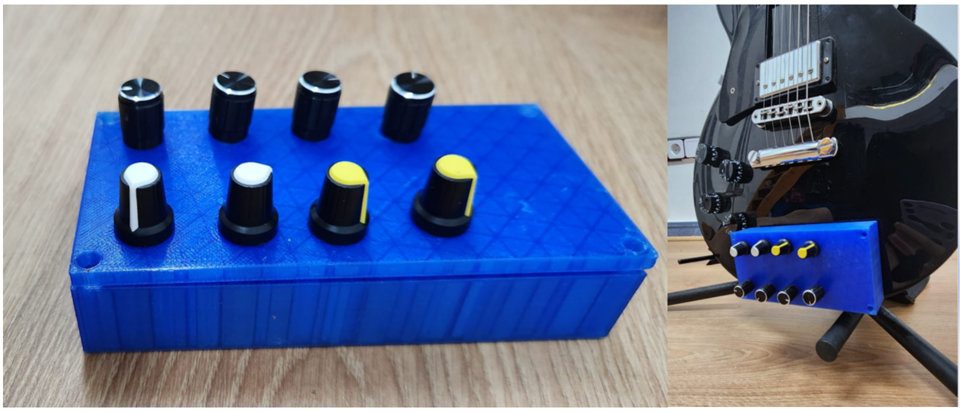

Figure 4: Second prototype. Neuron, and installation on the guitar.

them and then control all of them simultaneously within the selected software. This approach can lead to ambitious controls, repositioning very specific elements along the instrument and transitioning from reduced augmentation to true micro-augmentation.

In the present case, synchronization was straightforward with one data flow via Bluetooth and another via a sound card, as shown in the diagram (Figure 5). Currently, pedalboards available in the market offer robust and effective foot controls, although they are not wireless (except for certain models). Interconnecting them was not particularly difficult, given that the neuron operates via Bluetooth.

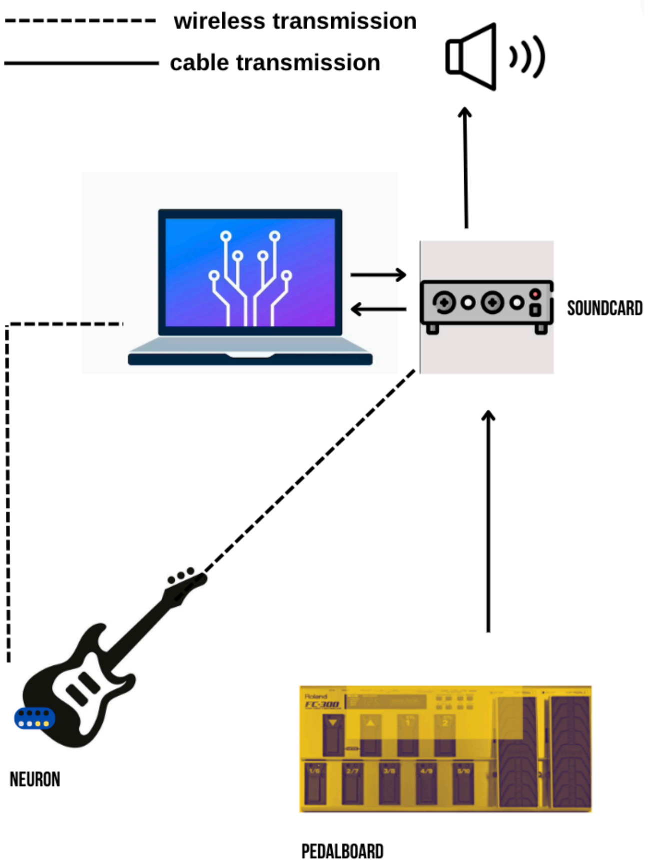

Figure 5. Sound chain Architecture

The processor used was an ESP32 chip with eight potentiometers soldered to the board. The idea of including switch buttons was initially considered but later discarded. The chip is Bluetooth-controlled using a virtual MIDI port manager, in this case, Hairless MIDI was used. Finally, power was configured through an MB 102 module.

The practical applications that have been used so far serve to facilitate the electronics in the works *Electric Counterpoint* and *Electric Guitar Phase* by Steve Reich (Steve Reich, 1987), and the work *Trash TV Trance* by Fausto Romitelli (Romitelli, 2002). These works were chosen because they progressively increase in difficulty in terms of their electronic component. Also, to illustrate the process of technological transfer and the interest in using new approaches and means to address the performance of works created in another technological context, but that can be simplified on a technical level without losing quality and musical intention.

> *Thus, we expand the scope of the concept of systems of dynamic relationships by applying it to works by other composers. In doing so, we become aware of the collateral aspect caused by the impermanence*

of works using technology and the consequent need for reconversion or, as we call it, technological transfer (Marques Ferreira, 2014).

In the first work, *Electric Counterpoint*, the neuron was used to control the start of each of the three movements, as well as timbral nuances between them. It was also used for volume monitoring.

In the second work, *Electric Guitar Phase*, the neuron was used to generate loops and control monitor volumes, live mixing. One potentiometer can be used for the first loop, another for the second, and another for the third.

In the third work, *Trash TV Trance*, the interface was used to control the gradation of delay and distortion. The common effects that can be controlled with the foot are: wah-wah, distortion, delay, gain, reverb, overall volume, and pitch. In this case, it is considered meaningful to manually control distortion and delay while using the foot for wah-wah and instrument volume control. In fact, one of the most interesting passages involves controlling the wah-wah with the foot simultaneously with the gradation of delay while the hands move around the guitar. Finally, the volume of the loops is also mapped to the interface.

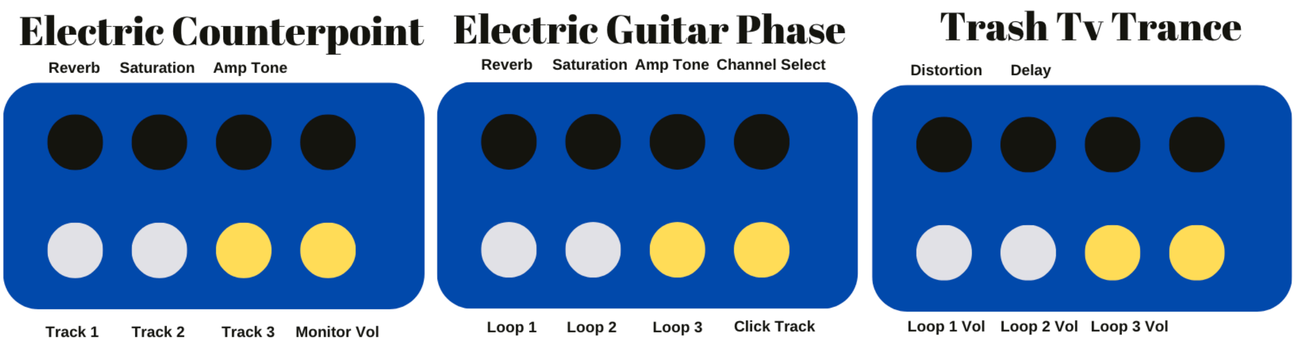

Figure 6: Mapping of the works electronics.

The software implementation involved using Ableton with a series of plugins, some native to the software and others based on Max for Live. The list of plugins and effects used is as follows:

- Ableton Delay with the potentiometer controlling the bus level.
- Two effects for compression and EQ: Guitar Compressor (Controlled Dynamics) and EQ (Electric Git EQ).
- Fixed Length Record: A plugin to automate loop (Max 4 Live).
- A Max 4 Live plugin adapted from Darwin Grosse guitar processor (patch for Max MSP).(Grosse 2009)
- Ableton Looper in two modes: Default Looper Plugin for *Trash TV Trance*, with its own reverse include and channel loop for *Electric Guitar Phase*.
- Silicon Flooring Auto Filter for the Wah Wah, with the potentiometer controlling the envelope parameter.

V

In summary, during the design of the interface two approaches were followed. On the one hand, theoretical research on the new lutherie that covers instrumental needs, the framework of augmentation, and issues of obsolescence and technological transfer. On the other hand, a performative approach that detects certain virtues and weaknesses, clarifying the design.

In addition, to carry out this study, communication has been established with guitarists, and the viewpoints of interviewed performers and composers have been taken into account, along with practical information from other researchers' studies.

To shape the device, a logic of creation guided by the following framework has been followed: 1) State of the art and knowledge of existing interfaces, 2) Visualization of possibilities, 3) Visualization of problems 4) Concrete positioning (possibilities to develop and problems to solve) and 5)Design search and prototype realization.

Within this framework of action, the decision was made to simplify the control of existing effects in works already created with predefined aesthetics. The proposed augmentation enables performances of the classical repertoire of the electric guitar. In a sense, the original potentiometers of the electric guitar are employed in a similar to those of the interface, with the former controlling the amplifier and the latter controlling the computer. This similarity makes them highly accessible and familiar to the guitarist.

Two options were discarded for carrying out the design: creating an interface that develops new gesturality or sounds and integrating the interface into an analog set. Even though the proposed interface is not focused in creating new gestures or sounds, any new interface can create a new technique; the interesting point is the control possibilities through the computer.

This idea about interfaces is accompanied by other relatively novel concepts that have been introduced in the research. The possibility of transforming fixed electronics into live electronics and addressing the technological transfer of contemporary repertoire.

Also, the reality that personal devices such as laptops, tablets, or mobile phones, combined with portable and compact augmentation, are beginning to materialize in a new generation of SMI instruments. Finally, the idea of an imminent embodiment of the computer in performance is present in several texts on post-digital subjects.

The influence that these advancements have in instruments is reflected in how technology affects performers and leads us to question certain patterns of contemporary interpretation. Does it make sense for an external performer to control parameters like monitoring volume? Does electronic mixing belong to the performer or not? A large part of the criticism applied to certain mainstream music, DJs, or producers is related to their lack of instrumental action. Meanwhile, to some extent, much erudite music is limiting the possibilities of the performer. Performers, on their part, increasingly value interdisciplinarity and being able to control electronic and technological actions, as shown by some of the consulted bibliography.

Regarding the interface in its current state, one of the most important aspects is that it is a programmable and wireless device, making it portable and exportable. There are several options to adapt it to other instruments where it can be useful. For example, within the same instrument family (bass, acoustic guitars). It can have a significant impact on an instrument like the piano, even in combination with a hand/foot system. Other studies also share this perspective of standardizing augmentation modules.

> *For this project, we were interested in designing a lightweight gestural control system that could augment live instrumental performance. Our proposed system would be flexible enough to be used with any instrument, and integrate easily into common live performance workflows (…) we devised a small wireless device that could attach unobtrusively to either the performer or instrument, accompanied by an OSC-based software interface for connection to other audio applications. (…) Most importantly, it would be simple for a performer to set up and configure without requiring extensive technical knowledge to operate* (Sullivan et al. 2018).

This pre-existing conception is complemented by an element that sets a guideline for the construction of ad hoc augmentation, where the musician can add and remove components. In other words, a non-invasive device that facilitates personalized augmentation. This will also depend on another part of the architecture, the ability to connect multiple chips together and support multiple MIDI data inputs to the computer.

The vision of augmentation as portable modules integrated into different easily manageable software environments encompasses two orientations: that of the user who simply wants to use desired effects, and that of the musician/programmer with computer skills. It should be emphasized that while Max MSP software is frequently mentioned in academic writings, Ableton or Logic digital audio workstations (DAWs) are the most commonly used at the user level, and it becomes almost a requirement to ensure that the interfaces are seamlessly embedded in these DAWs, especially considering that these software programs are already transitioning to tablets and even more portable devices than computers.

Finally, the research is in progress. Several work lines emerge that can serve as future guidelines in terms of thinking, theory, and design. In this regard, the proposed improvements for the model are as follows:

1. Reduce the size, transitioning from a compact augmentation to a micro-augmentation.
2. Modify the design of the casing to adapt it more specifically to the instrument.
3. Introduce lighting and screen information, initially with a display.
4. Incorporate buttons in another parallel module that sends additional data flow to the computer.
5. Synchronize all the data

These considerations will shape the guidelines for the next development of the device.

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