Dextoria – An embedded system to control electric guitar effects via sound-producing gestures

Björn Bernreiter[*]
Institute of Design and Communication
University of Applied Sciences Graz
Austria
bjoern.bernreiter@outlook.com

Katharina Groß-Vogt[†]
Institute of Electronic Music and Acoustics
University of Music and Performing Arts Graz
Austria
vogt@iem.com

Marian Weger[‡]
French-German Research Institute of Saint-Louis (ISL)
France
marian.weger@isl.eu

ABSTRACT

Standard guitar effects pedals are limited in their control possibilities, difficult to access on stage, and challenging to operate while playing. Innovative control systems are often not well integrated into the common guitar playing environment. In this paper we present "Dextoria" – a control system that allows guitarists to make additional use of their sound-producing hand gestures. With the fretting hand, guitarists can switch between two effect loops, depending on the hand's fret position that is measured by a distance sensor on the guitar's headstock. The posture of the picking/strumming hand is captured by an IMU sensor on a hand strap, in order to control guitar effects pedals that have an expression input. The Dextoria system is modular and embeds into guitarists' existing live setups.

Author Keywords

NIME, guitar effect, effects pedals, augmented instruments, expression pedal

CCS Concepts

•**Hardware** → *Sensor applications and deployments;* •**Human-centered computing** → **Interface design prototyping;** •**Applied computing** → **Sound and music computing;**

1. INTRODUCTION

The electric guitar has a long tradition as augmented instrument (also referred to as extended or hybrid instrument [13]). As guitarists have both hands involved in the sound production, control of all additional sound extensions can only be achieved by resorting to peripheral aspects of guitar playing [9]. Therefore, among conventional guitar players, floor-based controllers are still the predominant choice – for discrete effect changes as well as for expressive controls [8]. Along with the increase of sonic possibilities and corresponding control interfaces, playing the instrument has become increasingly complex [10]. In order to avoid exceeding the physical and mental capabilities of guitar players, most control interfaces for electric guitar have been conceived with simplicity in mind, featuring relatively simple controls and traditionally being conveniently placed within the guitarist's reach (typically, an effects pedal that is dis-/activated by stepping on it).

However, effects pedals also come with shortcomings. Hödl & Fitzpatrick [5] state that effects pedals are highly limited in their actual control possibilities, often only offering push buttons and no gestural or other, more embodied control options. Moreover, Konovalovs et al. [7] criticize their stationary nature, forcing guitar players to return to their effects pedal board to switch effects on/off or even having to kneel and reach down to change settings.

Several research projects have addressed these problems and set out to develop mitigating systems. While some of them succeeded to provide guitarists with real-time and more intuitive effect controls, they do not appear to be well integrated into the typical ecology of guitarists. For example, some projects force guitarists to interrupt their playing movements to access and handle new control interfaces [5, 12]. Other studies require guitarists to learn and perform unfamiliar or unconventional movements which may add another level of complexity [11, 7, 2]. Finally, virtually all comparable projects we found rely on personal computers and/or are restricted to specifically programmed effects. The conventional (live) guitar rig, however, tends to consist of a guitar going through various effects pedals into an amplifier. Requiring guitarists to incorporate laptops into their effects chain therefore constitutes an intrusion into their natural playing environment.

2. THE DEXTORIA OBJECTIVE

The idea for Dextoria was to develop a system that allows to register the sound-producing gestures [6] of both the fretting hand and the picking/strumming hand, respectively, which are performed during playing, and to use it for extending the sonic control possibilities of the electric guitar. These kinds of gestures are chosen because guitarists are already familiar with them and do not need to learn them anew so that a high degree of intimacy [4] can be assumed. Furthermore, as they are performed anyways, guitarists do not need to focus on other, potentially distracting, gestures during their

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[†]Dr. Groß-Vogt was supervising.

[‡]Dr. Weger supervised the prototype's development.

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performances.

To ensure integration into guitarists' live setups, the developed system should not rely on computers and not be restricted to specifically programmed audio effects. Instead, it was conceived to integrate well (plug & play) with off-the-shelf (guitar) effects pedals.

The design of the Dextoria system has been influenced by two concepts relating to music and the design of new musical instruments and controllers, i.e., musical gestures and intimacy.

As Dextoria should be integrated into the environment of guitarists, typical (live) guitar setups and playing techniques were explored. The findings are based on literature, a survey of online sales rankings [1] (types of electric guitars and effects pedals), and our own informal testing of the prototype.

- **Electric guitars**

  Our survey showed that the prototype needs to work with Fender Stratocaster and Telecaster as well as Gibson Les Paul guitars, as well as any other guitars from different brands that are modeled after these, to ensure integrability in as many guitarists' setups as possible. The headstock design of the electric guitar models is of special importance as the sensor of the fret-hand setup must be fitted onto the headstock.

- **Effects pedals**

  The typical ecology of guitarists includes an ample number of effects pedals. It is therefore important that Dextoria is compatible with this wide array of effects pedals and thus easy to integrate in existing setups. The fret-hand setup can be used in conjuncture with all guitar effects in various constellations. The pick-hand setup is compatible to pedals with expression pedal input.

- **Amplifiers**

  As Dextoria focuses on what is happening with the guitar signal before entering the amplifier, it works with any kind of amplifier. It is much more important to emphasize that guitar players still use amps and renounce using computers in their live setup.

3. DEXTORIA'S FUNCTIONALITY

The Dextoria system is made up of two setups, one for the fretting hand and one for the picking/strumming hand, as shown in Fig. 1 and named fret-hand and pick-hand setup, respectively. Both setups use two ESP32 microcontrollers each, programmed by using the Arduino Integrated Development Environment. ESP-NOW [3], a wireless communication protocol, was selected for data transmission. The Arduino source code and electronics schematics are shared in a public repository [1].

To better convey the capabilities of Dextoria, two short demonstration videos were made, a fret-hand demo[2] and a pick-hand demo[3].

3.1 Fret-hand setup

The fret-hand setup allows guitar players to switch between two effects loops according to the position of the fretting hand along the guitar's neck. The setup consists of two components, the Scout (see Fig. 1(a)) and the Mothership (depicted there in the corner).

The Scout is attached to the headstock of the guitar and can detect the fret position of the fretting hand. It comprises an optical Time-of-Flight (ToF) sensor, an ESP32 microcontroller as well as a custom-made attachment device. The ToF model chosen for this project is a VL531X on a breakout board manufactured by Blue Dot.

The attachment solution consists of a mount, originally designed for cameras, that was slightly adapted to hold the ToF sensor and ESP32. It can be clamped onto the headstock and, subsequently, adjusted to place the ToF sensor in the correct position. While it is flexible enough to fit onto common guitar headstocks of brands like Fender and Gibson, it is at the same time sturdy enough to maintain its true position while the headstock is moved during performance.

The Mothership is designed to sit on a pedalboard, next to the effects pedals. It splits the incoming guitar signal into two effect loops and switches between them according to the signals received by the Scout.

It is comprised of another ESP32 as well as several small electronic circuits, namely a buffer/splitter and a mixer that is controlled by a digital potentiometer MCP4251. Furthermore, the Mothership features a small OLED display and a rotary knob to set the fret threshold. All its components are housed in a box in the shape of a large effects pedal with a main input jack, send and return jacks for each effect loop as well as a main output jack.

The Scout uses the ToF sensor to measure the distance from the guitar's nut to the fretting hand. The distance data obtained is used to calculate the corresponding fret position of the fretting hand. To convert the distance measurements into the corresponding fret number k, Eq. 1(a) was used:

$$k = 12 \cdot \log_2 \frac{L_0}{L_0 + \Delta L_k} \tag{1a}$$

with the scale length L_0, the distance ΔL_k from nut to finger/fret,

$$\Delta L_k = L_k - L_0, \tag{1b}$$

and the string length L_k at fret k,

$$L_k = L_0 \cdot 2^{-k/12}. \tag{1c}$$

Since a guitar player's fingers are always between the area of two frets, a range of a fret can be defined by the upper value being the fret distance of fret k and the lower value being the fret distance of fret $k-1$, see Fig. 2. Following this principle, fret ranges were defined. Slight, manual adjustment was necessary when working with the actual setup. Currently, the prototype detects frets from one to nine accurately, with guitarists being able to play (barre) chords as well as single notes.

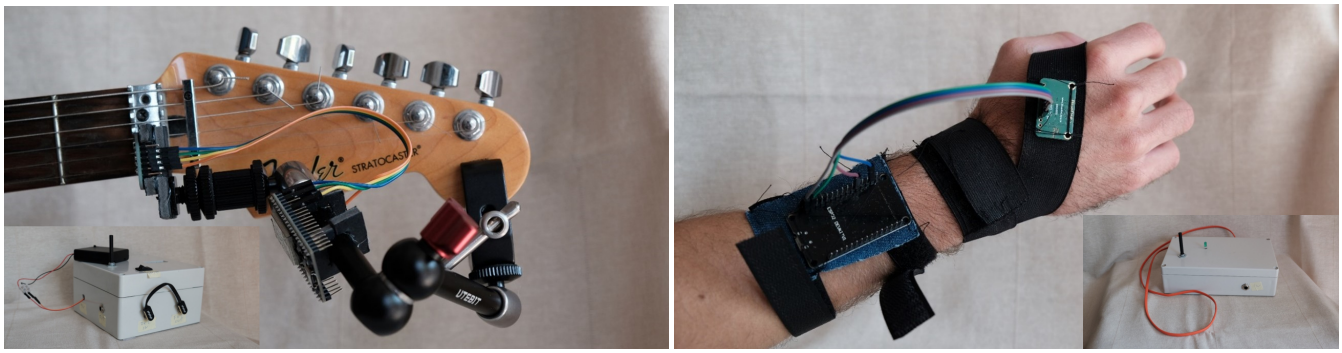
The current and previous fret positions of the fretting hand are then sent wirelessly to the Mothership using ESP-NOW. On the Mothership, guitarists can set the fret threshold from frets 1-9 via a rotary knob. This threshold determines the fret where one effect loop is engaged while the other is disengaged. The Mothership receives the incoming position data sent by the Scout and its ESP32 decides which loop to engage according to the fret threshold set by the guitar player. Actual switching is done by the digital potentiometer in the mixer circuit.

The fret-hand setup is conceived to work alongside all off-the-shelf guitar effects pedals and guitarists have the possi-

[1]Reverb.com online marketplace for musical equipment: `http://Reverb.com`

[2]fret-hand: `https://phaidra.kug.ac.at/o:130874`

[3]pick-hand: `https://phaidra.kug.ac.at/o:130875`



(a) (b)

Figure 1: The Dextoria setup. (a) shows the Scout of the fret-hand setup with the Mothership depicted in small, (b) shows the Expressor of the pick-hand setup with the Expressionist in small.

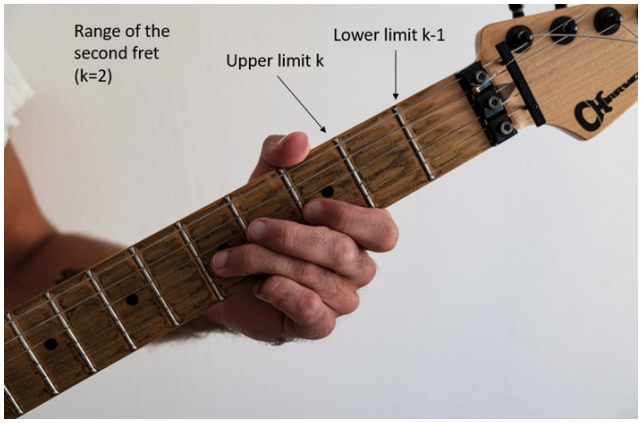


Figure 2: Depiction of the lower and upper limit of the fret range.

bility to individually customize their signal chain according to their needs.

3.2 Pick-hand setup

The pick-hand setup allows guitarists to control effects pedals that possess an expression pedal input by the movements or posture of the strumming/picking hand. The setup is made up of two components, the Expressor as shown in Fig. 1(b) and the Expressionist (depicted in small).

The Expressor is the device attached to the hand and arm of the guitarist, capable of capturing the playing and strumming movements of the player's hand. It consists of an IMU (inertial measurement unit) sensor (Blue Dot BNO055 breakout board), an ESP32, and custom-made textile straps to fix the mentioned parts to the guitarist's body.

The Expressionist sits on the ground on a pedalboard, similar to the Mothership. It receives and processes the data sent by the Expressor and uses it to control any guitar effects pedal that has an expression pedal input. It comprises another ESP32, the digital potentiometer MCP4251, an indicator LED, and an expression output (to be connected to an effects pedal's expression input through a TRS cable). The components are housed in a stomp box similar to standard effects pedals.

The pick-hand setup is intended to work like a common expression pedal, with the difference that instead of being controlled via foot, it can be set via the motion data of the picking/strumming hand. The IMU sensor on the Expressor measures the hand's orientation and linear acceleration data. These data streams are then sent wirelessly via ESP-NOW to the Expressionist which processes and maps the data. Via a rotary knob, guitarists can select which data (orientation or acceleration) should be used to control the effects pedal. The digital potentiometer alters the control voltage that is supplied by the effects pedal, as an analog expression pedal would do. The circuit also features a LED whose brightness visualizes the expression pedal status and gives players visual feedback.

Using the roll angle of the absolute hand orientation for sweeping through an effect parameter works well, for example, with filter-type effects such as a Wah-Wah. Using linear acceleration data, smoothed by a moving average filter, works well for controlling effect strength, e.g., of a delay effect.

4. CONCLUSION

The objective of this project was to design a control system that allows to further leverage the sound-producing hand gestures of guitarists to enable a smoother and more intimate control of effects while at the same time being capable to control off-the-shelf effects pedals to better integrate into guitarists' existing live setups.

The Dextoria system introduces guitarists to a novel, innovative approach to effects control while, at the same time, enabling them to keep using their favorite effects pedals.

5. ETHICAL STANDARDS

We comply with the NIME NIME Principles & Code of Practice on Ethical Research [14].

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