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Elektronizza Orkestra: Developing a new kind of Digital Music Instruments Symphony Orchestra

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ABSTRACT

This paper presents the different technological design stages of a Digital Music Instruments (DMIs) Orchestra similar in size and constitution to a traditional symphony orchestra. This ensemble has the particularity to include the digital equivalent of most of the traditional orchestral sections mixed with original interfaces. The choice was made to develop it without any laptop or screen on stage. The laptops are expensive, take space and tend to interfere with the musicians' performance and the audience's perception. This was made possible by using, on the one hand, wired audio and MIDI network technologies via IP, which allow the digital signal processing to be centralized in one or more computers in the FOH, and on the other hand, decentralized technologies with the use of Raspberry Pi single board computers embedded in 3D printed speakers with an amplified DAC, and a battery, all controlled wirelessly via an OSC network and a Web interface that run on any browser.

1. INTRODUCTION

1.1 Context

The Elektronizza project (initially titled MPEi - Multidimensional Polyphonic Expressive Digital Music Interfaces: From High-End Soloist Ensembles to Large Pedagogical Orchestras - Theoretical, Practical Studies and Developments on a New Class of Music Instruments) began in 2017 as part of the Université Côte d'Azur's IDEX (*Initiative d'Excellence*). This project was designed in partnership with several institutions and laboratories: Conservatoire de Nice, CTELA (Transdisciplinary Center for Epistemology of Literature and the Arts), CIRM (National Center for Musical Creation), LEAT (Laboratory of Electronics, Antennas and Telecommunications), IUT (University Institute of Technology), INRIA (National Institute for Research in Computer Science), XR^2C^2 (eXtended Reality Research and Creative Center), Studio Instrumental Association, and The Hublot (Digital Territory Factory).

The objective of this project was to create a research-creation-pedagogy ecosystem around the new DMIs (with a particular focus on "expressive" interfaces) by developing innovative devices allowing the deployment of all kinds of DMIs musical ensembles, from chamber music to the symphonic orchestra, intended for initiation in schools as well as for high level university students' musical practice.

1.2 Why a DMIs Symphonic Orchestra?

The beginning of the 21st century saw the tremendous emergence of laptop orchestras, primarily within institutions of higher education. Shelly Knotts listed nearly 160 such ensembles in 2014 [1]. Many of them are based on what we can call the "lorkian" model developed by the Plork (Princeton Laptop Orchestra) [2] in 2005. These ensembles are generally comprising up of an average of fifteen musicians, each with a laptop computer, often accompanied by interfaces from video games (Gamepads, Gametraks, Joysticks, Wiimotes, etc.) mostly used in a homogeneous way (each musician playing the same interface) thru omnidirectional loudspeakers associated with each station. For Dan Trueman [3], the symphonic orchestra is an incomplete model for laptop orchestras, and non-western orchestras have often more in common with this new type of ensemble. So why to revive this old institution?

In parallel with this movement of laptop orchestras, the progress of digital instrument making has allowed the emergence of a new class of interfaces giving the instrumentalist a fine expressivity, requiring assiduous practice and an advanced technique to be properly played. To motivate high level musicians to work and integrate these interfaces in their practice, it seemed relevant to constitute a DMIs orchestra directly stemming from the tradition of the symphonic orchestra, where the musicians and the public could find some familiar reference points while exploring new musical potentialities. This historical continuity, legibility and proximity to traditional instrumental music making allowed us to carry out a true transversal project with all the instrumental classes, taking this experimental practice out of the electroacoustic composition department.

As the two approaches can be seen as complementary, the lorkian model was also experimented in a pedagogical context with children, with the idea of eventually turning it into a kind of digital choir for the symphony orchestra. But this was done without the use of laptop, making the appellation laptop orchestra irrelevant for our project.

1.3 Why not use laptops?

While laptops have been essential since the beginning of the 21st century for real-time electroacoustic music creation, several reasons have led us not to use them.

A first reason is the cost. A Macbook Pro (by far the most used for live music) configured for sound usually costs around $2000, to which you must add an audio interface and various accessories and software. By switching to Linux and open-source software, the L^{2}ORK managed to go under the $750 per station in 2011 [4]. But this was still too much compared to the number of musicians planned to constitute our DMIs symphony orchestra. It was preferred to invest on high-end new interfaces for music expression rather than laptops.

A second reason is the lack of stability and the opacity in process management, especially in Windows and Mac OS, when musicians use the same computer as a home PC. In this case, the cost isn't a problem, but the use of devices primarily designed for office and multimedia tools has huge crash tendencies, hence the need for dedicated machines.

Finally, very often, the visual feedback from a screen on stage hinders the direct relationship between gestures and sounds for the instrumentalist and blurs the communication between the musician and the audience.

In 2012, Bruno Ruviaro [5] saw the possibility of changing this laptop architecture: *"(...) small pocket devices will soon have enough processing power to do anything a laptop can do today. At that point, the on-stage presence of an object such as a laptop may become completely unnecessary. The only hardware visible to the audience will be those the performer chooses to make visible, hopefully for an artistic reason. (...) The theater of a performance, then, may reappear in the actual human body. (...) The expression "laptop performance" may become as dated as the expression "tape music" today*."

In 2014, the L^{2}Ork started using low-cost Raspberry Pi single board computers for initial music pedagogy [6]. After evaluating different solutions, we decided in 2018 to follow this path, which seemed very promising for the type of future orchestra planned to be developed.

2. DECENTRALIZED SYSTEMS

The initial idea was to create a decentralized system made of a wireless network of Raspberry Pi. But as we were not at that time familiar with these new terminals, we decided to start the first experimentations of the project with the technological elements we used to work with: laptops to work on the new expressive interfaces and smartphones and tablets to create a pedagogical proto-orchestra.

2.1 New expressive musical interfaces

At the time of the constitution of laptop orchestras appeared many DMIs whose potentialities for the expressivity of musical performance exceeded the previous generations (Haken Audio Continuum in 2002, Eigenlabs Eigenharp in 2009, Madrona Labs Soundplane in 2009, Roger Linn LinnStrument in 2015, Roli Seaboard in 2015, etc.). In 2018, the MIDI Manufacturers Association adopted the MIDI MPE (Multidimensional Polyphonic Expression) protocol suitable for their operation. A panel of these interfaces was thus acquired to explore their potential.

It was decided to work with the students of the coordinated Université Côte d'Azur-Conservatory Master's degree with the aim of creating small ensembles of soloists able to exploit their abilities. For this, I composed *Toccata in C++* for Sylphyo, Soundplane, and Boppads (2018) and Francis Faber composed *Slow Down* for Sylphyo, Seaboard, Malletstation and Boppads (2019). The project was integrated into Jean-François Trubert's Master seminar in 2021 and Gino Mariotti created an improvisation ensemble with eight students playing Seaboard, Linnstrument, Continuumini, Theremini, Handsonic, Vdrum and Malletstation (Figure 1).

Figure 1. At the top: *Slow Down* by Francis Faber. At the bottom: Master's degree's students improvisation ensemble conducted by Gino Mariotti.

This first phase of the project allowed us to master the use of these new interfaces, and it was a successful milestone for the next step of the development of an orchestra with a large number of musicians grouped in different sections.

2.2 Smartphone and tablet ensembles

To reach this goal, we decided, inspired by the projects MoPho [7] and Smartfaust [8], to start with the constitution of a pedagogical orchestra of smartphones with 22 students aged 13-14 from school Matisse (Nice), playing a composition of Yohan Brimicombe, *Electrons* (2018), conducted by Hélène Gaspérini (Figure 2). This piece mainly used the MobMuPlat app [9] allowing to load Pure Data patches on smartphones.

Figure 2. *Électrons* by Yohan Brimicombe for smartphone orchestra with Handsonic and Boppad. Conductor: Hélène Gaspérini.

A second experimentation was performed with Virginie Kracht's class of 18 students aged 13-14 in school Don Bosco (Nice) and a use of FAUST DSP to generate mobile apps in 2019 [10]. Finally, the same year, Bertrand Petit Hédelin used tablets and SKINI, a shared and non-linear composition system that he programmed during his PhD [11] with 15 students aged 11-12 from Frédéric Lacroix's class in school Nucéra (Nice)[1].

These experiences were very beneficial to figure out the different obstacles inherent in the technological constitution of DMIs orchestra. The conclusions reinforced the idea of changing the devices and no longer use non-dedicated peripherals and screens on stage, whether laptops, smartphones, or tablets [12]. Smartphones, for example, lack efficiency for music pedagogy: the embedded small speaker sound bad, the gestures that they allow are far from the subtility of a music instrument and, above all, the young students cannot detach themselves from the screen which hinders their musical listening.

As the COVID19 crisis arrived and momentarily stopped our orchestral activities, we decided to reallocate the large amount of Raspberry Pi we were working on to a partner project that was suffering from the global shortage of components: the *PrÉ* (*Présence Électroacoustique*) project, led by Camille Giuglaris, Bertrand Petit Hédelin and Jean-François Trubert [13], which was in the process of making small autonomous modules comprising a 3D printed speaker, a Raspberry Pi, an amplified DAC, a loudspeaker, and a battery. One of the goals of this project was to place 54 modules under the seats of the spectators in the Pierre Boulez concert hall in Paris for Jean-Luc Hervé's composition *Autre Nature* performed by the Radio France Philharmonic Orchestra (2022).

2.3 Gametrak ensemble

In 2022, thanks to the *PrÉ* project, the Raspberry Pi came back as 24 modules that we were able to use for the second phase of our project. Following the lorkian model, we acquired 24 gametrak interfaces [14] connected to the *PrÉ* modules via USB HID. We programmed an audio engine in Pure Data and a set of shell scripts to update the patches and sounds automatically on the whole devices. The Pure Data patch detected the MAC address of the raspberry and loaded the corresponding sub-patch specified in a JSON configuration file. Via a tablet interface initially created with Pure Data in MobMuPlat, we were able to control via OSC communication the volumes and cue changes of each module.

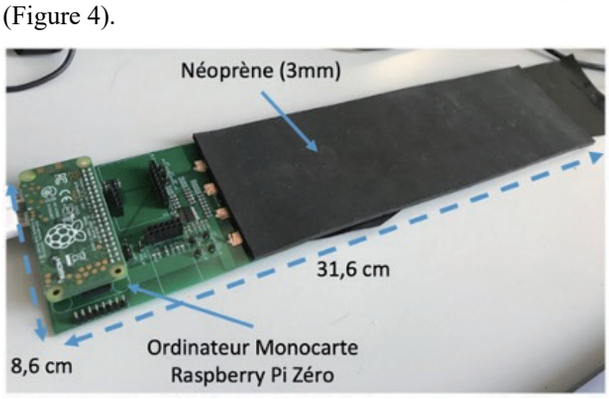
The gametrak allowing a large gestural amplitude, Elise Heinisch, who led these experiments in her class of 16 students aged 11-12 in the school Jean Rostand (Nice), decided to add a dancer and a choreography realized by Yaël Szwarcbaum. 8 students on music pedagogy at the university and the conservatory also took part in this project bringing the orchestra to 24 musicians (Figure 3).

Figure 3. Classroom work session and public performance of *Le Mouvement de l'Acanthe* by Elise Heinisch (2022).

The experiment was conclusive: this system was functional. Thanks to its lightness and its possible installation in a classroom facilitated by the battery powered *PrÉ* modules, it turned out to be perfectly adapted to orchestral teaching practice in schools. We decided to improve it and to add interfaces we were developing and specifically designing for the DMIs orchestral pedagogy.

2.4 New interfaces for musical pedagogy

The first idea was to develop a low-cost interface inspired by MPE interfaces like Linnstrument or Soundplane (Figure 4).



[1] This intervention was funded by the program *La Fabrique Musique Contemporaine* (SACEM).

Figure 4. Low cost MPE prototype. T. Louis, C. Andrieux, L. Zhuoer, A. Rochette and A. Pegatoquet, 2020.

But the result was far too complex and costly to build for this pedagogical context. We therefore oriented our development towards much simpler solutions (the Minimal Expressive Stick [12]), and after the realization of several other prototypes, we developed in 2023, with Patrice Colet and Wan Amira Syahirah Binti Wan Abdul Rahim, a pedagogical DMI named Hexapad (Figure 5). It was inspired by the Hang drum and the Roland Handsonic digital percussion. It is composed of a piezoelectric strike sensor, 7 capacitive sensors which allow to launch different sounds in a polyphonic way with aftertouch (resulting from the variations of contact surface with the capacitive sensors) and a Time-of-Flight distance sensor to modulate the sound. The microcontroller used is a Seeed Studio Xiao SAMD21 (which already has Atmel Qtouch inputs) and the ToF sensor a vl53l0x.

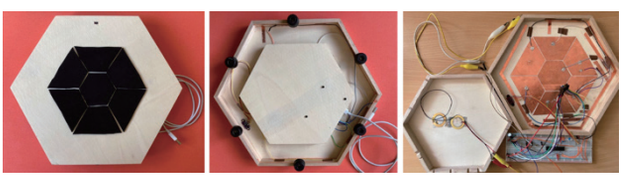


Figure 5. Hexapad first prototype.

The objective was to add an additional section of 16 expressive digital percussion instruments to the existing Gametrak section to allow the creation of full class DMIs orchestra (32 students), connected to the *PrÉ* modules and configurable in a network (Figure 6).

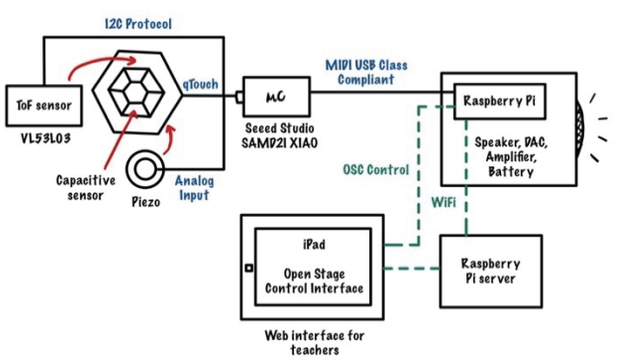


Figure 6. Hexapad orchestra architecture

But, while we were planning to experiment this new interface in an elementary school in spring 2023, a box ticked by mistake in a response to a call for projects[2] for the financing of school music assigned us to kindergarten classes. As these digital drums did not seem to be adapted to the awakening of the very young children, we decided, on the advice of Gilles Mottet, Professor at the Conservatoire de Nice specialized in school interventions, to make a simplified version. Only the hexagonal capacitive zone was kept and fixed on a plexiglass desk in order to slide in sheets with graphical illustrations (Figure 7).

[2] This intervention was funded by the program *100% Culture à l'École* (city of Nice).

Figure 7. Kindergarten prototype.

To change the sounds associated with the different illustrations (there were 6 different sheets during these interventions led by the composer Sarah Procissi at the kindergarten Madeleine Supérieure in Nice), and to manage the volumes of the *PrÉ* modules, our old Pure Data MobMuPlat interface was replaced by a much more practical Web interface (which does not require any installation) created by Patrice Colet with Open Stage Control (Figure 8).

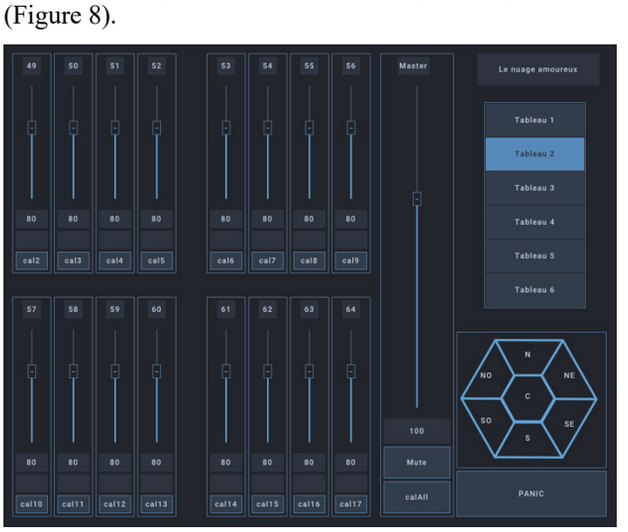


Figure 8. Open Stage Control OSC Web interface.

Playing this new prototype in kindergartens (children aged 3-6) showed that we were able to create digital orchestral tools for all types of ages. The Hexapad will be tested in school Jean Rostand (Nice), with students aged 11-12, in conjunction with Gametraks, as initially planned, between May and June 2023.

3. CENTRALIZED SYSTEMS

Experimentations in schools with decentralized battery-powered systems showed they are very efficient for educational interventions. But for working on high-end interfaces that require a lot of fine-tuning on the fly, it seemed to us more efficient to start on a more traditional centralized system.

3.1 Elektronizza Pedagogical Orkestra

Following the work we did with the students in small formations around the new expressive digital interfaces, we developed a first prototype of a heterogeneous DMIs orchestra (including sections inspired by the symphonic orchestra) with 22 musicians playing on a set of interfaces of the market: EWI, Sylphyo, Aerophones AE01, Linnstrument, Seaboard, Thereminis, Malletstations, Handsonics and Vdrums. For that ensemble, I composed the *ORK* study in 2021[3]. The orchestra was composed of 14 middle school students (aged 11-12) from the school Jean Rostand (Nice) and 6 university students in the context of an experimental music pedagogy workshop (Figure 9).

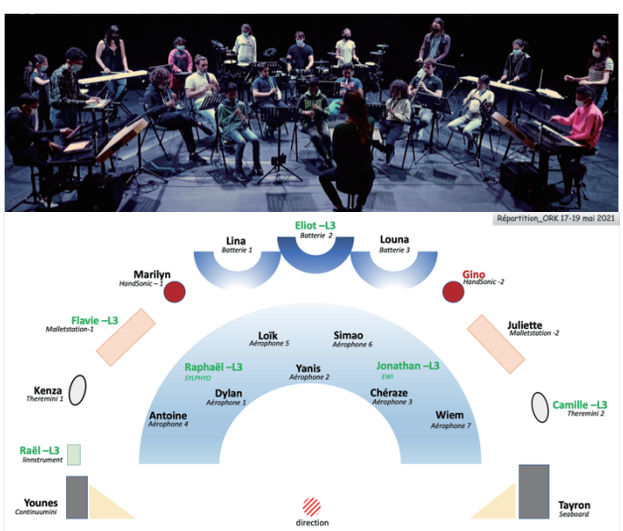


Figure 9. *ORK* by Gaël Navard. Conductor: Elise Heinisch. Espace Magnan, Nice, 2021.

The first test was to see if to hold such a DMI setup on a single Intel Mac Mini computer kept an acceptable latency in this context. We set the buffer size at 256 samples, and it was acceptable for this pedagogical experiment.

An encountered difficulty was the impossibility for the computer to recognize more than a dozen USB MIDI interfaces. This limitation, along with the desire to place the computer in the FOH (Front of House), led us to use an RTP-MIDI over IP network using several iConnectivity interfaces. This proved to be very efficient, and it allowed to plug and unplug the interfaces on the fly, without the need to rescan them with the Reaper DAW software used at the time. On the other hand, when having the same model of USB MIDI interface on the same MIDI interface (for example for the wind section) it was imperative to start the interfaces in the right order so that they would be routed to the right channels. This led to later use USB MIDI to MIDI DIN adapters to overcome this difficulty.

For the audio system, it was necessary to send the sound in multichannel to many speakers located on the back of the musicians, so that they could hear each other, and the audience could localize them. For this concert, 18 speakers, including 12 small 5″ speakers (5 on light 3m stands on the back, 3 on the percussion stand, and 4 on the keyboards stands), 4 small 8″ and 10″ subs and two omnidirectional wooden *Ondes* acoustic resonators from *La voix du luthier* (inspired by the work of Maurice Martenot) were used. An audio over IP system was used to simplify the wiring. After having tested the AVB protocol in another partner project (the Micadôme, a 32-channel immersive system installed at the Conservatoire de Nice and led by Michel Pascal) and having detected over time behaviors for a live context, we opted for an Audinate Dante system proved to be very robust with a small latency.

3.2 Elektronizza Symphony Orkestra

From this experience, we opened a series of workshops and courses offered by the department of electroacoustic composition at the Conservatoire de Nice and the Université Côte d'Azur, with the objective of training instrumentalists and composers of different levels in the handling of these new instruments. However, several sections of the symphony orchestra were still not represented in this digital instrument ensemble, which mainly includes woodwinds, percussion, keyboards, and other original interfaces. The choice was made to use electric string instruments (Guitar, Bass, Harp, Violin, Cello, Double Bass) and electrified brass instruments with Yamaha SilentBrass mutes (Trumpet, Trombone, French Horn, Euphonium) plugged into the Dante digital audio network and modified by digital effects.

2022 saw the launch of the development of this electroacoustic symphonic orchestra of 40 musicians interpreting Terry Riley's *In C* (1964). As a single central computer had not enough computing power for this large ensemble, 5 Mac Mini M1 were used in network, together with the Ableton Live software with Max4Live for more speed in the setting of the sounds of all these instruments. This also allowed us to lower the buffer size to 128 samples for having a better latency than the previous experiment.

This orchestra was installed on the whole stage of the auditorium of the Conservatoire de Nice behind the pedagogical orchestra of 24 Gametrak with the modules *Pré* on the proscenium, that was playing before on the same concert (Figure 10).

[3] This intervention was funded by the program *La Fabrique Musique Contemporaine* (SACEM).

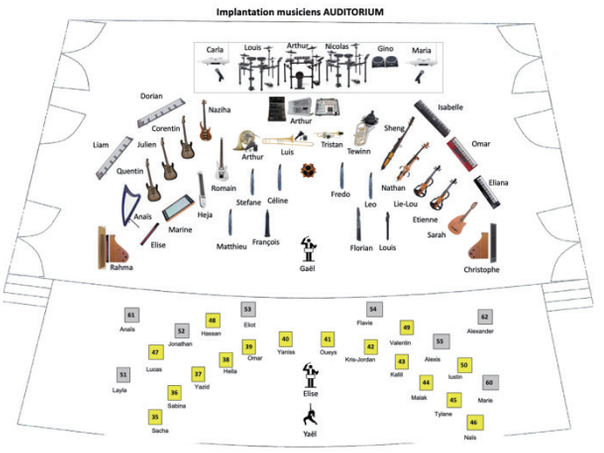


Figure 10. Technical implementation for the May 5, 2022, concert: 40 musicians on stage (conductor: Gaël Navard) and 24 musicians on the proscenium (conductor: Elise Heinisch).

On stage, the 18 loudspeakers previously used together with loudspeakers of the Conservatoire de Nice's Acousmonium (loudspeaker orchestra dedicated to the spatial projection of acousmatic music) allowed to have more than 40 loudspeakers on stage in order to localize the sound of the musicians where they were physically on stage (Figure 11).

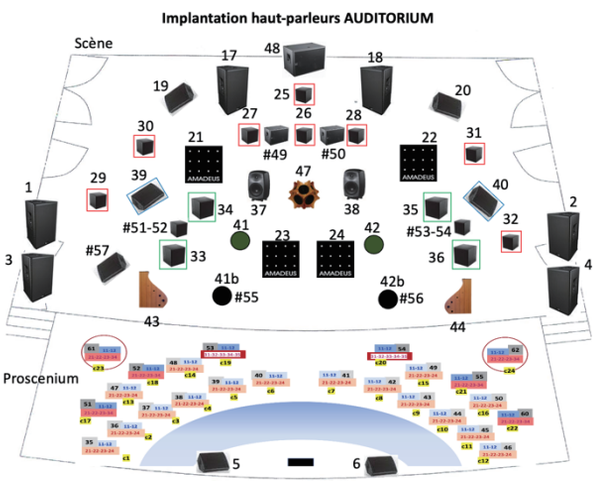


Figure 11. Technical implementation of the loudspeakers.

This orchestra played successfully May 5, 2022. The result was, for the first time since the beginning of this project, the installation of an electroacoustic orchestra of truly symphonic size and constitution.

There were several sections: 8 woodwinds, 8 plucked strings, 4 bowed strings, 4 brass, 4 keyboards, 6 percussions, 5 digital interfaces that have no link with traditional instruments and 1 modular synth (Figure 12).

Technically, the stage was divided into 3 zones (left, center and right) each one with a rack including an RTP-MIDI interface (iConnectivity mioXL) and a Dante audio network interface (Ferrofish Pulse16DX) for connecting the instruments and the loudspeakers. 3 Behringer X32 mixers with Dante cards was used on the FOH for controlling the speakers of these 3 zones, associate with 5 MIDI controllers Behringer X-Touch for controlling the 40 instruments inputs on the 5 Ableton Live sessions, synchronized via Ableton Link on the 5 computers.

Figure 22. Two general views of the stage and the FOH of the concert of May 5, 2022, at the auditorium of the Conservatoire de Nice. © Azur Photography

3.3 Elektronizza Big Band

In 2023, another type of digital instrument ensemble was experimented with students from the University and the Conservatory on a format inspired by pop music groups and jazz big bands, adapting compositions by Liam Chirico and Leo Morini.

As the required loudness was higher and the presence of microphones could cause some feedback problems, we mix our speaker system with a traditional Public Address configuration. The sound of the musicians was not only produced by a loudspeaker located near the musician as before, but also amplified in two main speakers on the front of the stage, with the use of wedges for the musicians, especially the singers. The absence of laptops on stage allowed to compact the set and to fit 20 musicians on a small 6x5m stage (Figure 13).

Technically, we simplified our system by using only the Behringer X32 mixer for inputs and outputs, without the need of the Behringer X-Touch MIDI controllers.

This concert allowed to test again our setup with many digital music interfaces in an audio and midi network, demonstrating once again its acceptable latency for musicians and its great robustness, since there were no technical crashes during the rehearsals and the concert.

Figure 33. Technical implementation for the April 27, 2023, concert at the 109 (UCArts, Nice).

4. CONCLUSIONS

The aim of this paper was to describe the technological implementation of several non-laptop based DMI orchestras. The availability of reliable audio and MIDI networking technologies (RTP-MIDI in 2005, Dante in 2006) and low-cost single board computers (Raspberry Pi in 2012) are game changers for digital orchestras, and the joint use of these two technologies is very promising. The absence of screens on stage proved to be a great advantage in the setup, and the project allowed a very large number of instrumentalists from the Conservatory and the University to approach the new DMIs for the first time. Almost all the classes of the Conservatoire of Nice were involved in this project.

The first technological phase of the project described here lead to the installation of a functional and efficient DMI orchestral ensemble. The next step will be the creation of an original repertoire able to fully exploit the capabilities of these DMIs, an exciting challenge with many musical issues to explore.

Acknowledgments

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