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Gilberto Bernardes, Eduardo Magalhães, Marcello Messina, Damián Keller,
Matthew E.P. Davies

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XIubimus

Ubiquitous Music Workshop

Gilberto Bernardes
Eduardo Magalhães
Marcello Messina
Damián Keller
Matthew E. P. Davies
(Eds)

Proceedings

of the 11th Workshop on Ubiquitous Music

September 6-8, 2021

(Matosinhos, Portugal & online)

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Workshop on
Ubiquitous Music (UbiMus 2021)

Anais do XI Workshop de
Música Ubíqua (UbiMus 2021)

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Matosinhos
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Preface

The 11th UbiMus — Ubiquitous Music Workshop (<https://dei.fe.up.pt/ubimus/>) was held at the Center for High Artistic Performance, the house of the Orquestra Jazz Matosinhos (OJM) in Portugal, during September 6–8, 2021. It was organized by the Sound and Music Computing (SMC) Group of the Faculty of Engineering, University of Porto and INESC TEC, Portugal, and OJM in collaboration with NAP, Federal University of Acre, Brazil. Due to mobility restrictions resulting from the Covid-19 pandemic, a hybrid format was adopted in this year’s workshop to accommodate the remote participation of delegates and authors that could not attend the workshop at Matosinhos.

The SMC Group, together with representative members of the Ubimus community, brought the UbiMus workshop to Portugal to reflect our mission and objectives: *to develop technology and content for users of all levels of expertise to engage in creative musical tasks by devising novel means for interacting with sound and musical content that sit at the intersection of sound and music description and interfacing*. The SMC Group hosts researchers within a large variety of fields, spanning from signal processing, art, and aesthetic sciences that all have a common interest in the perception and representation of music, sound, and visuals.

The workshop featured six scientific sessions that grouped the 21 selected papers from a peer-review process into ubimus thematic topics, including: physical devices and robotics; the Internet of Musical things (IoMusT), everyday musical creativity; educational practices; and ubimus composition, improvisation and comprovisation. The workshop program also featured a special session addressing post-proceedings calls, anticipating monographs that target the foundations and challenges for the second decade of ubimus. Additionally, five peer-reviewed musical or audiovisual works were presented in two workshop program sessions, where collaborative network and generative music had a particular emphasis. The musical works leveraged ubimus technology and challenged the Covid-19 social distancing restrictions by adopting the network as a performance platform and allowing active worldwide participation.

We were honored to have two internationally renowned keynote speakers in this edition of the ubimus workshop: Elaine Chew, Senior Researcher at CNRS/STMS Lab, IRCAM, and Visiting Professor at King’s College London, who presented her latest contributions at the intersection of music and health data sonification; and Daniela Coimbra, Coordinating Professor at the School of Music and Performing Arts

of the Polytechnic Institute of Porto, who addressed classical and recent approaches to musical excellency, notably including her work on this domain.

We wish to thank all the participants of UbiMus 2021 who contributed to making this workshop a remarkable event. We would also like to thank the Program and Music Committee members for their indispensable contribution to UbiMus 2021. We are very grateful to the OJM and the local Organizing Committee, who took care of the practical organization and ensured a smooth and efficient coordination between attendees, speakers, audiences, and musicians in scientific and artistic programs. We hope that UbiMus 2021 was a memorable event for everyone that participated.

The UbiMus chairs

Towards a Ubimus Archaeology

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***Abstract.** In this paper, we attempt to lay out a new area for ubimus, which not only connects with a number of existing interests within the field, but forges new possibilities for collaboration with other disciplines. We explore the idea of ubimus archaeology from four separate but overlapping perspectives: music software, creative resources, creative models, and creative ecosystems. Following a widely-laid out characterisation of these areas, we provide a practical exploration of music software archaeology. This is focused on the rescuing of three classic music programming systems: MUSIC V, CMUSIC, and MIT-EMS Csound.*

Ubimus deals with musical material resources, activities and by-products. One of the targets of the field is the advancement of design thinking, avoiding the pitfalls of fixation on design approaches restricted to an isolated piece of hardware, an instrument, a musical genre or to the constraints implied by some practices constructed around each of those items. An important aspect of ubimus research is the collection of data through field deployments of working prototypes or systems. While this is non-trivial for current technology, it is even more difficult for legacy technology. Problems include lack of access to hardware, lack of support for software, deficient documentation, limited practical usage and limited understanding of the social implications of music practices in contexts that in some cases are incompatible with current forms of music thinking.

1. Music Software Archaeology

Is ubimus archaeology a branch of archaeology, music or computer science? If we follow Roe's [Roe 2019] reasoning, what defines the target of archaeological work is its material of study. As it is the case in music, all the archeological work done today at some point involves computers. So why would you call a field computational archaeology rather than plain archaeology? According to Roe, the object of study of the computational archaeologist is the computer program. Nevertheless, he stresses the difference between the ultimate targets of archaeology and the goals of computer science. Archaeologists use material evidence to make inferences about the past. In contrast, software archaeologists acting within the realm of computer science are mostly interested in the inner workings of software.

Despite the apparent differences, the description of software archaeology provided by Hunt and Thomas [Hunt and Thomas 2002] and the later developments of the field make it clear that understanding the context and motivations of technological design decisions may help to expand the software-oriented archaeological knowledge. If considered as a subfield of the digital humanities, software development is not only shaped by utilitarian (aka objective) goals, it is also influenced by cultural and ideological trends that may impact key design decisions. For instance, should an implementation project target open-software tools and open licences? Should it target high portability or should it prioritise ease of use? How is personal data handled? At a time of unrestricted corporate usage of personal data, these decisions have profound consequences. Therefore, software archaeology also needs to engage with the context for which the computational tools were projected.

An aspect of the archaeological field underlined by Roe has a strong resemblance with musical research trends. Roe mentions that “analytic computational archaeology makes inductive inferences from data, whilst generative computational archaeology makes deductive inferences from simulation”. Analytical musical approaches tend to deal with the musical products after the creative act (but see also the exploratory approaches described below), while the music-compositional perspectives tend to involve generative techniques. The forward-looking strategies serve to prepare the terrain for the deployment of new technologies. And the backward-looking techniques help to evaluate the mismatch between the models and the collected data.

Thus, computational archaeology is firmly grounded within the digital humanities and shares some characteristics with music computing. Although the initial proposals of a software-archaeology practice could be construed as having utilitarian objectives that are mostly applicable to software-reconstruction tasks, by placing this proposal as a digital-humanities initiative the contextual aspects are highlighted. Software archaeology not only needs to engage with computer code, it also needs to take into account the culture in which the code was produced. The design decisions (materialised as software) reflect multiple negotiations among the stakeholders with contextual factors that lie beyond simple, immediate or utilitarian purposes. These factors point to ethics, aesthetics and cultural forces that constrain and shape computing.

Having set ubimus-oriented software archaeology within the context of the digital humanities, let us now deal with the potential targets of this new field. Our proposal gathers previous work in diverse contexts of musical research, including computationally oriented musical analysis, applications of prototyping and DIY design, and recent developments in ubimus theory and practice. We focus on three targets: the design and deployment of archaeological ubimus resources, the adoption of generative models as archaeological targets and the reconstruction and documentation of creative ecosystems that bring to life specimens of a lost musical past.

2. Archaeology of Creative Resources

There have been various proposals to apply computational strategies to recover traces of music making. Their methods, targets and implications for replicable music research are diverse and sometimes incompatible. Musicological approaches traditionally engage with aspects of a single musical work. This perspective has been applied in the reconstruction

of part of the 20th-century electroacoustic repertoire, including pieces such as *Articulations* (Ligeti 1967), *Cartridge Music* (Cage 1950), the *ST/10* series (Xenakis 1962), *Songes* (Risset 1979) and many others. Despite its relevance as a working unit, the musical work cannot be adopted as the only target of ubimus-archaeological pursuits. Some forms of music making establish clear temporal and spatial boundaries to define musical experiences, but others do not. Ubimus methods strive to be genre-agnostic, i.e., the concepts and methods attempt to engage a wide range of musical practices. Given the diversity of artistic formats, settings and stakeholders encompassed by ubimus practices, other working units beyond the artwork need to be considered.

An alternative to the artwork as a target for archaeological excavations can be built around the notion of creative resource. This concept was introduced in ubimus practices to avoid the corset of the instrument as the exclusive tool for music making. Resources encompass found sounds, images, audiovisual renditions or distributed hardware that may be accessible either synchronously or asynchronously. Several characteristics of the creative resource set it apart from the acoustic instrument. Resources may be persistent or volatile [Keller 2014]. This means they can be created, shared or discarded during the activity, as it is the case in the ubimus practice of live patching [Messina et al. 2020] or in the web-based improvisations that use distributed sonic resources [Yi and Letz 2020] [Stolfi et al. 2019]. They can also be designed and deployed as reusable infrastructure, remotely accessible for community usage [Zawacki and Johann 2014]. Its persistence or volatility defines the temporal and the spatial boundaries of the creative resource, which may or may not conform to the model of synchronous, co-located music making.

Oliver's *Silent Drum* [Oliver 2016] provides an example of a single creative resource deployable within multiple artistic contexts. According to Oliver and Jenkins [Oliver and Jenkins 2008], in contrast to the acoustic drums, the *Silent Drum Controller* does not emit audible sounds when struck. The prototype captures gestures to trigger sounds or to store the parameters for future usage. It supports up to 22 simultaneous data streams. Feature extraction is applied on continuous gestures to obtain discrete events. Apparently, this prototype fits the description of an enhanced, augmented, smart or hyper instrument as laid out by Machover and collaborators in the late 1980s [Machover and Chung 1989]. However, the deployments reported by Oliver hint that 'instrument' is not an appropriate label for its actual usage.

Oliver mentions seven artistic contexts in which the *Silent Drum* design was reappropriated. The ensemble *Qubit* replicated the prototype and composed a work for guitar, saxophone and *Silent Drum*. Students at the University of Lethbridge and the Texan Christian University composed scores for the *Silent Drum Controller*. Thai pop musician Panlertkitsakul modified the *Silent-Drum* design by adding elastic heads to two opposite faces of a cube-shaped box, thus calling it *The Box*. This prototype is played like an accordion and it is connected to a larger setup targeting techno-oriented performances. Collaborating with the *Associação Recreativa Carnavalesca Afoxé Alafin Oyó*, Ricardo Brasileiro modified the traditional Afro-Brazilian drum *Ilú* by reusing the tracking hardware and software of the *Silent Drum Controller*. Rather than dealing with fine motor articulation of hands and fingers, the performance artist Van der Woude's *Veerkracht (Resilience)* project targeted the modification of the *Silent Drum* prototype to play 'inside' the drum. This dance project engages the movements of the performer as a triggering

mechanism. Colombian musician Daniel Gómez's Yemas discards the body of the drum and simply stretches a fabric between two tables to represent the playing surface of the Silent Drum. The three dimensions of the hand movements are captured through a Kinect device.

The seven deployments described by Oliver highlight the flexibility of this interaction proposal, affording changes in functionality, shape and sonic qualities. He states that "as we move towards more fluid and participatory mechanisms of exchange, computer music instruments and, by default, music point to the consolidation of a global culture of appropriation and transformation that transcends the constructed boundaries of Western music and its instruments." We take the notion of a global culture with a grain of salt. The circulation of knowledge, particularly when it relates to technology, is neither evenly nor fairly spread among the central and the peripheral countries. This gap is also enforced by the cultural hegemony exerted by the large urban centres over the remote and 'exotic' locations within the countries. Thus, while erasing the artificial boundaries imposed by the acoustic-instrumental music discourse is a beneficial consequence of the ubimus archaeological initiatives, a complementary target – strongly skewing globalisation – entails enhancing the local cultural identities and fostering the coexistence of diverse cultural ecosystems. Given that degraded sonic materials circulate in some virtual communities and that they may have negative impacts on all forms of music making [Huron 2008, Truax 2015], tracking how the introduction of technology influences the level of resilience of the local cultures seems to be a pressing need before we reach a point of no return.

3. Archaeology of Creative Models

Creative resources adopted as archaeological targets may help to analyse the impact of a piece of technology on music making or may be used to compare deployments of tangible and intangible assets in various contexts – as exemplified by Oliver. Creative resources are useful units of study. But when the target is a complete musical outcome they may fall short. A complementary concept introduced by ubimus research is the relational property [Keller et al. 2015]. Relational properties emerge from usage and are usually observed through their byproducts. They are not properties of an object or properties of an agent. An advantage of targeting relational properties as complements to isolated resources is that they provide information in action. For archaeological purposes, this information may be inferred through the analysis of the sonic outcomes of the activity or it may be partially captured through visual, haptic and other streams of data. These techniques furnish insights into patterns of behaviours fostered or deterred by creative support systems. Therefore, they may also be useful as music-analytical tools [Keller and Ferneyhough 2004, Marsden 2012].

Analysis by modeling involves the reinstantiation of an algorithm by means of the archaeological traces left by its usage. These traces include but are not limited to source code, musical data, sonic renderings and various forms of documentation of the creative processes. Keller and Ferneyhough (2004) propose analysis by modeling for works that present widely varying results for each sonic realization of invariant underlying processes. This is the case in Xenakis's algorithmic music. Their approach allows to explore the parameter space of the model and the parametric combinations and interactions among models. The range of possible outcomes provides a qualitative picture of the

underlying processes. Since the published score is only a particular instance of the algorithmic mechanisms, a database of parametric combinations may be more informative for analytical purposes than the final rendition presented by the composer.

Xenakis employed his ST (Stochastic Music) program to compose a number of works, including ST/10-1 080262. The program was coded by M. F. Génuy and M. J. Barraud in FORTRAN IV on an IBM 7090 [Xenakis 1992, 145-152]. Xenakis utilized ST to generate data in text format. Then proceeded to transcribe the output to musical notation. ST provided a list of parameters such as attack time, instrument class, instrument (i.e., the selection of instruments within a given class and the playing technique), pitch, duration, dynamics and glissandi. Based on this information and on the transcriptions featured in the score, Keller and Ferneyhough were able to implement a temporal quantization model and a timbre distribution model to emulate a range of behaviours found in the piece. Two perceptual processes play an important role in auditory processing of sound textures: sequential and simultaneous stream segregation. The results indicate that grain density and timbre-based auditory streaming define whether fused granular streams could be created with the instrumental palette employed by Xenakis in ST/10. The authors raise the question of whether fused textures could have been obtained by employing slightly higher densities of events and a carefully designed timbral distribution.

Archaeologically recovered models feature some advantages over restored resources. As shown by the ST/10 exploration, through the remnants of historical deployments the output of a working prototype may be compared with the available data. This technique is aligned with the concept of scientific replicability. Consequently, the usual tools for validation can be employed. Nevertheless, a note of caution is necessary. There is an ongoing discussion in the ubimus community regarding the limits and relevance of replicability in creative practice. As highlighted by ecologically grounded creative practices [Keller 2000, Keller and Lazzarini 2017], the exact replication of a sonic output tends to reduce the creative potential of the method. So some level of uncertainty may help to boost creativity (see [Aliel et al. 2018] for applications of this perspective in improvisation). Another feature of sonic models is their potential to update their behaviour, given environmental changes. For instance, some parametric updates may be tied to subjective choices or they may incorporate the computational analysis of the available resources, thus opening the door to the usage of automated methods that do not depend on human decisions (see [Sinclair 2018] for an implementation, and [Coelho de Souza and Faria 2013] for a creativity-oriented discussion of its usage).

4. Archaeology of Creative Ecosystems

Excavations of creative resources range from fairly straightforward cases, when they involve persistent objects (comparable to the bones recovered by zooarchaeologists), to more difficult cases, when they target volatile resources. Volatile resources may become tangible and shareable through various means, including capture, transcription and rendition in formats that may combine digital and material elements (see, for instance, the use of creative surrogates in Keller et al. 2019). With the demise of the printed score as the ideal representation of the musical piece and the demise of *the piece* as the most relevant representation of the musical experience, the replicability of a creative process increasingly depends on intangible assets (see [Bressan 2020] for the first steps toward a ubimus-oriented musicology). So model-oriented archaeological excavations may be an

alternative when the musical experience is based on volatile resources that have not been rendered as tangible assets. Model-oriented software archaeology encompasses digital and material resources to enable the rendition of sonic outcomes that are compatible with the creative target of a past experience. But what happens when the goal of the excavation cannot be identified as a creative resource or as an algorithmic model? This section deals with this question.

Ecologically grounded creative practice has been applied in artistic practice, in educational settings and in software design [Keller 2000, Keller and Lazzarini 2017, Lazzarini et al. 2020]. The influence of ecological thinking in creative practice has yielded the concept of *ubimus* ecosystems. *Ubimus* ecosystems encompass infrastructure, creative resources, stakeholders and the dynamic relationships emerging from their interactions, also known as relational properties (see previous section). *Ubimus* ecosystems may be based on distributed infrastructure – such as the internet of musical things – or they may use intangible assets as key tokens for exchanges among the stakeholders [Ferraz and Keller 2014]. The latter types of organizations are harder to recover and may demand working on inferences from traceable by-products. A characteristic of creative ecosystems that sets them apart from creative resources and models is their unbounded behavioral domain. Resources and models can be identified by their material qualities or by the profile of their sonic outcomes. Complex creative ecosystems may yield behaviours that are not prebuilt or projected. Therefore, an analysis of their output is not enough to identify their potential. Some knowledge of their inner workings is also necessary. An illustrative example is furnished by the music programming systems [Lazzarini 2017].

Music programming systems provide domain-specific languages dedicated to sound synthesis, processing, and the manipulation of events (at various levels from the micro to the macro). They tend to support music making in a variety of ways, with a level of transparency beyond other types of music software. Consequently, music programming languages have been adopted for artistic practices that encompass multiple aesthetic trends and have been employed both for simple utilitarian tasks and for non-trivial creative goals. Given the open nature of their outcomes, their strong bonds to a community of developers and users, and the demand for permanent adjustments to keep up with new hardware and operating systems, music-programming languages are better described as ecosystems, as opposed to fixed or bounded tools.

The three cases reported in the next section illustrate the shortcomings and advantages of targeting creative ecosystems as the objects of software-archaeological diggings. The three chosen specimens constitute historically relevant bodies of work that feature multiple contributions from continuous community efforts. Thus, they function as a repository of knowledge that is more than the sum of the isolated individual contributions. How relevant or effective is the knowledge embedded in these ecosystems given the current creative demands? Only by restoring and deploying these archaeological specimens we may eventually be able to answer this question.

5. Case Studies

As we enter the seventh decade of computer music, it is worth considering, from a software archaeology perspective, the study and preservation of systems that were fundamental for its development. Rescuing documentation, design notes, learning materials,

and music made with such software is an important part of it, but a key part of the process is to be able to recover the software itself. This would allow a study of its design, from both a computer science and a musical point of view, which may inform our understanding of music software design in general. Besides the question of actually finding the software in some machine readable format, there is the difficulty that some code may be hardware-specific, either written directly as machine code, or in some form of assembly. Understanding the software then may be tied to the knowledge of the architecture of the platform in question. The existence of simulators [Burnet and Supnik 1996], such as the one provided by the SIMH project [Supnik 2021] may be helpful in this process. If, however, the system has been written completely or partially in a recognisable high-level language, the process is reasonably more straightforward, depending solely on the availability of enough source code to allow for some reconstruction.

To illustrate in particular some of the practical points of music software archaeology, we would like to investigate a few cases. Sound synthesis and processing of digital audio signals with a computer was first achieved in 1957 by Max Mathews MUSIC I program running on the IBM704 [Lazzarini 2013], although earlier ad hoc attempts at connecting computer hardware directly to loudspeakers had been made elsewhere. At the time, Bell Labs, where this took place was the only place in the world where a digital-to-analogue converter (DAC) of the type suitable for musical signals was available [David et al. 1959]. Without such hardware, computer music using digital signals was not a practical possibility. The MUSIC I software did not support any form of programming besides taking parameters such as amplitude, frequency, and duration, and produced only single-voice sine waveforms. Following on from this, we have MUSIC II (1958), which added the possibility of other waveforms and more than one sound at a time. The breakthrough took place with MUSIC III (1961) [Mathews 1961, Mathews 1963], which could be considered the first dedicated music programming system. It comprised of a collection of BEFAC assembler macros for the IBM 7094 computer defining a few structural elements, such as the idea of an *instrument*, which was a container for *unit generators*. There were only a handful of these, and the table lookup oscillator was the central element in the system. Such a modular approach was very influential as it preceded the existence of the voltage controlled modular synthesiser by a number of years, providing a model for it. MUSIC III also introduced the principle of the *acoustic compiler*, that is, a translation program designed specifically to create sound-generating programs. These could then be fed parameter lists to produce anything from individual tones to complete compositions.

MUSIC III was superseded by MUSIC IV (1963) [Mathews and Miller 1964], a much more complete system, also written in BEFAC, but now sporting its own language. MUSIC IV included a series of preprocessing routines which facilitated the preparation of parameter lists, or *scores*. A sound processing program was compiled from MUSIC IV code, the *orchestra*, which consisted of one or more instrument definitions. As with MUSIC III, the score would instantiate these to produce the audio output samples in a digital tape, which could then be run through the DAC to produce sound. While it is not possible to recover the original code for MUSIC IV, it is possible to understand fairly well how it operated from the reference manual. Since MUSIC IV provided the model for later systems which exist in source code form, we can also surmise much of it by looking at the common elements that were passed on to this next generation of software.

We can now explore three case studies based on software whose source code is available. These systems are either first- (MUSIC V), or second-generation (CMUSIC, Csound) derivations of MUSIC IV. In this study, we are particularly interested in examining the state of the existing code, whether it runs or not, any existing documentation, and possible modifications made to it. We are not looking to make a comparative study of the software beyond the most salient aspects of their operation.

5.1. MUSIC V

MUSIC V was first developed by Mathews and his team at Bell Labs in the late 1960s as an updated version of MUSIC IV written mostly in Fortran, although it allowed the addition some machine-dependent components to be called from the main program. The version that has been rescued was typed in from a 1975 print out of the source code and adapted to work with the gfortran compiler by Bill Schottstaedt in 2008. This was fully adapted to yield a working program that can be used in a modern operating system. Additions to this restoration were made by Victor Lazzarini in 2009. MUSIC V consists (as MUSIC IV did) of separate *passes*, which may be seen as individual processing programs. These have been kept as three separate Fortran programs, which are used in sequence to produce the sound output:

1. pass1 takes a score file named ‘score’ and produces ‘pass1.data’
2. pass2 takes a ‘pass1.data’ file and produces ‘pass2.data’
3. pass3 takes a ‘pass2.data’ file and produces ‘snd.raw’

Since none of the programs take any arguments, it is often better to have a shell script call them to

```
#!/bin/sh
rm snd.raw
cp -f $1 score
./pass1
./pass2
./pass3
mv snd.raw $2
```

The output is a raw, system-endian, 4-byte floating-point number at 44.1KHz (the sampling rate can be adjusted in the Fortran code).

The rescued program from 2008 did not originally contain all of the unit generators reported to exist in the first version at Bell Labs (and also none of the additions that appeared in various other installations). In particular, it lacked the IOS unit generator, which appears in some of Jean-Claude Risset’s *Catalogue of Computer Synthesized Sounds* [Risset 1969a], most famously in his example 513, the Risset-Shepard tone instrument, based on circular pitch scales [Risset 1969b, Shepard 1964]. An assumption was made that this is a linear interpolation oscillator, and so it was added to the source code. The code also did not include four table generation routines (GEN 4 - 8), which were used in Risset’s catalogue. These were added to the present 2009 version. The FLT unit generator is also not present in the code, but since we have no description of it, we can only guess it is a filter, presumably a two-pole resonator. This unit generator has not been restored yet.

Since MUSIC V was for many years used at IRCAM, it is a possibility that its site installation may have been preserved there, but we have no confirmation of this. Furthermore, it has been said that Jean-Claude Risset used the program until recently, and so his private version might also exist in some form. In any case, as far as the authors are aware of, the Schottstaedt restoration with the additions described above is the only publicly available source for MUSIC V. The code and documents is available at <https://github.com/vlazzarini/MUSICV>

5.2. CMUSIC

CMUSIC [Moore 1990], or perhaps more properly, CARL [Loy 2002], is a large computer music system comprising of several programs designed to work cooperatively within a UNIX shell environment, developed by Richard Moore, Gareth Loy, and others at the University of California, San Diego. For this, it takes advantage of the typical means of input/output (IO) proposed by that operating system, using redirection of the standard IO and piping to connect programs together. The source code is written mostly in Kernigham and Ritchie (K&R) C, which poses some challenges for any attempt to recover it within a modern system based on the ANSI C standard. Nevertheless, it has been mostly recovered in 2009 from an available archive of the CARL-0.02 linux distribution containing all of its source code. As part of this process, it was pruned of few elements that were “outdated, irrelevant, or could not be built” [Lazzarini 2021]. For this restoration, the build system was simplified to a few static Makefiles, which work correctly in modern UNIX-like systems. Part of the code is written in Fortran, but, similarly to MUSIC V, has been made to compile under gfortran. One of the components of the system is a realtime playback program called `todac`, which was based on machine-dependent code. In the restoration of the system, a cross-platform program was written to replace it.

The CMUSIC program is derived from MUSIC V, but it is much expanded and, in particular, it uses the facilities given by the C preprocessor to allow scores to use macros to simplify the code. It consists of a single pass program, which produces audio output as ASCII samples to the standard output. This is, as noted above, in line with the UNIX way of doing things. In order to produce a soundfile or to listen to the result directly, the output needs to be piped into a translation or playback program. The `tosf` program, for example, produces IRCAM-format soundfiles,

```
cmusic toot.sc | tosf -if -of -R44100 -c2 toot.irc
```

At the time of writing, some of the unit generators are producing segmentation faults due to fencepost errors. It is supposed that these may be due to incompatibilities between the original K&R C code and modern compilers, as noted by the many warnings and errors that needed to be silenced/corrected in order to build the software. It is an area for further work. Code and documentation are available at <https://github.com/vlazzarini/cmusic>

5.3. MIT-EMS Csound

Of the three case studies, Csound is the only one that continues to exist in an updated codebase [Lazzarini et al. 2016], which is now completely different to its original sources. Therefore the question is not one of rescuing the software to run existing compositions, as these can be run in the modern version of the software, but more related to use the

source code as a way of studying the internal structure of the original system. As with CMUSIC, the original Csound from the MIT Electronic Music Studios is written in K&R C, although the system is more monolithic and does not rely on the UNIX operating system particularities to work. This might be a reason why it was ported almost universally from the mid 1990s onwards, when the codebase was fully modified to comply with the ANSI-C standard by John ffitich.

Due to its K&R C codebase, it does not appear to be possible to build the MIT-EMS Csound without modifications in a modern system (e.g. with clang). Unlike CMUSIC, which was maintained possibly until the late 1990s, the codebase for the original Csound was superseded around 1993 by its ANSI-C version as noted above, thus it is over thirty years old by now (fully introduced in 1986 and publicly released in July 1987). However, it is possible to build and run the software on a VAX platform with BSD 4.3 UNIX under emulation using SIMH. Due to its licensing, it is currently not possible to make the source code available on a repository such as the ones hosted by github. However, disk images and instructions for the SIMH VAX emulator can be obtained from the authors.

6. Conclusions

In this paper, we examined the ideas around what we have termed ubimus archaeology, which comprises three inter-related areas: music software archaeology, archaeology of creative models, and archaeology of creative ecosystems. We have given a wide overview of these areas, highlighting the relevant elements within the scope of ubimus. Completing the paper, we provided three practical case studies of music software archaeology, demonstrating some of the ideas put forward earlier. It is hoped that this first attempt at characterising an archaeological approach to ubimus may inspire some further work in the area.

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From the Edge

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Abstract. *From the Edge* is one of a series of audiovisual installations that explores nonlinear audiovisual installations in a process I have come to term as *Ecological Performativity*. These works explore the relationships of environment, material, and process, and are derived from an intensive data-gathering procedure and immersion within the respective environments.

1. Artwork Proposal



Figure 1. St. John's SmartBay Buoy

From the Edge is one of a series of audiovisual installations by the author that explores the environment of East Coast Newfoundland. The work expands on my use of

environmental datasets as an artistic device to create nonlinear artworks for public engagement. The creative system is coded to live-stream data off the SmartAtlantic St. John's Buoy, which is located 1 kilometre offshore of Cape Spear, NL (Fig. 1). The buoy is capable of measuring and transmitting a variety of atmospheric and surface conditions including: surface temperature; wind speed and direction; wave height, period and direction; as well as current speed and direction. From the Edge is coded to stream and parse these data-sets to trigger and shift parameters of this nonlinear work, which includes a visual particle system, audio and visual field recording material captured off this coast, a live streaming hydrophone feed from the St. John's SmartBay Buoy and improvised musical motifs. Developed in Max/MSP, the work continually evolves depending on the transmitted measurements.



Figure 2. *From the Edge* particle system generated from Ocean datasets streamed off the SmartBay St. John's buoy, NL, Canada.

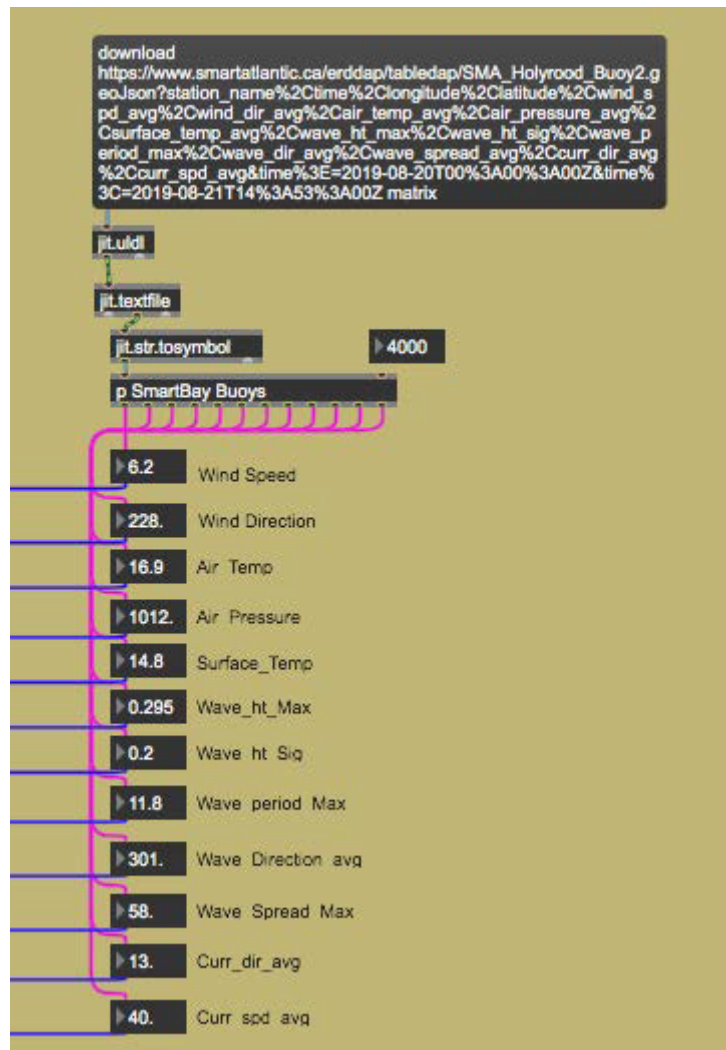


Figure 3. From the Edge data-streaming code

2. Technical and logistical requirements

From the Edge can be live-streamed from my location in Montreal and onto a twitch account. From there, anyone can view the work via the following twitch account link.

The Lifeworld Context in Comprovizational Tools for Laypeople – A Phenomenological Approach to Explain Ease-To-Learn Aspects in User Interfaces

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***Abstract.** Especially laypeople cannot be expected to learn completely new theories in order to be able to use a computer-aided composition tool in an understandable way. Often without explicitly addressing this fact, this difficulty is met in concrete applications by basing the respective user interfaces of such tools on something that can be expected to be already known to the users. Only a new context of meaning must then be experienced and learned experimentally by the users. The known, which is referred to in the user interface, comes from the lifeworld of the users. The concept of lifeworld is borrowed here from Edmund Husserl's late writings on phenomenology.*

1. Introduction

What is the reason for determining whether a user interface ensures a comprehensible interaction with a tool for comprovization?

Such a question for a rationale is typically not asked at all in the context of the description of meaningful concepts for the usability of user interfaces. One only finds a rather quantitatively oriented question about ease-to-learn and instructions on how this can be answered by means of statistical evaluations, see e.g. [Arevalo 2020], [Madan, A.,Dubey, S.K. 2012]. Although this allows a subsequent evaluation, it does not provide any clues for the design phase.

Contrary to the common approach, where the focus is on the concrete interaction of the users and a downstream inquiry and/or statistical survey, it is proposed here to place it on the context that the user interface establishes with the user's lifeworld. The thesis is: The effort and the hurdles in the understanding of a tool for comprovization can be greatly reduced, if the tool refers to the user's existing reference structures and their systematics and reinterprets them in the sense of the goal of providing the design possibilities of a musical structure. There are life-world contexts that all people share and are therefore predestined to be used, such as our physical relationship to the space around us, and those that are very individual, such as our respective concrete social environment.

It is also to be expected that it will be used in a complementary way rather than in competition with other methods, since what can be said with its help complements and extends that found with other methods rather than contradicting it.

It is often tried to find some ideal method of description in a field of knowledge, which stands out before others. To substantiate the choice, this is then often placed at

the end of a historical development, as for example in [Worrall 2019] in the field of sonification. It should be noted, however, that such an assessment is itself always tied to a particular methodology, including the theory on which it is based, and so is not even able to delve into the different theories it is assessing.

Here, however, rather the point of view in the sense of the pragmatism of a Richard Rorty is to be taken, according to which there is a multiplicity of languages in science, which have in each case a special suitability for the description of certain connections, but are unsuitable for other fields of knowledge. So one needs them all and there is no superior language to which all contents represented by means of the other languages could be traced back:

" We have not got a language which will serve as a permanent neutral matrix for formulating all good explanatory hypotheses, and we have not the foggiest notion of how to get one." (Richard Rorty in [Rorty 2018], p. 348)

The proposed method is understood as a phenomenological investigation in the sense of Edmund Husserl's phenomenology, as developed by him especially in his late writings on "lifeworld" and "genetic phenomenology" and to which concrete reference is made throughout this paper.

2. Determination of the Terms of Lifeworld and Genetic Phenomenology Used Here

Prerequisite for an understanding of the terms lifeworld and genetic phenomenology, is first an understanding of what phenomenology is in the sense of the philosophical direction of the same name.

Without going into the specifics of different schools and developmental phases in Husserl's work, the concept can be roughly outlined by quoting Martin Heidegger:

"Phänomen – das Sich-an-ihm-selbst-zeigende" (Martin Heidegger in [Heidegger 2006], p. 31, translation from the original German text: *"Phenomenon – showing-it-self-from-it-self"*)

Example music: If I listen to a certain piece of music, the musical structure, the instrumentation, etc. of this music is revealed to me by itself. Counterexample: If, on the other hand, I were to read a score of the same piece of music, the instrumentation of the music would not be revealed to me through it itself. If, on the other hand, I were interested in examining the score itself, then reading the score would be a phenomenological approach to the score. Another counterexample: If I classify the piece I am listening to as pop music, this is again not a phenomenological approach to this music, because the categorization as pop music is not shown by the music itself, but results from my prior knowledge of other music and my ability to abstract.

According to Husserl, it is necessary to radically abandon all presuppositions, model conceptions, and prejudices if one intends to really engage with a phenomenon, see e.g. [Husserl 1995], pp. 20-23.

On the other hand, everything that comes to my consciousness can be the object of my phenomenological observation. This can be something I am experiencing at the

moment, it can be an idea, but also a memory. What matters is that I am concerned with this experience itself, with this memory itself, or with this idea itself, and not with something else. Also a model conception can be phenomenon for me, if it is in that case just about the model itself and not about what it refers to, see e.g. [Husserl 1995], pp. 20-21.

By lifeworld is not meant the sum of all aspects of the world as we describe them in models. So it does not mean abstractions like social relations, traffic systems, environmental problems, politics, etc. In the sense of phenomenology, lifeworld means the sum of all possibilities how a world assumed to exist expresses itself phenomenologically. It is the horizon / totality of possibilities of the world in all its aspects as we experience it on a daily basis. Examples of excerpts from it are: Our bodily experience, our spatial experience, our encounters with other people. But also more specific, individually shaped and time-dependent things, such as: smartphones and how we use them, music that sounds in the supermarket, the immediate understanding of written texts, the change of seasons, environmental pollution as a daily experience, news about environmental problems as a daily experience, etc. However, our physical being-in-the-world in particular plays a prominent role for our life-world experience:

"For everything that exhibits itself in the life-world as a concrete thing obviously has a bodily character, even if it is not a mere body, as for example, an animal or a cultural object, i.e., even if it also has psychic or otherwise spiritual properties." (Edmund Husserl in [Husserl 1970], p. 106)

The fact that a stop sign appears to us in traffic, that we can recognize a doorbell sign as belonging to our neighbor by reading it without thinking, that a million euros for a car seems expensive to us, presupposes a learning process that we can recall in our memory. Other aspects of our life-world, such as the above-mentioned body and spatial experience, are rooted in our preconscious child development and we cannot make ourselves conscious of their genesis. If Apparently such pre-formations are a precondition for our lifeworld experience that has been forgotten for us.

Genetic phenomenology is concerned with precisely these questions: How does it come about that the world expresses itself to us in very specific phenomena? How and when did this ability of ours develop? What conditions are necessary to form a new synthesis, to forget it and then to have it as a self-evident part of our life-world?:

"Here the consideration of the constitution of the world for me as a human being, who is already a human being for myself, meets with the continuing consideration of how I became 'human' for myself and came to this constitution of the world. I go back to my childhood, as far as I remember - I was always already man, I had always already world experience, although such of a poorer content and with much less formed horizons." (Edmund Husserl in [Husserl 2008], p. 478, translation from the original German text)

3. About Coffee Cups and User Interfaces – First Steps Towards a Phenomenologically Based Attempt to Explain Ease-To-Learn

It should be noted in advance that Edmund Husserl strove throughout his life to elaborate phenomenology as a theory of knowledge.

However, the focus of this article is precisely not to examine Husserl's theory in competition with other theories in terms of the possibility of gaining knowledge about the world, but to unfold the phenomenological approach as an alternative, complementary possibility with which it is possible to focus on areas of knowledge that lie outside the categorical horizon of other approaches.

In other words, no further consideration is given here to whether Husserl's own claim that at some point in development phenomenology can replace critical rationalism, but in Rorty's terms both are understood as co-existing incommensurable languages, each capable of describing different sub-aspects of reality, and where it makes sense to learn both.

Husserl's primary approach was that what comes to a person's consciousness should be the starting point of any epistemology, be it actual perceptions, memories, thoughts. All this he summarizes as phenomena. These are to be grasped first exactly and as they appear and not mediated by any preconceived theory and not by mere categorization. Assumptions about the phenomena that come to us, such as "this is my coffee cup", are, according to Husserl, already presuppositions that must be left aside for the moment. However, he also emphasizes that these presuppositions, on the other hand, are so self-evident that they belong to the phenomenon, indeed make it appear in the first place. My coffee cup appears to me directly as a coffee cup and not as somehow colorful spots on my retina. And by perceiving the coffee cup as such, it is part of our life world. In other words, coffee cups are anchored in our culture. And so, for the individual who has grown up and lives in this cultural environment, the coffee cup has also constituted itself as part of the lifeworld.

As mentioned before, how this constitution might have proceeded would be the subject of what Husserl called genetic phenomenology.

Here Husserl distinguishes between what he calls an active and a passive synthesis. With passive synthesis would be meant the fact that due to my cultural context and my preceding development the coffee cup shows itself to me as such. With active synthesis is meant my ability to connect the multiplicity of single phenomena as in this case belonging to a spatial thing, see [\[Husserl 2000\]](#), [\[Husserl 1966a\]](#).

So the coffee cup appears to me as a coffee cup, but not "just" as a coffee cup. This means that one should be careful that an abstracting and reducing categorization does not get in between the unbiased awareness of the phenomenon.

When a user is confronted with a new user interface for a computational tool, he gets used to it and it becomes part of the user's lifeworld in the sense described above. How this habituation proceeds and the question whether, how and under which circumstances it can succeed would also fall into the field of genetic phenomenology. Thus, genetic phenomenology would already be an approach to study user interfaces. The user interfaces would be examined to what extent they have become part of the user's lifeworld and how this process takes place.

Something fundamental can be said about this right away, and this already represents a preliminary conclusion that results from what has been said so far: In order to provide an easily understandable user interface for laymen, it must present itself to the user as something familiar to him. This familiarity should come from an area of life that

is expected to be shared by most people. For example, we all share a basic understanding of spatial structures. We have a perception of our own body, how it is there in space, and many other things. For a novice user can neither be expected to have a deep knowledge of music theory, nor to be willing to spend days learning the usage of the tool. Here now a special problem arises, which is closely connected with it: The interface cannot be identical with this, which is known to the user, otherwise it would not be a user interface for a comprovizational tool. Instead, it shows itself as something familiar, but behaves differently, respectively creates music, when an interaction takes place. Familiar things, say the movement of geometric bodies in space, or movements of one's own body, are reinterpreted by the interface. They experience a reinterpretation by the user interface. Now the question arises whether the user recognizes and comprehends this reinterpretation and under which circumstances this succeeds more or less well.

Clues to this can already be found in the previous description. With entry into this consideration the investigation already begins in the sense of the genetic phenomenology.

The key here lies first in the requirement that the interface presents itself to the user as something familiar to him, i.e. something that occurs in his life world. And in the same way, the reinterpretation, which is essentially a change in the structure of the reference, should in the end also result in something familiar again.

Music, too, is part of the layperson's lifeworld. The new linkage that is established, therefore, establishes a new functional context of familiar lifeworld elements for the user. Where this does not happen, according to the hypothesis put forward here, there the user interface remains misunderstood in its meaning and no comprehensible use of the comprovizational tool is possible. Reasons why this genesis of the comprovizational tool as a new part of the user's lifeworld by means of the user interface does not work can now be broken down:

- The user is not aware of the familiar context of the user interface. There can be various reasons for this:
 - The user comes from a different cultural context than the one within which the interface was developed.
 - The lifeworld of the user differs from that to which the interface refers, for example, due to certain health impairments. The user cannot do anything with colored patterns if the user is blind.
 - The representation of what is actually familiar has not been well done in the implementation of the interface. For example, it could be that the rendering of 3D objects to be manipulated is so poorly implemented that they cannot be recognized as figures in space.
- The reinterpretation is not recognized as such, or remains incomprehensible, respectively not comprehensible. Also for this different causes could be conceivable:
 - The connection between user interaction and musical results is not perceived as causal by the user. This may be due to the fact that too many internal states also play a role in the resulting musical outcome.
 - There is no congruence in the reinterpretations between the original meaning and the new one. Often there are interfaces where a spatial dimension

is reinterpreted as a timeline. Think of a cyclic musical phrase on whose timeline sound objects can be placed. If the original meaning (example: position in space) diverges too far from the new one (example: timeline), the chosen way of reinterpretation is incomprehensible for the user.

4. Sonification Interpreted as a Precursor to a Comprovizational User Interface, Refraining from Seeking a New Way of Dealing Beyond the Familiar in Interaction

Initiated by Prof. Rolf Großmann and implemented by students of the Leuphana University of Lüneburg, the training equipment of a sports studio was modified by means of appropriate sensor technology in such a way that it produced sounds, noises and music depending on the type and intensity with which it was used, [Tege 2014](#). In this example, the various lifeworld domains mentioned above can be identified very well:

On the one hand, there is the gym with the training equipment. People who want to keep fit come there and work out. The fitness equipment is typically designed in such a way that it is easy to learn how to use it after a brief introduction, and certain simple movements are then constantly repeated, which are strenuous but do not require any special attention to perform.

On the other hand, visitors are familiar with sounds and music. In fact, such sounds and such music were also used, which can be assumed to be rather familiar to most people.

Finally, the modifications of the sports equipment ensure that new quite concrete functional relationships are established between the musical parameters of certain sounds or music, respectively, and the sports movements. These connections are then gradually experienced, understood and finally even consciously controlled by the visitors in the course of the sporting activities.

5. Kaleidophone

It may be noticed that this entire article, while describing the phenomenological method as a means of arriving at an assessment of the usefulness of user interfaces in the field of comprovization for laypersons, does not itself contain a single phenomenological description. One such description would be, for example, the temporal perception of a sound, as Husserl himself elaborated:

"When a tone sounds, my objectifying conception can make the tone, which lasts and fades away, to an object, and yet not the duration of the tone or the tone in its duration. This as such is a time object. The same applies to a melody, to any change, but also to any persistence considered as such. Let us take the example of a melody or a continuous piece of a melody. At first, the matter seems very simple: we hear the melody, i.e. we perceive it, because hearing is perceiving. However, the first tone sounds, then comes the second, then the third and so on. Don't we have to say: when the second tone sounds, I hear it, but I don't hear the first one anymore, etc.? So, in truth, I do not hear the melody, but only the single present tone. That the expired part of the melody is objective for

me, I owe - one will be inclined to say - to the memory; and that I, arrived at the respective tone, do not presuppose that this is everything, I owe to the anticipatory expectation.” (Edmund Husserl in [Husserl 1966b], p. 23, translation from the original German text)

But just as in Husserl’s work, which contains more than 40000 pages, only a small part is phenomenological, but is mainly dedicated to the consequences and theories that can be developed from it, which result from a phenomenological approach, the present text also tries to show what comes into focus, which was previously outside the reachable horizon of cognition, if a phenomenological approach is chosen.

But in order to prove that this is possible at all and to show how this can look like in the context of user interfaces for comprovizational tools, the user interface of the work ”Kaleidophone” (see [Kramann 2021]) from this area shall be examined at least finally as an example from such an approach:

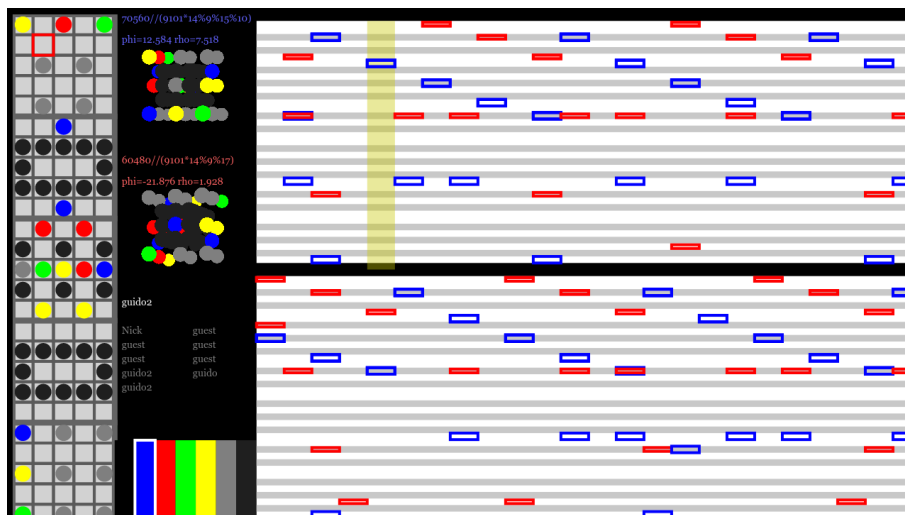


Figure 1. Kaleidophone.

Kaleidophone corresponds in concept to a work called THE FLIPPIN POM-POMS’ [Kramann 2020] but is unlike this web-based and is collaborative by means of the internet. Kaleidophone has two successively connected transformation layers responsible for generating the currently sounding music, see Figure 1. On the first layer, a multicolored spatial figure is designed. This figure is projected twice into the plane. The contiguous colored areas in these two 2D projections are each translated into an arithmetic formula. These two formulas represent the second transformation layer and henceforth represent a generation rule for the tone sequences of two software-based musical instruments. Since all participants in Kaleidophone are not only listeners, but should also have and use the opportunity to change into a role in which they actively influence the musical performance, Kaleidophone itself is available as a web page under the link <http://kramann.info/kaleidophone> and an introductory video into its use is given here: <https://youtu.be/HzZjTQTjJko>. Special attention was paid to easy usability in order to give all participants the possibility to influence the musical performance themselves: Only a nickname must be entered before the start. When the START button is pressed, the view changes to a display showing a 5 by 5 by 5 grid with

colored spheres on the left and two 2D projections of this structure next to it. Still further to the right, a piano roll-like representation depicts the musical structure currently being created. The data describing the current state of this structure and the angles at which the projections are made are continuously downloaded from a central server and thus updated. Conversely, any user can add or remove a colored sphere at any time. This action is then stored on the server and is available to all users after some time. There is only one simple rule how the actions of the different users are handled: Each location in the 3D grid and each angle is considered separately. If a change is made at a particular location by user A, it will only take effect if either the last change at that location was also made by user A, or the last change made by a user B at that location was at least 30 seconds ago. Sound generation takes place locally at each client. Only the structural data of the 3D shape and its projection angle are exchanged between the participants.

5.1. What Sense Does It Make, as in Kaleidophone, to Unfold a Musical Structure Across Multiple Hierarchical Layers of Representation?

The layers of representation used are borrowed from a context of meaning from the life-world of the users, who are familiar to them: because of their own corporeality and the corporeality of the world around them, users already know what it means to form a spatial gestalt and to project it into the plane.

The use of arithmetic formulas as a function of time on the underlying level, which finally lead to the generation of the musical events, was similarly done with the intention of referring to a familiar context of meaning from the users' lifeworld.

The point is not so much to actually fully comprehend the context, but to provide a plausible, compact, easy to survey and manipulate symbolic representation for the currently audible musical structure. The basic idea overall is that a comprehensible handling of Kaleidophone can be learned over time via the perception of the presented connection between figure and formulas on the one hand with the current sound events and their visualization as piano roll on the other hand.

5.2. Phenomenological Investigation of Kaleidophone

From an empirical point of view, the following fictitious description of a layman's experience with Kaleidophone and even more the assessment of the quality of Kaleidophone's design derived from them may seem very questionable, because after all they do not result from a survey of laymen, but only from a user experience of the author himself. Now, on the one hand, this description is indeed model-like and the results derived from it are to be understood as possible outcomes. On the other hand, the intention of this article is to claim a relative truth content for the statements made. This is based on the fact that although the author is not a layman, those aspects of his lifeworld that are of importance for the use of the user interface developed here have a high degree of correspondence with those of the laymen targeted as users. Now, even the most hard-nosed empiricist makes use of this circumstance when developing a user interface, even if he usually does not address it. Otherwise the design of a user interface would end in an endless chain of trial and error. But by specifying very concretely here which possibilities of experience we typically share, be it spatial experience, or an understanding of arithmetic, and which rather not, be it being able to read a score, or being able to recognize intervals audibly, a very concrete assessment can also be made of the extent to which the designer of a user

interface can predict the ease-to-learn of the targeted users already in the course of the design, and not only via statistical surveys of user experiences afterwards, see Figure 2.

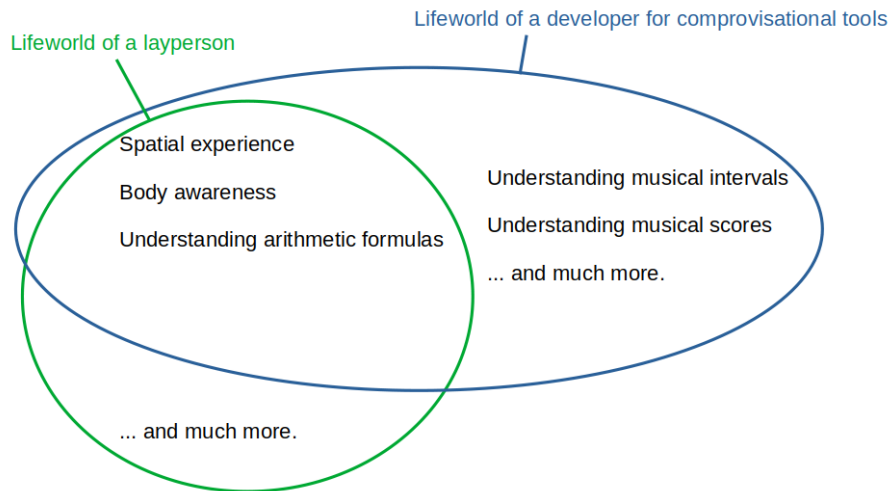


Figure 2. The lifeworlds of a layperson and a developer for improvisational tools.

As a user who has already used Kaleidophone several times, or has seen the introductory video, I know that on the left I can develop the 5x5x5 3D grid, in the middle I can influence two 2D projections of this grid by rotating them by two rotation angles each, that above these projections the formula generating the musical phrase appears, and that on the right a piano roll always appears showing what will be generated in the future from the formulas as a musical structure.

For the 5x5x5 grid, I am thinking strategically about how I can design the structure in such a way that the contiguous color areas appearing in the possible projections, from which the operations of the formulas are derived, turn out to be as varied as possible. In particular, by using black spheres, I manage to hide and reappear partial structures in the projections depending on the angle of twist.

From the point of view of genetic phenomenology, in the previous two activities, my ability of spatial perception formed a prerequisite for mastering them. During the following activities, my school knowledge in arithmetic helps me and finally my musical background.

It is not easy to keep the number of contiguous gray areas in the projection as varied as possible. Instead, I try to distribute gray spheres in the grid as randomly as possible to get the desired effect of formulas as long as possible with operations as varied as possible.

In the process, I become aware that modulo operations (%), especially when they appear combined with rather small operands, tend to lead musically to repetitive figures, whereas multiplication leads to rather open, constantly freely varying phrases. Disturbing are the constantly appearing similar arpeggios downwards. They can be avoided if the formula is made more complex or alternatively by choosing a bigger base number in the parameter area.

While I now had a vague idea according to which I formed the 5x5x5 grid, I now start to rotate the figure in the two projections. In doing so, I notice that my attention is now more focused on the piano roll and I am more like searching for a station with a radio knob to get as varied a structure as possible in one voice and a more repetitive one in the other.

Finally, I begin to perceive the piano roll only marginally and I concentrate on the harmonic development of the performance, for which I try to achieve that it becomes neither too monotonous nor too dissonant. I try to achieve this while preserving the basic shape (free melody in one voice, pulsation in the other) as it is visible in the piano roll.

6. Discussion

In the interview at the end of the video for "(Sport)-Studio Musik" (<https://vimeo.com/105546941>) Großmann describes the experience of the participants as one in which they can be part of a work of art. This implies a rather non-emancipated participation with little understanding. Essentially, this is true for this realization, even though it can be perceived in the video how the participants consciously influence the musical events within a certain framework by changing their interactions, but rather in the sense of a slight variation of something that is otherwise always the same, rather than in the sense of creating their own composition.

On the one hand, this kind of interactive sound installation is a safe way to involve lay people. With Kaleidophone, on the other hand, there is always the danger that participants will mentally drop out at some point, be it that they do not see the given connections at all, or be it that the connections between user interaction and the resulting musical performance that open up to them do not seem far-reaching enough for them to get the feeling that they are really creators of what is happening here.

That is, in conclusion, it can be said from what has been presented and from the newly gained phenomenological perspective that the connection to lifeworld contexts facilitates access to a comprovizational tool in any case, but the reinterpretation of the familiar in the sense of a musical performance generated from the interaction requires some skill so that familiarity can be gained here quickly. This can be achieved again by making sure that the context of the interaction with the musical event is also based on the familiar. In Kaleidophone, the arithmetic formula should function as a mediator in the form of something familiar. But most importantly, the representation of the musical events in the form of a score-like representation represents such a reference to something familiar.

In general, any contributions in the field of user interfaces for amateurs in the field of comprovization can be considered from the point of view of how familiarity is created through a life-world reference, for example by the possibility of hitting something [Grierson, M., Kiefer, C. 2013], or by translating dance movements into music [Källblad, A., Friberg, A., Svensson, K., Edelholm, E.S. 2008].

There is much that is very different in character here, and this article has fulfilled its purpose if these different things can now be thought of being each one a representant for a (new) recombination of (already existing) life-world references.

7. Some Concluding Remarks

*"ancient pond
a frog jumps in
the splash of water"*

(Basho [1686], see [basho 2021])

What do sound gardens, soundwalks, ready-mades, haikus and the late works of John Cage have in common? The moment of understanding is all it takes to be able to immerse oneself in these works. What does understanding mean? On the basis of the foregoing, the term "understanding" is to be conceived of as a reorganization of existing lifeworld references, with a view to attaining an adequate conception of a given phenomenon. What is meant here by adequate can be mediated by other people and a particular, currently valid lifeworld context, such as being in the exhibition rooms of a museum where ready-mades are shown and not in the museum toilet, or being told that the garden you are in is a sound garden, that you are now a participant in a soundwalk, or that you have forgotten how to engage with mere sound at the conservatory. Haikus themselves could be understood as an invitation to revise what one has until then accepted as an adequate conception of a given phenomenon.

Examples: Participants are encouraged to assume the sounds caused by wind in plants are spatial sounds (sound gardens and soundwalks, see e.g. [Fowler 2014]). Understanding sounds and sound sequences as organized events is already inherent in the participants. However, there has never been a reason for them to focus on this in the environment of plants and gardens.

In the case of Duchamp's "Fontain" ([Duchamp 2021], ready-made), it is necessary to refrain from the function of a urinal and to regard it instead as a mere form, as in the case of an abstract sculpture. This possibility is also present in the recipients, only they never made use of it in connection with a urinal.

After all, it is a personal decision, following John Cage, to accept the sound event, as it presents itself at a busy car intersection, as such, instead of constantly spending energy on it, wanting to fade it out [Cage 2007].

So what does all this say about user interfaces for comprovizational tools? – Perhaps this, that sometimes a good explanation makes the best user interface, and the most important thing about the whole thing is how the tool shows itself phenomenologically to the user, not so much the system description of the tool. And finally, mediated by the last examples presented: Sometimes the ubiquity of music does not have to be established, but it is enough to point it out to enable others to participate in it.

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Managing an IoMusT environment and devices

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Abstract. *The Internet of Musical Things (IoMusT) is an interdisciplinary area that encompasses concepts from the Internet of Things, ubiquitous music, new interfaces for musical expression, human-computer interaction, and participatory art. Despite being a recent field of study, it already presents well-defined contributions and challenges to the interdisciplinary areas involved on it. Among the challenges, we highlight the lack of standardization in the protocols and data that circulate in these environments and also a possible lack of interoperability between devices. To contribute to the solution of this problem, this paper presents Sunflower, a tool that allows communication between different technological and musical elements present in an IoMusT environment, focusing on its management strategies based on a parallel established with other tools that help in musical practice via the network.*

1. Introduction

The Internet of Musical Things (IoMusT) arises from the expansion of the Internet of Things (IoT) domains to musical practice [Turchet et al. 2018a]. This area of knowledge is characterized by being multidisciplinary and encompassing several devices connected in a network, to exchange musical information between musicians and their peers, and between musicians and the audience members, proposing a drastic change in the way music is created and perceived [Turchet et al. 2020, Turchet et al. 2018b]. Its infrastructure predicts a new class of devices that are connected to the network and are capable of acquiring, processing, acting, or exchanging data that serve a musical purpose. These devices are called **musical things**.

Musical things are not useful on their own. Unlike traditional instruments or audio devices, that can be played in a standalone way, these devices are not physically connected, so it is necessary to think about two important points for them to interact with each other. The first point concerns the behavior of these devices. They must be context-sensitive and allow their behavior to be changed in the face of specific characteristics of each environment. An example is to allow certain equipment to adapt its conditions to resemble other elements found in the same network. It is also important to allow the software to be updated remotely or even changed more deeply to suit the needs and limitations of users [Turchet et al. 2018a, Vieira et al. 2020b].

The second point is also the most critical and it deals with the exchange of data among devices. For audio exchange, for example, they can accept different file formats, such as MP3 and WAV, while control can take place through the Musical Instrument Digital Interface (MIDI) and Open Sound Control (OSC) protocols, which can bring some

important issues about the interoperability between them. Besides, musical things are sensitive to latency and other aspects of the network.

IoMusT is an area that probably has the ability to revolutionize several fields in the borders between music and technology, like the public participation in interactive programs, remote rehearsals, music e-learning, smart studio production, and various other aspects of musical practice. However, this field also faces some problems, such as those related to socio-environmental issues, arising from the insertion of new technologies in society, or those inherent to artistic practice. From a computational point of view, the technological problems are latency, the design of the equipment, which can be poorly ergonomic, consume a lot of energy and network resources, and mainly, the lack of standardization of these devices. Furthermore, considering that the musical things are created by different researchers and companies, they may use data and protocols of the preference of their creators, and in most cases in can be out of standard [Turchet et al. 2018a, Vieira et al. 2020a].

In this context, the authors propose an architectural prototype for an IoMusT environment, called Sunflower. Able to exchange data in real time, its main purpose is to allow musical things to exchange data with each other without having to physically configure them. As this is an environment where communication takes place over the network, a connection is required throughout its use. Its structure is arranged in four layers: audio, video data, control, and management. The focus of this paper is precisely this last layer, detailing its development, importance, and main characteristics, where the management of the environment must be similar to that performed by sound engineers in musical presentations and network administrators in computer systems. That is, it must receive information from the devices and direct the data flow to those with an interest and ability to receive it. In light of this elucidation, it is important to emphasize that details about implementation and use of the environment as a whole, as well as network issues related to latency and synchronization will not be addressed.

Sunflower's management layer is inspired in other tools that work similarly, such as Libmapper [Malloch et al. 2013] and Medusa [Schiavoni 2013], and also in tools present in musical desktops, like ALSA MIDI¹ and QJackCtl². Section 2 presents these technologies to attest that this form of control is already recurrent in musical practice and can be extended to the domain of the Internet of Musical Things, while more details on the Sunflower implementation are noted in Section 3. Section 4 discusses the similarities between Sunflower and the software and libraries presented throughout the text, as well as their influences on the layer developed by us. Finally, Section 5 brings summarized conclusions and indicates the future works to be developed.

2. Related Work

This section presents some graphical tools responsible for connecting objects with different characteristics and configurations. Given their contexts of use and functionality, they served as inspiration for our project.

¹<https://www.alsa-project.org/>

²<https://qjackctl.sourceforge.io/>

2.1. Libmapper

Libmapper³ is an open-source, cross-platform library that identifies data on a network, allowing arbitrary connections between them. For this, it creates a distributed mapping network and a close collaboration between the elements of this network, limiting the scope of its values. This makes it simple to connect a device to any object in the same environment. Its main focus is to provide tools for interactive control of media synthesis [Malloch et al. 2013].

This library focuses on some crucial points, such as the automatic discovery of pairs, connections from the name and data type, and description of these devices. It can also be integrated with applications developed in C, C++, Python, Java, Max/MSP, and Pure Data [Malloch et al. 2013].

Its operating mode is “plug and play”, where musical keyboards, controllers, synthesizers, and digital musical instruments announce their presence on the network, in addition to making their input and output parameters available and able to communicate, in an arbitrary way, to other elements. An example of its Graphical User Interface (GUI) and the way it is connected can be seen in the Figure 1 [Malloch et al. 2007].

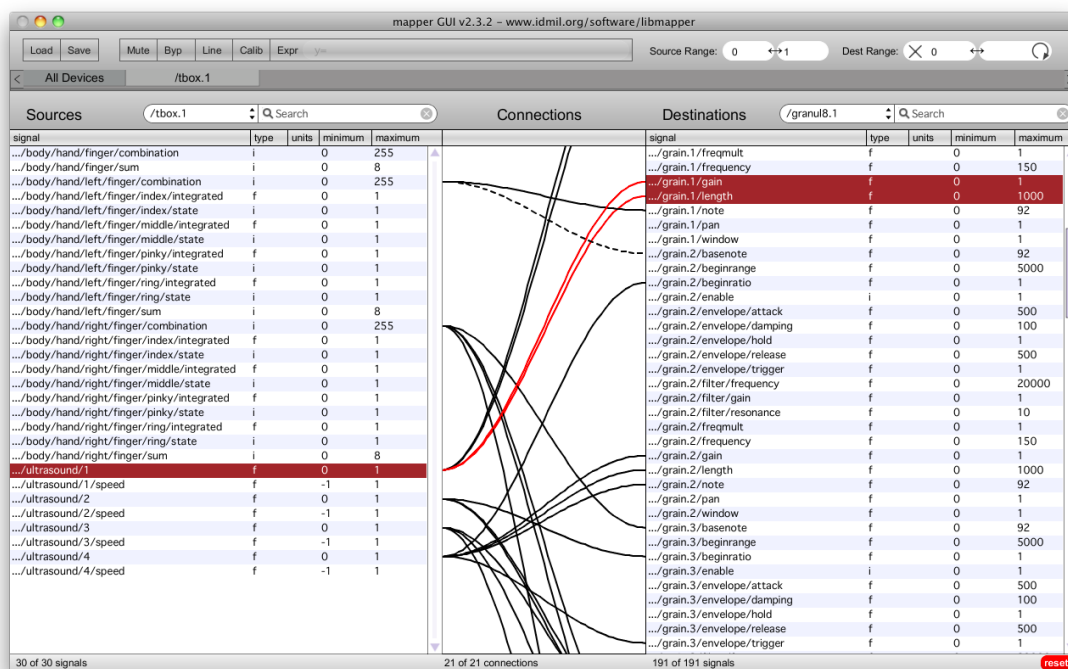


Figure 1. Libmapper’s Graphical User Interface [Malloch 2010].

2.2. Medusa

Medusa [Schiavoni 2013, Schiavoni et al. 2011] is a distributed environment that allows the connection of several machines on a local network to send and receive audio and MIDI data. It does not have centralized servers, which means that each computer acts as both a server and a client. Furthermore, Medusa creates a shared environment characterized by

³<https://libmapper.github.io/index.html>

allowing sound resources to be reconfigured and used transparently. Its objective is also to allow communication between different systems and software.

This system is divided into three layers [Schiavoni et al. 2013a]: network, control, and audio. The first one is responsible for creating the connection between the network and the transmitted data. It implements different transport protocols, such as UDP, DCCP, TCP, and SCTP [Schiavoni et al. 2013b]. That way, the user can choose the one they prefer, which is faster or safer.

The control layer, in turn, is responsible for the management, packaging, and unpacking data. It distinguishes the elements of the network in consumers and suppliers. The third and final layer is more external and deals not only with audio data but also with MIDI [Schiavoni et al. 2013c]. In it, the functions of consumer and supplier are converted into plugins that exchange audio streams between machines.

This division guarantees the desirable characteristics of Medusa, which are: transparency, heterogeneity, graphic display with connection status, various types of input and output data, integration with legacy software, and sound processing capability.

2.3. ALSA MIDI

Since its creation, the Linux audio system was based on the Open Sound System (OSS), including all its limitations and restrictions. To remedy this problem, the Advanced Linux Sound Architecture (ALSA) [Kysela 2000] was created, which initially focused on the automatic configuration of the soundcard and manipulation of multiple devices in a system, but has evolved to support professional audio, 3D surround sound, advanced MIDI functions, software mixing, and audio multiplexing [Phillips 2005, Yu et al. 2015].

Its outstanding features are efficient to support the types of audio interfaces, fully modularized drivers, a library that simplifies the programming of top-level applications, and compatibility with programs made in OSS. As for the main objectives of the ALSA project, the following stand out: creating an open and modularized sound system for Linux; maintain backward compatibility with legacy applications; allow easy development of libraries; interactive configuration for the driver, etc.

Each soundcard can be identified by its input, output, sound control or by a string. The parameters of the soundboard, such as sample rate (44.1 kHz for stereos, and 48 kHz for home theater), bit depth (8, 16, 24, or 32 bits), and channel numbers are also informed.

Inspiration has also been extended to the control screen. Firstly, through `aconect`, a textual system for connecting or disconnecting ports on an ALSA sequencer. Secondly, via `aconect-gui`, a graphical utility that performs the same function, representing an evolution of `aconect`.

2.4. QJackCtl

For network music practice, it can be useful to use an audio server. From it, it is possible to share files and functions, besides the synchronous execution of low latency clients. To monitor audio flows between clients and servers, the presence of graphical interfaces is required. A tool that plays this role is `QJackCtl` (Figure 2), a free and open-source software which provides a dialog box for managing the transport and connection status of network elements [Silva 2016].

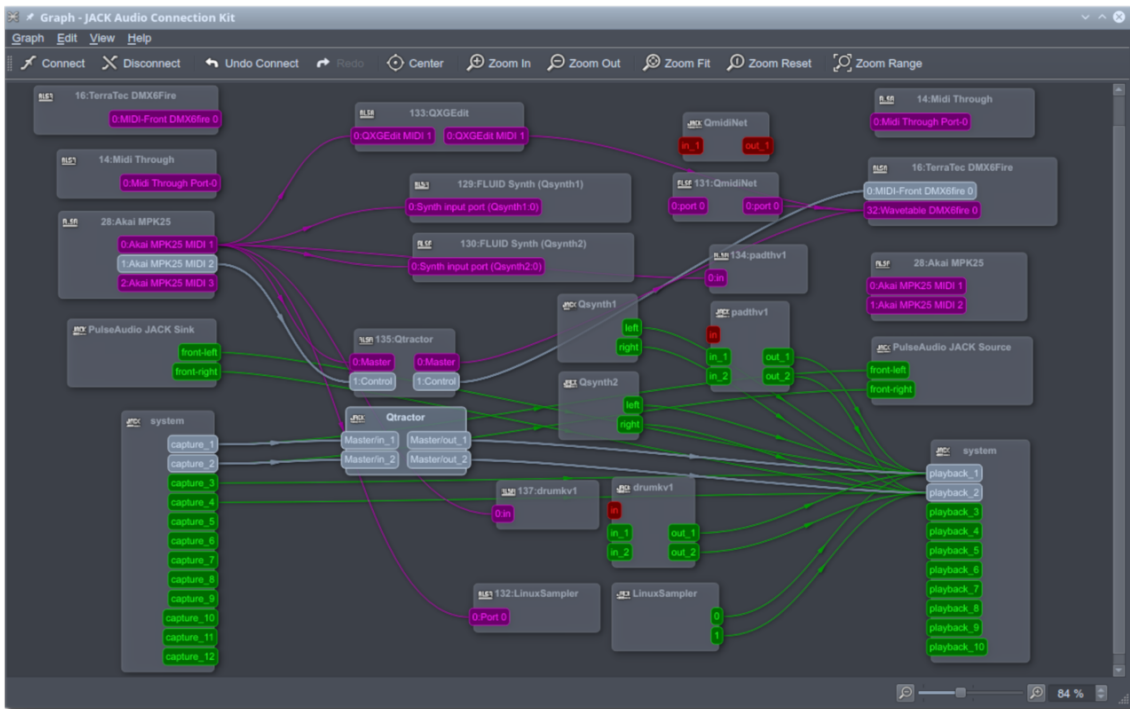


Figure 2. QJackCtl's Graphical User Interface.

Among its advantages are the fact that it is intuitive, as connections are made by point-and-click, connecting the output of one device to the input of another; it is structured, where the software guides make it clear which devices can connect; and offers a quick and easy way to integrate audio and MIDI.

As for the weak points, we can mention the inability to store the state; segmentation can cause doubts about those who are new to this type of system, and has some difficulty connecting or disconnecting cables.

3. Sunflower management environment

Defining the architecture of a system is an essential step in its development, as it indicates how the components of that system will interact with each other, as well as the details for its implementation. This section, therefore, is dedicated to presenting the architecture and the main characteristics of the Sunflower environment. Although it is still in the prototype phase, it is already capable of supporting numerous instruments and musical devices, in addition to having defined roles, being controlled by the network, and presenting data patterns to be exchanged.

Its structure is based on the Pipes-and-Filters software architecture model, since its functioning can be observed in various musical activities and tools. In this way, musical things will behave like filters, acting independently and without prior knowledge of their neighbors [Vieira and Schiavoni 2020]. The means used to send information, on the other hand, will behave similarly to the pipelines, which are solely responsible for sending information over the network, not changing the data that travels through them.

However, when faced with a large variety of data, this mode of operation faces three problems: inability to deal with data in different formats, possible overloads and

difficulty in reusing filters. To alleviate these problems, the system was divided into layers.

Several tools use layered architecture, such as operating systems and the TCP/IP protocol stack. In most cases, this structure is used to isolate implementation details from one layer to another, providing some maintainability for the system. In contrast to this, the layers in Sunflower are independent and do not need to be placed in the order in which they are presented in this paper.

We define layers according to the type of data exchanged between your devices in an IoMusT environment: an audio layer, a video layer, a control layer and a management layer. More details about each of them are shown below.

3.1. Audio Layer

The audio layer, as the name implies, is responsible for generating and sending audio data to the environment. For this project, a multitude of patches was created, responsible for simulating common objects in musical practice, such as a loudspeaker, a drum machine, and a pitchfork. They were also responsible for allowing the connection of microphones and instruments (guitar and bass) to the computer, sending their respective data to the network, and making the transformation from analog to digital audio and vice versa.

The audio engine was made in Pure Data, a programming language created by Miller Puckette, in the 1990s, belonging to a branch of the programming language family known as Max (which includes Max/FTS, ISPW Max, Max/MSP, etc). Initially conceived to remedy the deficiencies of these languages, its use has expanded and today it can be applied in musical creation, live coding, audio synthesis, composition assistant, and multimedia works [Puckette 1996, Vieira and Schiavoni 2020]. Pure Data was chosen due to its ability to have its properties edited while it is running, for allowing data to be sent to the network, and for being simple and easy to use.

Another point worth mentioning is the externals (or external libraries), which are developed by the community and expand Pure Data's functionalities [Puckette 1996]. One of the externals used in the audio layer was `mrpeach`⁴. This module is responsible for sending the audio over the network, in a UDP socket.

3.2. Video Layer

An element that can enhance a musical performance is video transmission. It can be used to capture, in real-time, the movements of the musician and/or the audience, or to display a videoclip that works together with the music to produce a desired artistic effect, in addition to offering the audience a new layer of control, unlike those inherent in audio.

Each of these examples uses an image encoding and decoding system, as it will travel over the network in bit format. This transformation is accomplished through a computational element. Here, Pure Data's multimedia capability was used to perform this function, in particular, Graphics Environment for Multimedia (GEM)⁵ external, which is in charge of graphic processing in real-time, as well as reproducing data from DVD players, laptops, webcams or any other medium that has compatible input.

⁴<https://puredata.info/downloads/mrpeach>

⁵<https://puredata.info/downloads/gem/>

For the Sunflower environment, the video comes from an external webcam, with an image captured by the patch shown in the Figure 3, and sent via multicast to all machines with interest and the ability to receive this type of data.

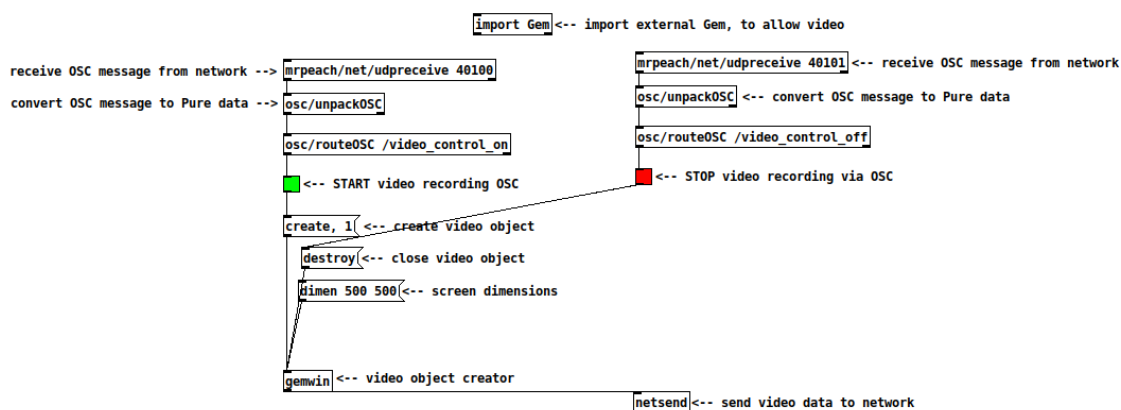


Figure 3. Patch responsible for capturing and sending video data over the network.

3.3. Control Layer

The control layer is made up of manager objects. It controls different actions in the audio patches, such as turning a sound source ON/OFF; change the drum machine's beats per minute (BPM); control the volume of the microphone and instruments; start or pause the recording; open files, and several others actions.

It is possible to exercise general or specific control over the patches that have this property. All of this is done by the network, sending these control messages packaged in the OSC⁶ format.

OSC was created in 1997, by Adrian Freed and Matt Wright, and was initially developed for communication between computers, synthesizers, and multimedia devices. Among its advantages, interoperability, flexibility, organization, and robust documentation can be observed [Wright and Freed 1997].

OSC messages can be sent using UDP, without the need for prior knowledge of the host's IP, channel, or path, making it accessible either over the local network or the Internet. Because of this, he was chosen to compose the environment shown here.

This protocol can also be used as an alternative to MIDI, especially when a higher resolution and amount of data are needed. This is not to say that one protocol is better than another, just that it has slightly different characteristics and applications.

Figure 4 shows a microphone control patch, also made in Pure Data. It is important to highlight that for each element of the audio layer there is also an OSC controller, with small differences that reflect the particularities of the operation of each object. However, the operating logic and controllers data transmission are the same for everyone.

⁶<http://opensoundcontrol.org/>

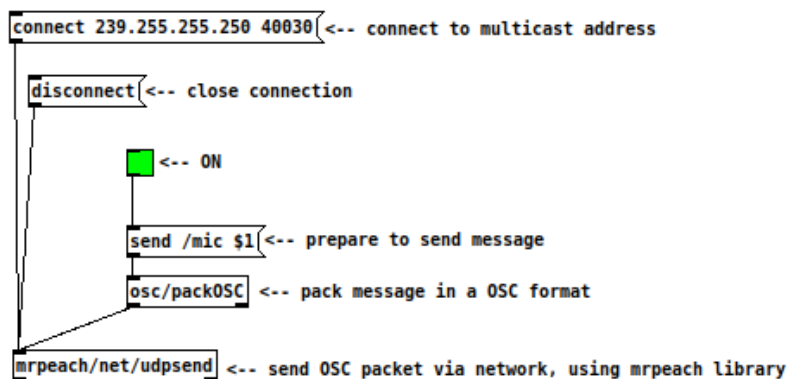


Figure 4. Microphone control via OSC.

3.4. Management Layer

In the computer networks architecture, it is essential to have an administrator who acts both in helping users, as well as in the configuration and maintenance of the network infrastructure. At concerts, there is the technician or sound engineer, who provides the necessary support to musicians. Here, these two roles are inseparable, with the administrator being responsible for ensuring the usability of the network and also taking care of sound aspects.

For this, the management layer was created to receive information from the audio devices available in the network, such as the connection status, indicating when a device entered or left the environment; port number, a key part in the connection, and responsible for indicating which port was chosen to receive input data; protocols, such as UDP for sending packets over the network or OSC, for controlling musical information; and bit depth, sample rate, and audio format, which convey information about the sound properties of the devices. In this way, the behavior of objects becomes analogous to the publish/subscribe method, where all tools publish their attribute and indicate their connection interests.

A sequence of commands responsible for capturing this data and sending it to the network is done in Pure Data. For practicality, all information is displayed on a screen made in Python. The management script containing the actions of some musical patches is present in the Figure 5.

```

/hello ['Hello']
/publish/thing Drum Machine ID#002
/publish/input INPUT: ID#002 -port: 40010 (ON/OFF) 40011 (BPM) 40012 (kick & snare & hi-hats) 40013 (Drum pattern) -protocol: UDP & OSC
/publish/output OUTPUT: ID#002 -audio(port 3000) -sample rate: 44100 Hz -bit depth: 16 bits -audio file format: wav
/goodbye Drum Machine says Goodbye!
/hello ['Hello']
/publish/thing Pitchfork ID#006

```

Figure 5. Part of the management screen, showing the patches that have been connected to the network.

Before addressing interoperability issues at this layer, it is important to use the

way a traditional audio environment works as an example. So, imagine a concert by a band, which has a microphone, guitar, bass, drums, and an audio system. It is not possible to directly connect the guitar's audio output to the microphone input. Or, make the sound generated in the bass to be played by some component of the drums. Given these restrictions on connections in musical practice, it is noteworthy that a musical thing cannot connect with all devices present in the environment. For this to happen, they must have some degree of compatibility. That said, the importance of this layer is highlighted, which even in a simple way, displays all the main connection characteristics of a musical thing, and it is up to the administrator to make the connection.

Figure 6 summarizes all these layers, showing their main elements, files and protocols.

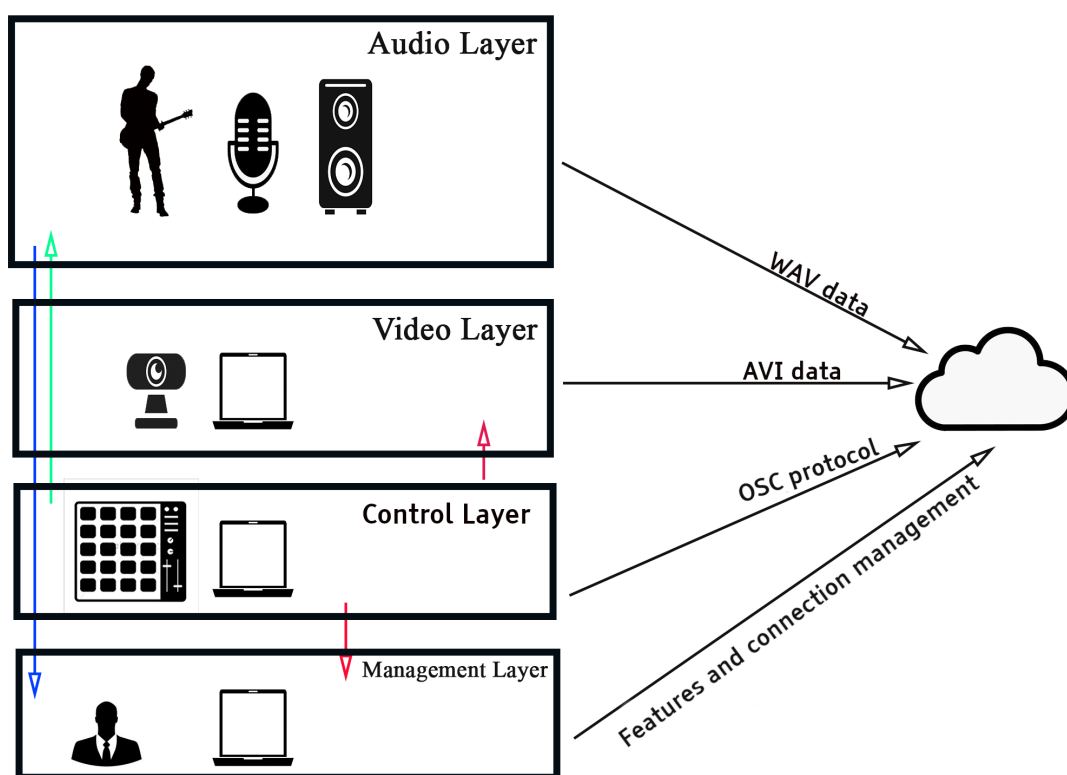


Figure 6. Basic Sunflower Architecture.

Practice Tests

After completing the development of the environment, tests were carried out to verify its functionality and measure the results obtained. Therefore, the authors ran tests on two machines, an Acer Predator Helios 300 laptop (computer A) with a 2TB hard drive, 16GB RAM, and an Intel i7 processor, and a Dell Inspiron 14 3442 3000 series laptop (computer B) with a 1TB hard drive, 8GB RAM and Intel i5 processor. The sending of information occurred in three different ways: in localhost, in a wired connection, using a twisted-pair cable, and in a wireless connection, via Wi-Fi.

Due to the Covid-19 pandemic, the authors were unable to run the tests with a group of people. Therefore, it was up to them to verify the results obtained. To keep the

focus of this paper, only the behavior of the management layer will be discussed in the next section.

4. Discussion

The purpose of creating Sunflower is to present a new way of contributing to what may be the biggest challenges faced by the IoMusT area, which are the lack of standardization of the data that travels on the network and the difficulty of obtaining interoperable objects. Thus, the environment in question intends to allow the use of different computational devices, from an architecture with similar functioning to Pipes-and-Filters and divided into layers, an approach different from those traditionally used in the area [Turchet et al. 2018b, Turchet and Barthet 2018, Centenaro et al. 2020].

For this, some desirable characteristics for the system were mapped, such as the client-server architecture, the self-management of objects and the types of messages that would travel on the network and, mainly, how the management layer should behave.

To justify this work, a systematic research was carried out to find tools with similar functioning. The first one is Libmapper, which associates with Sunflower by allowing the connection of different objects, treating them as filters with the capacity to receive and process data, which will later be sent to its adjacent through pipelines. Libmapper also has the ability to adapt OSC data to or from different ranges and dynamically change an OSC namespace. Using distributed mapping and identification by name to manage the objects were also taken into account in the environment developed here.

In the sequence, the Medusa environment corroborates with its well-defined division of layers. Like its management layer, Sunflower also distinguishes objects between suppliers and/or consumers of resources. Furthermore, it is assisted with its distribution of resources on the network, which enables the occurrence of a musical performance along these lines. Medusa also uses network messages to set up a musical environment and has different forms to exchange these messages using, for instance, command line and graphical user interfaces to provide these functionalities to lay users and experts too.

While the collaboration of the previous tools took place in the structure of the data and the performance, ALSA contributed mainly to the aesthetic aspect. Again, ALSA MIDI has different ways to manage the device connections, presenting the `aconect-gui` management screen and `aconect` command line interface. Using the same strategy, Sunflower also presents, so far, a screen that displays only textual information about what elements are present in the environment, as well as the ports and protocols it uses for connection and their sound properties.

QJackCtl presents, in a way, all the features listed previously, but its main contribution was concerning the possibility of listing the data present on the network. Although simple, this way of displaying data helps in organizing the system and also makes it easier for laypeople to understand.

So far, Sunflower does not have a data conversion layer. Hence the importance of musical things expressing their characteristics when they connect to the network. Thus, they will be able to find and send data to those devices that support the same types of audio configuration and also use the same network and music information protocols, ensuring that different gadgets can communicate based on this minimal similarity.

5. Conclusion and Future Work

The development of a tool for IoMusT proved to be a complex activity since it requires knowledge in several areas of computing, such as computer networks, signal processing, software engineering, and sound design, as well as the music itself. The target audience of these devices is formed of sound engineers and technicians, musicians, music teachers and students, and audience members who are interested in participating in the show. The tool must also contemplate the artistic-musical creation process and deal with any network problems.

From a general analysis, it was observed that the performances that happen in-network, as is the case of those intended by IoMusT, the identification of the elements by name and/or characteristics, the availability to publish or subscribe to certain services, and a control screen help a lot in the management of resources present in the environment. The division of it into layers with well-defined performance and attributions also helps in the process, since it is easier to identify and fix possible failures.

In-depth research showed that the techniques adopted in Sunflower were previously used, allowing musical connections and management of the environment in scenarios with different objects, ensuring robustness to the system. The Sunflower's strengths revolve around its ability to link the various instruments and audio patches connected to it, as well as allowing the administrator to have general and precise control of the environment. Among the weaknesses, we highlight the simplicity of the management layer, which only displays textual data, and the need for the administrator to manually execute the code.

This work was more concerned about how to manage an environment with such diverse aspects. To this end, it focused its attention both on the main characteristics of the devices, such as the protocols and audio formats used in the network communication, as well as on their ways of identifying themselves on the network and showing their connection status. Parallels have also been drawn between it and other technologies that work similarly.

Once the influences of related works are explained, importance is given to the architectural and sonic characteristics of musical things and the role to be played by the administrator of this system, the contribution of the Sunflower management layer to ensure the interoperability of the environments is observed. That makes the features of musical things clear, and it is only up to the administrator to connect them. The fact that they are identified and inform of their connection ports also facilitates this process. But as noted, it is common for this type of management to be done graphically and not just in a textual way. Consequently, for future work, it is intended to develop an interface along these lines for the Sunflower, making it even more intuitive and contributing to a more efficient workflow.

By no means do the authors intend to close the discussion on IoMusT environments, especially with regard to their forms of management. This work, therefore, is another contribution to the area, which can lead to improvements in live performances, ubimus environments with different technological artifacts, studio recordings, and music e-learning, as it will indicate the possibilities of connecting the musical objects in these contexts and make them easier.

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Overview of Generative Processes in the work of Brian Eno

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***Abstract.** Brian Eno is a famous a musician, producer and artist known for his endeavors in rock music who has devoted the latter part of his career to ambient and generative work. There are a few publications regarding his work (Albiez & Pattie, 2016; Sheppard, 2009; Tamm, 1988), but they do not focus exclusively on his generative processes. The only paper that details Eno’s generative music only addresses the concepts of generative music and describes Eno’s apps (Marshall & Loydell, 2017). The paper focuses more on his apps and it does not present a detailed correlation between his background/ influences to his work. This paper bridges that specific gap, by detailing Eno’s school background, his influences, generative processes and how he moved on from traditional to more technological approaches.*

1. Introduction

This paper originated from research into Brian Eno’s work and the lack of summarized information regarding his endeavors in the generative field. Whether he invented generative music or not, and we will see he did not, Eno might be considered the most popular name in the world of generative music. Due to his status, he popularized the term, and his work may serve as an introduction to the compositional method, so it is surprising that there are not many papers summarizing his generative work, in order to aid newcomers to the field.

This paper’s main objective is to showcase some of Eno’s work that introduces any kind of generative processes, detailing his early creations with more traditional methods and his most recent ones which feature more sophisticated and technological algorithms. The paper is composed of six sections. It will firstly introduce some historical background and concepts in generative music; secondly, it will present the theoretical and practical influences that led Eno to create music in such a manner; afterwards it will showcase Eno’s most important generative work and processes, separating his early years from the most recent ones. It will then provide an overview of all the influences and techniques and lastly it will address the future work that this paper could incite.

2. Understanding Generative Music

In order to find the seeds for Eno’s interest in generative music, one needs to understand its historical background and concept. Eno might have been the one that popularized the

term 'generative music', but he surely did not create it. He even acknowledges it in an interview. "I should stress that the idea of Generative Music is not original to me (though I think the name is). There have been many experiments towards it over the years" (Eno, 1996).

2.1. Historical background of generative music

The early instances of generative composition draws back to the mid XVIII century, with the dice musical games like Mozart's *The Musikalisches Würfelspiel* (Musical Dice Game) (Lorrain, 2003). These games "made it possible for the person ignorant of music to write minuets, marches, polonaises, contredances, waltzes and so forth by selecting bits of prefabricated music through the use of chance operations" (Hedges, 1978). With the technological advancements during the 1950s and 1960s computers started being utilized to generate musical compositions. The *Illiac Suite* by Lejaren Hiller, Leonard Isaacson and Robert Baker was one of the first computer generated compositions. It was achieved by "random selection constrained by lists of rules" and by "Markov chains, also random, in which the relative likelihood of each option was conditioned by one or more immediately preceding choices" (Ames, 1987). While still operating with the Illiac computer, Baker and Hiller created MUSICOMP (MUSIC Simulator Interpreter for COMpositional Procedures), the first systems for automated composition. Throughout the rest of the century, other techniques and programs, like genetic algorithms, emerge providing more and sophisticated results (Alpern, 1995).

2.2. What is generative music?

So, what makes all these processes generative? As a broad definition any artwork that "is generated, at least in part, by some process that is not under the artist's direct control" (Boden & Edmonds, 2009) can be considered generative art. The process can be achieved with various tools, just like a painting can be achieved with different brushes. What all these artworks have in common is that the artists determined beforehand a set of rules that allows a system to create a version of the artwork. This artwork can be created through simple algorithms, with the usage of randomness or stochastic processes, or with more complex advanced systems, that may include Markov Chains, genetic algorithms, L-systems, chaos, amongst others.

Throughout this section we have been referencing algorithms quite a few times. It is worth noting that there has been a significant correlation between generative music and algorithmic composition. According to Essl (2007) an algorithm is "a predetermined set of instructions for solving a specific problem in a limited number of steps." Therefore, one can consider Mozart's dice musical games an algorithm, and *The Illiac Suite* can be considered an algorithmic composition. When speaking about generative music one is almost always considering algorithmic composition. Going back to the preceding paragraph, generative art is achieved by the artists inability to have control over the artistic outcome. Claiming that *The Illiac Suite* is both an algorithmic composition and generative music is correct. One does not invalidate the other. Algorithms are a part of the process and a tool that artists use in order to create generative music.

3. Eno's Background and Influences

3.1. The school years

Brian Eno was born in 1948 in Suffolk, England and has a background in contemporary art studies at the Ipswich Art School (1964 – 1966) and received his Diploma in Fine Art from Winchester Art School in 1969 (Tamm, 1988). One can say that the basic artistic and educational foundation for Eno originated from painter Roy Ascott, head of the Ipswich Art School, who was an avid advocate of cybernetics, “the study of complex communication systems and their structures” (Sheppard, 2009). To Ascott the emphasis of modern art “is on behaviour, on what happens, on process and system, the dynamic interplay of random and ordered elements” (Ascott, 1968). With this approach in mind he created the Groundcourse at Ipswich, a course whose main philosophy “was to question preconceptions and established strategies of approaching art and creativity through the use of chance operations, games and exercises and behavioral psychology”, highlighting the “process and not the product” (Albiez & Dockwray, 2016). Eno would later speak of cybernetic theorist Stafford Beer as a great influence to him (Eno, 2017a).

Initially Eno was interested in visual arts, but during his time in school, with the help of his teacher and painter Tom Phillips, he was introduced to John Cage, who presented similar conceptual ideas to what Roy Ascott taught at Art School. “For Cage, composition was partly a matter of chance; a process of circumscribing parameters within which any number of sonic events might be allowed to occur” and he also used diagrams and charts to write his scores (Sheppard, 2009), something Eno later used in the album sleeve of *Ambient 1: Music for Airports*.

Although Cage's conceptual ideas regarding composition were very important in Eno's development, one might say that the most essential outcome from discovering his work was the group of artist that were also inspired by Cage's philosophies (Albiez & Dockwray, 2016). Some of these artists gave lectures to Eno in school. Visits from Christian Wolff, Frederic Rzewski and Cornelius Cardew introduced Eno to music that were relatable to him because it did not require musical notation knowledge (Bangs, 1979). These artists produced pieces that were created by providing a set of rules and conditions that the performers needed to interpret. This type of compositions appealed to him because they were pieces of music he could produce (Sun, 2016).

3.2. Specific practical influences

Apart from introducing Eno to John Cage and the avant-garde music scene, Tom Phillips also encouraged Eno to exploit minimalistic compositions and tape recorders, using the work of La Monte Young, Terry Riley and Steve Reich as examples. (Sheppard, 2009) This section will present and describe three pieces of inspiration that had a profound impact in Eno's development as an artist.

As it has been established, John Cage is one of the most significant artists in Eno's career (Albiez & Pattie, 2016), so it might be safe to assume that the deck of cards *Oblique Strategies* (Eno & Schmidt, 1975), which will be addressed later, was inspired by the *I Ching* used by Cage. The *I Ching*, or Book of Changes (*I Ching, or Book of Changes: The Richard Wilhelm Translation Rendered into English by Cary F. Baynes.*, 1967) is an ancient Chinese text that was given to Cage by Christian Wolff in 1949. Cage would use the text to make decisions and compose some his work. (Kostelanetz, 2003)

Another influential piece was Terry Riley's *In C*. (Riley, 1967) It is a generative composition where "the score consists of fifty-three notated melodic fragments, which the performers, who are variable in number, are to play one after the other, in synchronization with a steadily repeated "pulse" on the top two C's of the piano keyboard, repeating any given fragment an indeterminate number of times and pausing between fragments as they see fit. The piece ends after everyone reaches the fifty-third fragment." (Tamm, 1988) The composer sets a foundation of rules that the performers must follow, while still allowing the performer the creative freedom to repeat the fragments as many times he or she sees fit. Due to this individual choice imposed on the performers, the piece and its length it is always different. Robert Carl (Carl, 2009), who wrote a book about this piece, claims that "it is a piece that relies on the continued imagination and reinvention of its performers to survive" and that "in *C* is a piece of software. I define "software" as a series of rules and predefined relationships that execute a task; the user can then customize input and tweak aspects of the rules and relations to produce a product that is regarded as personal." This type of compositions, perhaps a bit difficult to duplicate, would reinforce Eno's appeal to music composed via a set of instructions and rules.

These two pieces are indeed very significant to Eno because they established his mindset as an artist and also his approach to composing. But there is, however, another piece of work that is probably the most significant (Albiez & Pattie, 2016; Tannenbaum, 1985). In the famous *It's Gonna Rain* (Reich, 1965) by minimalist composer Steve Reich, he used a recording of African-American preacher, Brother Walker, saying the sentence *It's gonna rain*. Reich initially wanted to align the loops against each other, but the tapes slowly started to shift. "I had intended to make a specific relationship: "It's gonna" on one loop against "rain" on the other. Instead, the two machines happened to be lined up in unison and one of them gradually started to get ahead of the other" (Reich, 2002).

Eno recognizes the impact that the piece had on his career claiming that it is "probably the most important piece that I heard, in that it gave me an idea I've never ceased being fascinated with – how variety can be generated by very, very simple systems" (Tannenbaum, 1985). Even though the piece is based on the same sentence being repeated over and over again, Eno was fascinated by its outcome. "The amount of material there is extremely limited, but the amount of activity it triggers in you is very rich and complex" (Tamm, 1988). To him, this piece required the listener to have an active role in the composition. It required a new form of listening. According to Eno "the creative operation is listening. It isn't just a question of a presentation feeding into a passive audience" (Korner, 1986). Besides the conceptual impact on his artistic development, this piece also provided Eno a new method to composition, by using tapes and looping them out of phase with one another. This was the first technological implementation of the philosophy he learned in school and because it was a simple process, he was capable of duplicating it.

Eno would use these three pieces as inspiration, tailoring them to his specific artistic needs and using these improved techniques and approaches throughout his career.

4. Eno's Generative Processes

4.1. Oblique Strategies

Eno was familiar with the I Ching and he wanted to make something a bit more specific to certain situations. Still in school Eno would write down phrases/ instructions that would help him when he would feel lost in the artistic process. "The idea of Oblique Strategies was just to dislocate my vision for a while. By means of performing a task that might seem absurd in relation to the picture, one can suddenly come at it from a tangent and possibly reassess it". He would continue to write these phrases down and place them in the studio when producing for Roxy Music. When he showed the phrases to Peter Schmidt, he also admitted to doing something similar and they decided to publish Oblique Strategies in 1975 (O'Brien, 1978). The deck included some phrases like: "Don't be afraid of things because they're easy to do." "Turn it upside down." "Do we need holes?" "Is it finished?" "Don't break the silence." "What are you really thinking about just now?" "Honor thy mistake as a hidden intention." Eno was notorious for using the deck in his production endeavors (Oblique Strategies was heavily used during the production of David Bowie's *Heroes*) and on a lot of his work during the mid to late 70s and possibly into the 80s (Tamm, 1988) and Eno has claimed to still using it. (*Brian Eno: Behind The Reflection*, 2017)

4.2. A Set of Instructions

Clearly influenced by the artists from the avant-garde movement, specifically Terry Riley's *In C*, Eno created some pieces based on a set on instructions. During the production of *Another Green World* (Eno, 1975a) Eno would give simple instructions to the musicians. "I tried all kinds of experiments, like seeing how few instructions you could give to the people in order to get something interesting to happen. For example, I had a stopwatch and said, 'Right, we'll now play a piece that lasts exactly ninety seconds and each of you has got to leave more spaces than you make noises', something like that, and seeing what happened from it" (Miles, 1976).

But the piece that most embodies In C method is present on the second half of *Discreet Music* (Eno, 1975b), where Eno's "interest in self-regulating and self-generating systems is exemplified in the 3 variations on the Pachelbel Canon" (Eno, 1975c). In this composition a group of performers, the Cockpit Ensemble conducted by Gavin Bryars, obey a set on instructions (Tamm, 1988). "Each variation takes a small section of the score (two or four bars) as its starting point, and permutes the players' parts such that they overlay each other in ways not suggested by the original score. "In "Fullness of Wind" each player's tempo is decreased, the rate of decrease governed by the pitch of his instrument (bass=slow). "French Catalogues" groups together sets of notes and melodies with time directions gathered from other parts of the score. In "Brutal Ardour" each player has a sequence of notes related to those of the other players, but the sequences are of different lengths so that the original relationships quickly break down" (Eno, 1975c).

Eno would later admit to not liking the piece, considering it not very successful (Sheppard, 2009) and it is probably due to the input material since it is possible that it had too many notes and "the randomness here created cacophony" (Tamm, 1988).

4.3. The Tape Loop System

As previously mentioned, Eno claims that *It's Gonna Rain* is probably the most important piece he had ever heard (Albiez & Pattie, 2016; Tannenbaum, 1985) and he would be right. Eno would go on and use the tape loop system throughout his career. The earliest account of the usage of the tape loop system is in his collaboration with Robert Fripp on the album *No Pussyfooting* (Fripp & Eno, 1973) and later on the first side of *Discreet Music* (Tamm, 1988) but the most prominent evolution from Steve Reich's two tape loop system is used in *Ambient 1: Music for Airports*. (Eno, 1978a) The second track on the first side, or "2/1" as it is called, is created out of very little material, like most tape loop compositions. It is composed of 7 loops of "taped female voices singing single pitches with an absolutely unwavering tone production, on the syllable "ah," for about five seconds per pitch." (Tamm, 1988) The length of the tape was somewhat arbitrary, because Eno just "wanted silence at least twice as long as the sound" and "It wasn't measured." (Tannenbaum, 1985) So the timing of the cycles ensures that the odds of the piece repeating itself would be very low, and because it does not provide a lot of structure, the listener does not have anything to hold on to. He/ she pays as much attention as he/ she pleases. This was, after all, Eno's intent with ambient music. "Ambient Music must be able to accommodate many levels of listening attention without enforcing one in particular; it must be as ignorable as it is interesting." (Eno, 1978b) For Eno, ambient music revolves around the idea that the music is part of the environment, even comparing it to paintings. "I'd like people to have the expectations of music that they presently have of painting. If a painting is hanging on a wall where we live, we don't feel that we're missing something by not paying attention to it. (...) It's a sort of continuous part of the environment." (Korner, 1986) Unlike a painting however, which is a static work of art, by using the tape loop system in his ambient music, he allows the listener to hear an ever-changing composition that never repeats itself but still introduces familiar elements, leaving the listener in a state of limbo between acknowledging the music or not.

Unfortunately, one of the issues or inconveniences in utilizing this system, is that what the listener is hearing is a sample of what the system can produce. He/ She cannot experience the actual system in action, playing something different every time that it is played. Eno would have to wait nearly 20 years to finally publish the generative system as it is and not the result of one.

5. Eno's Computer Generated Music

In 1994, a company named SSEYO that developed 'algorithmic music-generating software' released the SSEYO Koan Plus (Cole & Cole, 2021b). In Buddhism, koans are brief sayings, dialogues, or anecdotes that can be used as a mean to find enlightenment in particular situations. "Koans frequently comprise elements that render them difficult to understand at first glance" and some even "defy logic or common sense." (Foulk, 2000).

While they were preparing for the release of Koan Pro in 1995, they were capable of bringing it to Eno's attention and in 1996 Eno released *Generative Music 1* with SSEYO Koan Software on a floppy disk (Cole & Cole, 2021a). The software worked "by inputting basic guiding parameters, or 'seeds', the software could 'grow' unique musical developments – none of which would ever repeat in exactly the same configuration" (Sheppard, 2009) and it allowed Eno "to allocate any of around a hundred and fifty

different conditions, each operating within its own probability range, to any given voice or instrument” (Mills, 1996). Eno saw this as an opportunity to initiate a new era of music. “From now on there are three alternatives: live music, recorded music and generative music. Generative music enjoys some of the benefits of both its ancestors. Like live music, it is always different. Like recorded music, it is free of time-and-place limitations - you can hear it when you want and where you want” (Eno, 1996) and he finally could deliver the compositions as he wished, but the medium still wasn’t the best.

At the same time as Eno was working on Generative Music 1, Peter Chilvers, a musician and software designer, was working on a series of videogames called *Creatures* and for the soundtrack he had to resort to generative ambient music. “We needed something that hung in the air like a presence; something that gave color to the environment. That led me to generative music and ambient music” (Crane, 2020). Due to the clear common interest, a mutual friend put Eno and Chilvers in contact and in 2006 Chilvers helped Eno on a generative soundtrack he was developing for a videogame called *Spore*. From that experience they created a prototype for *Bloom* (Eno & Chilvers, 2008), that ran in Flash using a Wacom tablet (Chilvers, 2016) which required a stylus. They thought that a lot of people did not have this kind of stylus tablets so they just shelved the project for a while, until the first iPhone was announced in 2007. (Cohen, 2007; Crane, 2020) Chilvers and Eno recognize that it was difficult to offer the proper experience for generative music and iPhone provided the best platform. “The difficulty developers have faced with generative music to date has been the platform. Generative music typically requires a computer, and it is just not that enjoyable to sit at a computer and listen to music. The iPhone changed that - it was portable, powerful and designed to play music” (Milani, 2009). For Eno, it finally allowed the people to “own the process rather than the results of the process.” (Dredge, 2012)

Bloom is an app that offers two modes to the user: “Listen, which plays an interactive generative composition, and Create, in which you create each note that plays in real time” (Buskirk, 2008). The user can compose by tapping the screen and circles appear with each tap. “The sounds are pitched low to high from the bottom to the top of the screen, with the software including 12 ‘moods’ which alter the color palette of the ink blots, and subtly change the characteristic of the sounds, their relationship with one another and the length of sustain. Additional functions allow for the adjustment of delay, and the sounds themselves – offering either a higher attack in ‘impact’, a hollower ‘bowl’ sound, and ‘blend’, which combines the two (Marshall & Loydell, 2017). According to Chilvers, it “is sample based. Brian has a huge library of sounds he’s created, which I was curating while we were working on the *Spore* soundtrack and other projects” (Milani, 2009).

Since *Bloom*, Eno and Chilvers developed other generative music apps, like *Trope* (Eno & Chilvers, 2009), *Scape* (Eno & Chilvers, 2012), *Reflection* (Eno, 2017b). The main difference between them is the visual elements, interaction and composition method. For example, in *Trope* the user draws shapes “using five differently shaped cursors” and can choose between 12 moods and, although hidden, can adjust “delay and the interval between notes”, whereas in *Scape* “the user selects shapes whose placing and interrelationships change the sounds and development of the piece, while the different colours and patterns of the backgrounds add a further layer to the music production” (Marshall & Loydell, 2017). Of all of them the one that might stand out the most is *Reflection*, because unlike *Bloom* or *Trope*, the listener has a more passive role. With this

app, Eno regained control of the composition. The only control that the listener has is “pause playback, set a sleep timer and allow streaming to Apple TV via Airplay” (Marshall & Loydell, 2017). The app is based on randomization scripts that Chilvers would create and Eno would use them in Logic Pro (Sherburne, 2017). Some of the examples of the scripts can be seen during a piece that BBC did on Eno upon the release of *Reflection*. On a specific track Eno says that he has three rules (which are scripts): “one is that a random 14% of these notes are going to be pitched down by 3 semi-tones; the second is that 41% of them are going to go an octave down; the other is a corrector, so if any notes are produced that I don’t want there, I can correct it with this” (*Brian Eno: Behind The Reflection*, 2017). It appears that Eno has a MIDI track with notes and because of the scripts on the track, it changes the notes every time that it is played. On this specific track Eno says that there is not any change in the position of the note, but there are other tracks where a script will shift the position of the notes. Other scripts include: Markov chain; bouncing ball delay; damp velocity above a certain pitch; different randomizers; among others.

Another variable for the album is the time of day. “The rules themselves could change with the time of day. The harmony is brighter in the morning, transitioning gradually over the afternoon to reach the original key by evening. As the early hours draw in, newly introduced conditions thin the notes out and slow everything down” (Chilvers, 2017). This showcases that external variables, that the composer cannot control, can be used to provide another layer of rules to change the outcome.

Eno and Chilvers continue to release generative work, the most recent being *Bloom: 10 Worlds* (Eno & Chilvers, 2018), in celebration of the 10 year anniversary of the original *Bloom*. It presents 10 different worlds with different sounds and different rules. Unfortunately, like many of the apps, the difference between these rules is not explicitly known.

6. Conclusion

Knowing now Eno’s background and influences, it seems logical that he would contribute to the field of generative music. Ever since the beginning of his academic career Eno was introduced to the conceptual ideas of systems, rules and chance, so a significant part of his theoretical framework was established very early on. Nevertheless, by studying the artists and composers from the avant-garde movement, not only did he deepen his theoretical knowledge, but he also adopted and improved some of the generative techniques that they used.

Eno was also extremely lucky with the timing of the technological advancements. In parallel with his time in school, the first developments in computer generated compositions were being accomplished. As Eno’s career progressed, so did computer generated music and eventually the two would meet. There are two instances where Eno was introduced to new technology that allowed him to create generative music: one was with the SSEYO Koan program and the other was when the first iPhone was released. Given these two instances one can speculate that without these products, Eno would not have reached the full potential of generative music.

While technology is allowing Eno to fully explore generative music, there are

contrivances with the usage of software as opposed to more traditional and less technological means. There is a possibility that the software may become obsolete and Eno's work could be lost, and it may happen sooner rather than later. Generative Music 1 was released on a floppy disk, which are currently not in use and the system also required a specific soundcard to hear the sounds as Eno wished (Cole & Cole, 2021b), not only making it difficult to listen now, but also in the near future. Concerning the apps developed with Chilvers, there is also potential that some component in smartphones, either hardware or software, changes and impedes the apps from being used. The same cannot be said about the more traditional techniques, like the dice games from the XVIII century. They can still be used today. Although speculating, a possible solution to this issue could be presented by the authors and artists. They would have to allow the code to be open-access or publish instructions to reverse engineer the code. But the desire and will power to provide future proof access needs to come from them. They would need to be willing to release that information to ensure that their creations can be reconstructed or analyzed when technological advancements prevent their work from being seen or heard.

From an academic perspective, another problem that computer generative compositions present is the accessibility to the actual code making it difficult to understand the underlying rules and techniques that were imposed. It is surprising however, although admittedly challenging to achieve, that a musical and software analysis has not been done. For instance, it would be interesting to know what techniques are used in each app; why use one in favor of another; why use one in a specific app but not on another; if they use certain techniques for specific moods; why allow control over certain parameters, amongst others.

Even though Eno is a technological oriented artist he is not a programmer and as much as he enjoys talking about the process behind his work, there is not a lot of information regarding the specific generative techniques used in the apps. While this article tried to provide some information in this matter, there is a need for further investigation. It is safe to assume that in order to know about these techniques and how the software behaves one needs to talk to Peter Chilvers and Peter and Tim Cole from Intermorphic (previously known as SSEYO), who are the main software designers behind Eno's most technological work. And even with a possible interview with said software designers, we still may not find out relevant information. Unfortunately, the specific techniques used in their products are subject to proprietary restrictions for as long as the apps are in commercial use, therefore the techniques are not available for an in-depth analysis.

Since Eno is an artist that evolves with the technological advancements it would be interesting to know what kind of work, he could produce with the new technologies available (such as neural networks). And because of the adaptability of his generative approach, it seems fair and plausible to claim that, with the right help, Eno could be, just like generative music, an artist that can create new work that never repeats himself but still is familiar. The only thing that changes is how the rules are created.

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Live Coding on Orca, the Geopolitics of the English Language and the Limits of Creative Semantic Anchoring: A Preliminary Hypothesis

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Abstract. *Orca is a live coding environment based on one-letter alphanumeric operators, different from the English-based commands of other coding or patching tools. Our main hypothesis is that the one-letter operators that regulate Orca’s functioning might make it a much more accessible environment, especially for those users that may benefit from an alternative to the dominant English language. In this preliminary paper, we also present our hypothesis in terms of Orca’s interactions and contradictions vis-à-vis Creative Semantic Anchoring (ASC).*

1. Introduction

Orca is defined in its own homepage as “an esoteric programming language, designed to create procedural sequencers in which each letter of the alphabet is an operation, where lowercase letters operate on bang, uppercase letters operate each frame” [Rek & Devine 2018]. The introducing blurb on the Orca website proceeds to clarify that “[t]he application is not a synthesizer, but a flexible livecoding environment capable of sending MIDI, OSC & UDP to your audio interface, like Ableton, Renoise, VCV Rack or SuperCollider” [Rek & Devine 2018].

Our experience with Orca so far has indeed been largely assimilable to the operation of a live coding tool, based on minimal case-sensitive, one-letter alphanumeric commands in the place of the common English language methods and operators that characterise other coding (or patching) environments. One of the main hypotheses underpinning this work is that, rather than making it an “esoteric” environment — as claimed in the app’s own homepage — the one-letter operators that regulate Orca’s functioning might make it a much more accessible environment, especially for those users that may benefit from an alternative to the dominant English language.

As suggested in the aforementioned blurb, another noteworthy characteristic of Orca has to do with its sound output: rather than working with Digital Signal Processing (DSP), the tool sends MIDI (or else OSC or UDP) data to virtual or physical devices — this might result in a series of important constraints that might nevertheless prove productive

in terms of creative decisions and excogitations.

Another important characteristic of Orca's functionality is its hybrid status as a text-based coding environment that nevertheless incorporates fundamental characteristics of Graphical User Interfaces (GUIs), such as the pertinence of NSEW cardinal directions and positions. In this sense, for instance, a specific operator like [E] moves eastward throughout the screen, using the coding environment as a patching canvas: thus, the spatial position of specific objects becomes relevant in order to predict the timing and order of specific events.

2. Creative Semantic Anchoring (ASC)

Creative semantic anchoring (ASC, from its original Portuguese formulation *Ancoragem Semântica Criativa*) is based on the use of verbal indicators in order to facilitate creative processes. Previous research within the g-ubimus,¹ and in particular by the Amazon Center for Music Research, has focussed on the interpretative study of Flausino Valle's work, based in turn on the compilation of a set of methodological tools called Interpretative Tokens (in Portuguese, "*Fichas Interpretativas*") [Keller and Feichas 2018; Keller et al 2020]. The interpretative tokens were created by Leonardo Feichas in order to help musicians perform the extended techniques called for in Valle's scores. In general, the results have shown an enhanced response to notated material thanks to the help of verbal clarifications. Abundantly drawing upon these experiences, Messina and Aliel (2019) and Messina and Mejía (2020) have proposed artistic works that use ASC as a facilitator of artistic collaboration within improvisational practices.² Another important creative experience that has been situated within the ASC sphere is Keller and Aliel's (2019) soundtrack to the film *Atravessamentos* (cf. Simurra et al. forthcoming). An issue that has been widely discussed within our research lab, and yet has never been at the forefront of any of the aforementioned publications, is the status of coding commands in view of ASC: on one hand, they can be literally described as semantic hooks that take advantage of verbal meaning (typically, in English) in order to facilitate creative musical outcomes; on the other hand, coding is such a typical activity in ubimus and other types of music creativity, that considering it part of ASC could have the side effect of weakening the very same argument about the specificity and particularity of ASC itself. In this paper, we embrace the former hypothesis. In fact, considering the practice of music coding as a form of ASC helps us reveal and reflect on some of the important specificities of Orca as a live coding environment.

2.1. Orca and ASC

Let us consider Orca through the theoretical and operational prism of ASC. In Orca, one-letter operators lack the semantic content that normally characterises objects and categories in other music programming languages. For instance, in Pd³ the object [pipe]

¹ The Ubiquitous Music Group (g-ubimus) is a network of researchers encompassing engineers and computer scientists, educators and musicians, with members and collaborators worldwide..

² "Comprovisation" can be described as a practice-led approach to research in music creation that envisages actions at a middle ground between free-improvisation practices and compositional practices [Aliel, Keller and Costa 2015].

³ Pure Data (Pd) is a patching environment originally developed by Miller Puckette [cf. Puckette 1996].

delays a message for a specified number of milliseconds, evoking precisely the hydraulic functionality of an actual pipe, where one can pour a liquid that will come out from the other end with a delay that depends precisely on the length of the pipe. Although other objects in Pd might not be based on the same metaphorical thinking that characterises [pipe], many of them are still characterised by a massive reliance on verbal meaning: in this sense, objects like [noise~], [timer], [pack], etc. maintain a strong verbal proximity with the semantic content normally associated to the operations that they perform. In other words, Pd relies massively on the English language in order to orientate — and, literally, anchor — the creative actions of its users. In Orca, the semantic anchoring that characterises Pd is radically crumbled in minimal one-letter commands that often do not bear any resemblance with the verbal rendition of the operation they perform. So, for instance, [T] outputs a value from a list, while [B] outputs the difference between two values — in none of these cases there appears to be an immediate connection between the specific operations that are performed and the wordings normally used to describe them. Some operators do bear a more intelligible connection with their specific function: that is the case of the aforementioned command [E], where the E apparently stands for “eastward”, or of the command [R] that outputs aleatoric values and obviously recalls the initial R in the word “random”. Even considering these subtle analogies, however, coding on Orca is necessarily associated with mnemonic operations that cannot rely on the semantic hooks offered by other languages such as Pd, Supercollider, etc. This is, quite obviously, the main reason why Orca is described as an “esoteric” tool: in other words, it is assumed that non-reliance on semantics is likely to make the programming environment less accessible and less comprehensible. But what if this characteristic actually made the tool more accessible, especially to users who do not benefit from a strong command of English? In this paper, we preliminary explore this hypothesis, and reflect on it with an eye on ASC.

3. The Geopolitics of the English Language

Various authors have commented on the disproportionate hegemony of English in the general context of thought production: in this context, Applied Linguistics and ELT (English Language Teaching) Studies have been particularly prolific in coming up with critical addresses towards this situation [Rajagopalan 1997; Lacoste & Rajagopalan 2005; Rubdy 2015; Gerald 2020]. Most of these authors criticise the disproportionate status accorded to native speakers [Rajagopalan 1997] as well as the implicit centring of whiteness [Gerald 2020] in the context of English-based educational interactions. In ubimus, Messina et al. (2019) have reflected on the varied geopolitics of power that emerge within collaborative live patching across intercontinental distances. Now, the “Geopolitics of the English Language”, as formulated by Lacoste & Rajagopalan (2005) certainly contributes to regulate the access to music programming languages, potentially impairing ubimus efforts in terms of granting universal access to creative musical practices. In this context, the aforementioned semantic hooks in English offered by tools for musical creativity might produce an implicit advantage for native speakers of English, resulting in the exacerbation of an already existing learning gap in disfavour of non-English speakers.

4. Hypothesis

In light of all this, we propose a preliminary hypothesis: namely, the idea that Orca, with its mono-letter operators, might help bridge a gap that is produced precisely by the English language as an instrument of global hegemony and access control. We argue that live coding with Orca might prove equally efficient for users with different levels of access to the English language. At this preliminary stage, we propose to complement our preliminary argument with a practical live coding demonstration during *ubimus2021*. As a proof of the relevance of such an experimental presentation, we advise that 3 of the 5 authors of this paper are new to Orca. Later stages of this project will involve working with students from different universities in Brazil in order to measure the productivity of our argument. In doing this, we adhere to the methodological principles that characterised the *Live/Acc/Patch* project in 2018-2020 [Messina et al. 2020] — namely, the establishment of a schedule of training on Orca, followed by a series of collective, game-like sessions of collaborative live coding with the instructor, and finally by data collection, preferably in the form of qualitative information. As suggested above, our study attempts to identify the limits of ASC by testing it against the critical caesuras and lacerations brought about by global patterns of linguistic and ethnic inequality, which also results in situations of gender, class and race domination. Furthermore, we seek to come to a more substantial decision with regards the status of coding commands in ASC. Finally, we do not intend to invalidate our own work on ASC here — on the contrary, we seek to identify the discursive and operative limits of ASC in order to optimise and deepen our current understanding of it.

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MusicTXT: A Text-based Interface for Music Notation

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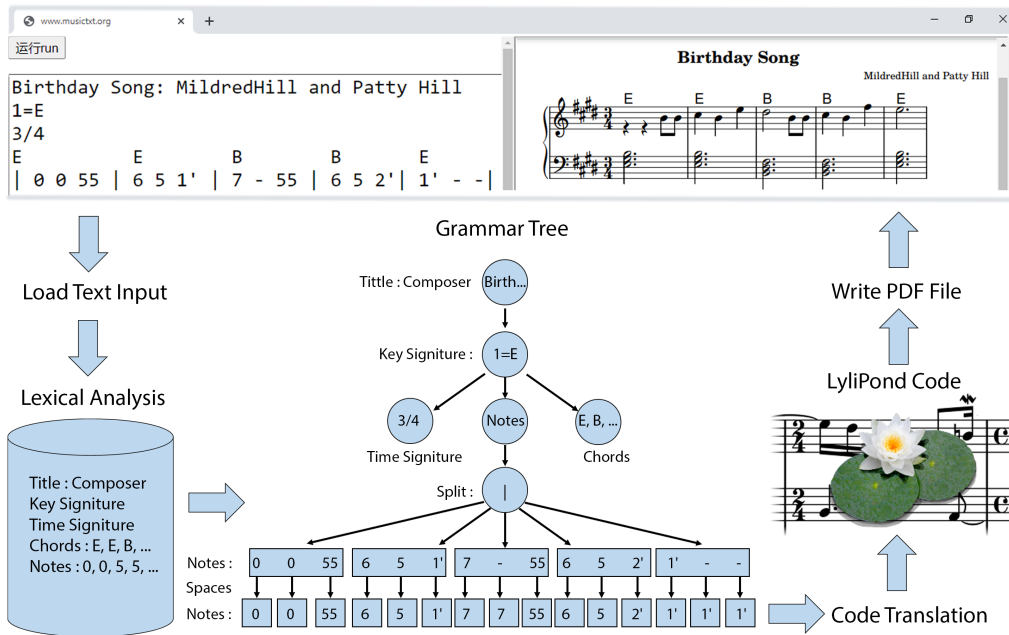


Figure 1. Pipeline of MusicTXT user interface.

Abstract. For most music notation software, due to the complex nature of modern staff notation, extra mouse interactions and manual efforts are highly demanded. According to this observation, we propose MusicTXT, a plain text-based user interface for music notation that is almost mouse interaction-free. Based on our easy-to-learn online user interface, users are able to notate music by typing a paragraph of numbers and alphabets as plain text. We validated the music notation efficiency of our interface by comparing it with another popular online software-NoteFlight. According to statistical analysis, we prove there is a significant improvement in music notation efficiency by using MusicTXT.

1. Introduction

As music production becomes democratized [Galuszka and Brzozowska 2017], more people, including nonprofessionals, step pace into the music production industry. Typically, music production speed seriously depends on music notation efficiency [Mauch et al. 2015]. Especially, musicians tend to prefer the software which can deliver their musical expression with very little time and manual effort. Unfortunately,

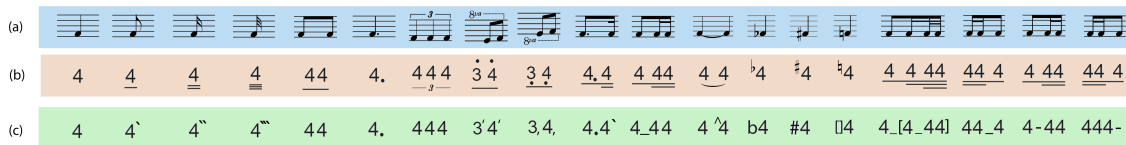


Figura 2. Comparison among the (a)modern staff notation, (b)numbered musical notation, and (c) our plain text-based notation.

most of the existing music notation software[Byrd 1994] share the common drawback that it takes extra manual efforts to notate the music due to the heavy mouse interactions.

Therefore, such inconvenience of those existing music notation software lifts the learning curve for most music composers as beginners, especially for nonprofessionals. These high demands of complicated interactions even strangled some of the beginners' interests in music production. Especially, in music education programs, younger children cannot be able to start the hands-on practice with those music notation software in a timely manner[Gudmundsdottir 2010].

Inspired by the numbered musical notation which is firstly invented by Jean-Jacques Rousseau[Rousseau 2009], people realize that using numbers instead of using notes increases the efficiency to express the music in reading and writing[Winangsit and Sinaga 2020]. In China, numbered musical notation, also called "JianPu", successfully turns down the beginners' learning curves for playing the Chinese musical instruments such as Guzheng[Gaywood 1996], Pipa[Myers and Myers 1992], and Erhu[Stock 1993], and "JianPu" is widely accepted by Chinese musician as a standard music notation system.

According to this observation, we design MusicTXT, a novel efficient text-based user interface for music notation that is easy-to-learn and easy-to-input. Our user interface takes advantage of such numbered musical notations and move a step forward by introducing a novel plain text-based music notion system. With our music notation interface, musicians are able to get rid of heavy mouse interaction by simply typing a paragraph of numbers and alphabets as plain text. The contributions of our work include:

- We design a novel plain text-based music notation system that extends the existing modern numbered musical notation.
- We devise a computational algorithm to automatically convert the plain text music notation into the standard music score as a PDF file and playable audio MIDI file using the LilyPond library[Nienhuys and Nieuwenhuizen 2003].
- We develop an online website-based Graphics User Interface (GUI) for our MusicTXT platform which can be reached at <http://www.musictxt.org/>.
- We have validated the music notation efficiency of MusicTXT by comparing it with another popular web application-NoteFlight[McConville 2012].

2. Numbered Musical Notation

With different cultural backgrounds, musical notation has its different expression forms. For example, one of the earliest musical notions is found by the Ancient Near East in about 1400 BC known as Music of Mesopotamia [Duchesne-Guillemin 1984]. Within

thousands of years of progression, modern music notation is most widely accepted as Modern Staff Notation (The standard notation)[Rastall 1983]. Modern Staff Notation[Gerou 1996] employs the staff lines upon which pitches are indicated by placing oval note heads on or between the staff lines. As another popular form of musical notation, numbered musical notation, also known as Ziffernsystem[Klassen et al. 1959], is widely accepted within China or some other countries such as Japan, Indonesia, Australia, and Ireland, etc. As a natural way to indicate the pitches using numbers, numbered musical notation gained wide popularity among beginners or none-professional music composers[Jiang et al. 2006]. Also, text-based notations, such as LATEX[Suyanto 2019], have been proposed for representing numeric music notation systems. Besides, lots of existing software provides a convenient GUI for users to type their numbered music score by dragging and clicking such as JP-Word[Word] enables the user to notate the numbered music score like using a word. However, due to the limitation of numbered music notation's nature, most of the existing software needs lots of unnecessary mouse interactions so that be able to create the correct numbered music score. Those limitations of the numbered music notation theoretically make it impossible for the user to compose music without too many mouse interactions. Therefore, we made a further step forward to adjust the standard numbered musical notation into a novel plain text-based notation which is similar to the standard one but needs fewer mouse interactions as it contains only plain text. We provide a user-friendly web page-based GUI (Graphical User Interface) as an easy-to-use platform for music notation. Our website can be visited through this link <http://www.musictxt.org/>, our demo video can be viewed through this link <https://youtu.be/yFTbm7tpLII>, more usage details can be found in Section 4 under the subsection of Code Translation.

3. Text-based Musical Notation

Plain text-based music notations are always interesting topics to explore[Read 1987]. As the basis of our MusicTXT interface, we design a novel plain text-based musical notation system that takes further improvements upon the standard numbered musical notation. As shown in Figure 2, the comparisons among the modern staff notation, numbered musical notation, and our plain text-based notation are listed. Users who are using our tool can learn such notation and create their own music work with only typing letters and symbols on the keyboard just like write a paragraph of sentences in a Word document. As our proposed text-based music notation roughly follows the styles that the numbered musical notation possesses, it is easy to master for those beginners who have any knowledge of the stand numbered musical notation which is nowadays widely accepted by both professionals and non-professionals. Given the fact that we hope to reduce the mouse interactions during the music notation process, as such mouse interactions seriously slow down the music notating process, we introduce some differences between the traditional numbered musical notation and our proposed notation. Those differences are listed below:

- Eighth note is represented as the half duration of a quarter note (a single number, say fa, 4) by appending the number with one back quote (4'). Similarly, two back quotes for sixteenth note (4'') and three back quotes for thirty-second note (4''').
- Beamed notes are connected with eighth notes that there are no spaces between numbers. We separate different beats using spaces. All numbers concatenated without spaces results in one beat. For example, three numbers connected without spaces represents a triplet.

- Octave signs are represented by appending the number with one single quote (') or one comma (,) where single quote (') represents one octave higher and comma (,) represents one octave lower.
- Common accidentals are represented by symbols appears before a number including b (Flat), # (Sharp) and [] (Natural).
- Beats subdivision are represented by underlines (_) which equally divide one beat into two half beat (Recursive method) or are represented by dash lines (-) such as if a note's duration is prolonged twice it can be followed by a dash line (Iterative method). More details will be clarified in Section 4.
- Other symbols such as a tie (^) which indicates that the two notes are joined together, repeat signs are represented as (: :!), volta brackets are represented as ([1]... [2]...) and chords are represented by alphabets such as (C, G, Am, ...).

4. MusicTXT Interpreter

As the essential algorithm to convert users' plain text input into readable music score documents such as PDF files, we develop a computer program as the interpreter[Reynolds 1972] to achieve such a translation process. Our defined high-level language, as illustrated in Section 3, is transformed into the low-level data structure that is understandable by machine through this interpreter. Main pipeline of our interpreter includes: Lexical analyzing, grammar tree parsing, and Lilypond code translating. In this section, we will explain the details of our algorithm to implement the interpreter.

4.1. Lexical Analyzer

As the first step for an interpreter to work with, lexical analysis[Hanks 2013] is applied to the plain text input. Like a standard compiler, a lexical analyzer is used to identify commands, keywords, and special symbols when scanning the input text. In our proposed user interface of MusicTXT, we define a framework for lexical analysis which includes recognizing title, composer, key signature, time signature, measures and musical symbols. After the user's specifying that information at the beginning of a plain text, a couple of lines of strings are used to specify the notes of the whole music. During lexical analyzer's scanning of the whole content of input text, the user's information specified through keywords such as "Title : Composer", "1=C", and "4/4" are analyzed and stored in the interpreter. Afterward, each line of the string is separated into measures according to the symbols of vertical bars. Each measure is separated into several beats according to the symbols of spaces. Each beat will be separated according to two methods: iterative method or recursive method. After iterating each line in the plain text input, a group of words is created by the lexical analyzer. Through such words list, it can create a tree data structure called grammar tree to interpret the input text as music notations.

4.2. Grammar Tree

After the lexical analysis, a list of words is generated. In order to convert those words into sheet music, a tree data structure is created. In the compiler system, such a tree data structure is typically called a grammar tree[Kovács and Barabás 2011]. The grammar tree is efficient to capture and analyze any recursive expressions and is widely used in modern compiler systems[Grune et al. 2012]. According to an observation that music notation expression naturally possesses a recursive feature[Armand 1993], we use a grammar tree to parse the words analyzed through the lexical analyzer into the final sheet music.

As shown in Figure 3, a sentence in Ode to Joy by Beethoven is written in our music notation. After the lexical analysis, we extract the numbers in plain text. Then according to the grammar tree that we have built from such a sentence, we assign the duration for each number and convert those numbers into meaningful music notes. The note duration d_i calculations are achieved through a recursive mathematical formula $d_i = \frac{d_{i-1}}{n_{i-1}}$ where i is the depth of the node in the grammar tree and n_i is the total number of nodes in that depth. For example, if the sentence is: | 3 3 4 5 | 5 4 3 2 | 1 1 2 3 | 3. 2' 2 - | and as user-specified that there are 4 beats each measure and each sentence has 4 measures, therefore, the during a node at the root level is $d_0 = 16$ beats and number of nodes at the root level is $n_0 = 4$ measures. According to the above formula, the during for the nodes in the 1st level is $d_1 = 16/4 = 4$ beats. Similarly, we can have the nodes in the 2nd level is $d_2 = 4/4 = 1$ beat. This formula is flexible for analyzing the rhythms including both invariant and variant measures.

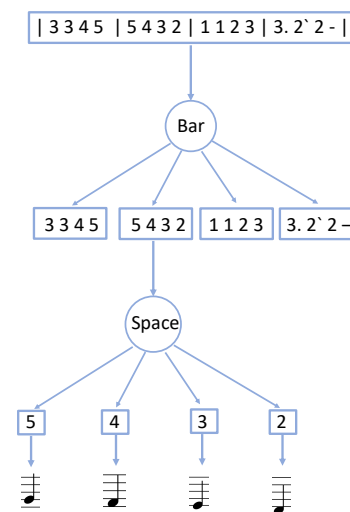


Figure 3. Grammar Tree.

With respect to the representation of beamed notes, we provide two separate interpreting methods of how to further subdivide one single beat into half or less. One being the recursive method while another being the iterative method. According to different users' preferences of reading the music sheet, the understanding of beamed notes are typically separated into two ways: some of the users are trying to subdivide one beat into two halves or further subdivide the half-beat while some other users are trying to subdivide one beat into many equal minor parts and count how much of the portions are occupied by each note. Hereby, we use the recursive method to satisfy the users who are reading the music in the first way while using the iterative method to attract users who prefer the second way. More detailed explanations are itemized below:

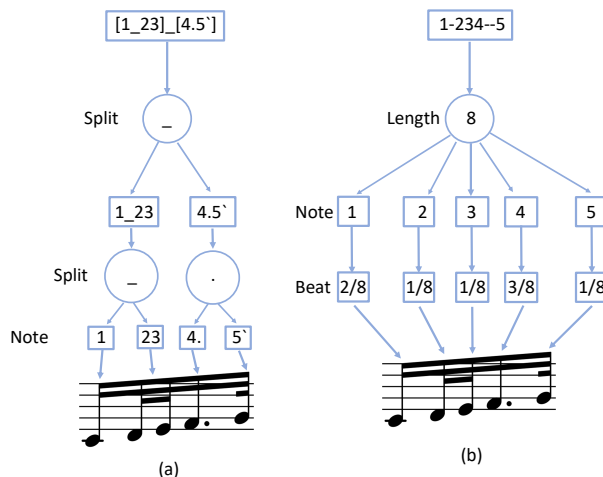


Figure 4. Beat subdivisions. (a) Recursive method. (b) Iterative method.

- The recursive beat subdivision is represented by underlines which equally divide one beat into two half beat. For example, in a measure noted as 32_4, 32 takes half-beat together, 4 takes half-beat itself, 3 and 2 take a quarter beat individually.
- The iterative beat subdivision is represented by dash lines. A note's duration is prolonged if it is followed by a dashed line. For example, in a measure represented by 32-4, 2 is prolonged and takes half-beat, 3 and 4 take a quarter beat individually.

Here we demonstrate a more complex example to show how are these two methods applied to our MusicTXT interpreter. As shown in Figure 4, we have one beat consisting of five notes which are 1, 2, 3, 4, 5 where 1, 2, and 3 take half-beat while 4 and 5 together

Figura 5. Examples: Inputs are the plain text-based notation of four songs and the outputs are the modern staff notation of the corresponding inputs.

take another half beat. In the recursive beat subdivision method, we use brackets [and] to specify the priority of subdivision order so that the notes in a bracket will be subdivided further. The subfigure in (a) is the recursive beat subdivision process while the notes are texted as [1_23]_[4.5'] and (b) is the iterative beat subdivision process while the notes are texted as 1-234-5. These two representations result in the same music score in modern staff notations. As we can see that the recursive (first) representation is more structurally resembling the modern staff notation while the iterative (second) representation seems more convenient for the user to express their music in a straightforward way.

4.3. Code Translation

After the grammar tree has been built from the users' input as text, we translate it into the LilyPond[Nienhuys and Nieuwenhuizen 2003] code according to the process and algorithms clarified above. LilyPond, as a part of the GNU project, is a well-known program to produce sheet music through a programming language, free to use and is widely used for online music notation applications[Solomon et al. 2014]. By virtue of this convenient software for music sheet encoding, we achieved the music notation process by translating our MusicTXT script into the Lilypond script. By invoking those API functions in Lilypond's Python libraries, Lilypond's code translation process is integrated into our web-based GUI interface. As shown in Figure 1, we develop a web-based GUI for users to input plain text and run their scripts. After users load the web-page and clean the website buffer by pressing "Ctrl+Shift+R", user can type their scripts of the music in plain text. To generate the corresponding sheet music, they can click the "Run" button. During the music sheet generation process, we first load the input text and apply the lexical analysis, then we generate the grammar tree data structure as mentioned above. In the end, we convert the grammar tree into a music sheet by invoking the LilyPond APIs, finish Lilypond's code translation process, and generate the PDF file for display. We also provide the buttons for downloading the synthesized music in the formats of PDF file, midi file, and LilyPond script file. As shown in Figure 5, the input is the plain text-based notation of four songs and the output is the standard modern staff notation of the corresponding inputs. Different pieces of music are highlighted in different colors including blue (Twinkle Twinkle Little Star), green (Fur Elise), yellow (Ode to Joy), and pink (Birthday Song).

5. Experiments

To validate the efficiency of using our proposed user interface, we compared MusicTXT with another well-known music notation software NoteFlightn[Richmond 2015], which is an online music composing application that lets users create, view, print, and hear professional quality music notation through a web browser. NoteFlight is well accepted by lots of professional music composers as it is install-free, easy-accessible, free-to-use, and incorporated straightforward mouse-keyboard interactions that are easy-to-learn. Therefore, we choose such a successful music notation software of NoteFlight as our counterpart, which is able to prove the efficacy of our MusicTXT if it overperforms NoteFlight.

Participants. We recruited 15 users to compare the efficiency using MusicTXT with the one using NoteFlight. All of the users have some music background, most of them are from the music majors. All of them can read and write music score. They have background in reading music both using standard modern staff notation and the numbered notations. Some of them have a background in using NoteFlight. Before, the experiments, we give the users enough time to learn how to use NoteFlight and how to use MusicTXT. From our observations, users who are not familiar with both usually take about 10-20 minutes on average in learning MusicTXT, while takes 20-30 minutes in learning NoteFlight, most users tend to learn MusicTXT faster than NoteFlight.

Efficiency Test. The efficiency test is used to evaluate how much time needed to finish typing the same music using different interfaces. When the users are ready to start the efficiency test, the researcher will ask them to transcribe two pieces of music in the NoteFlight and MusicTXT respectively where the first task being the Twinkle Twinkle Little Star and the second task being the Fur Elise. For each task, the researcher will record the time in the beginning and the end, then the duration can be calculated to measure how long it takes to finish each task. During the experiments, half of the users are randomly chosen to use NoteFlight first while the remaining half use MusicTXT first. As we know that Twinkle Twinkle Little Star is much easier than Fur Elise to read and write, therefore, we test the interaction efficiency of our interface for both easy songs and difficult songs. Their efficiency test results will be explained and discussed in Section 6.

6. Results and Discussions

The efficiency test results are shown in Figure 6 where the time (in secs) that the users have taken to finish writing two songs in two different software are plotted. The numbers are the seconds that have been taken by the users to finish writing the music score of the song named Twinkle Twinkle Little Star (Task1) and Fur Elise (Task2) using NoteFlight (Colored in blue) and MusicTXT (Colored in orange) respectively. According to the descriptive statistics, for Task1, the average finishing time using NoteFlight and using MusicTXT are 202.8 sec and 107.6 sec respectively. For Task2, the average finishing time using NoteFlight and using MusicTXT are 523.2 sec and 377.2 sec respectively. Furthermore, we analyze whether there is any statistically significant difference among two different software (NoteFlight and MusicTXT), we applied two factors ANOVA tests (with replication)[St et al. 1989] to evaluate users' efficiency on both two tasks. Two factors null hypothesis includes:

- *Among groups:* there is no statistically significant difference between the users' efficiency using NoteFlight and using MusicTXT.

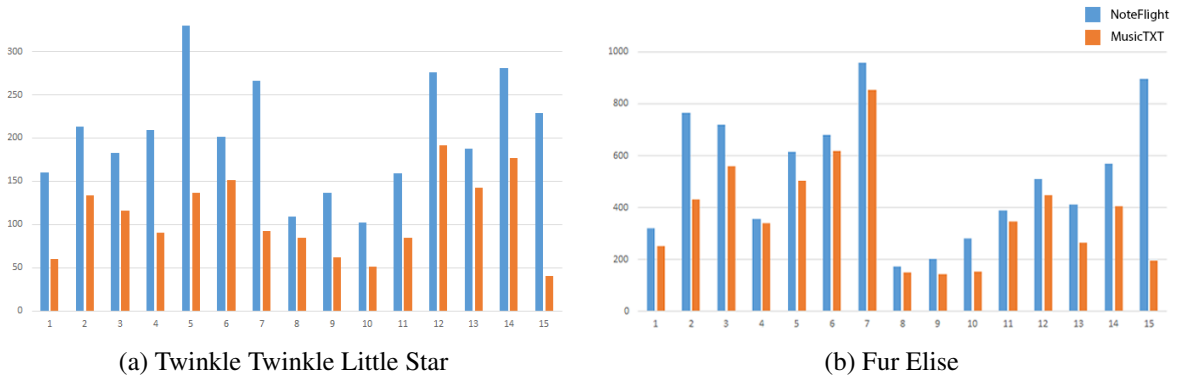


Figure 6. The result of efficiency test. The numbers are the seconds that have been taken by the users to finish notating the music score of the song named (a) Twinkle Twinkle Little Star and (b) Fur Elise using NoteFlight (Colored in blue) and MusicTXT (Colored in orange) respectively.

- *Among columns:* there is no statistically significant difference between users' efficiency in finishing Task1 and Task2.
- *Interaction:* there is no statistically significant interaction between these two factors, namely, the different software and different tasks.

By setting $\alpha = 0.05$ (95% confidence interval), we get the ANOVA test result showing that among different software (NoteFlight and MusicTXT) $P_{\text{value}} = 3.66E-9 < 0.05$, among different columns (Task1 and Task2) $P_{\text{value}} = 0.005986 < 0.05$, and the interaction $P_{\text{value}} = 0.54 > 0.05$. Therefore, with 95% confidence, we reject the null hypothesis among groups that there is no statistically significant difference between different software. And additionally, with 95% confidence, we reject the null hypothesis among groups that there is no statistically significant difference between different tasks. Alternatively speaking, with 95% confidence, we conclude that the users using MusicTXT are much more efficient than using NoteFlight. At the same time, users finish the Task1 much faster than Task2. This result basically suggests two facts: (1) Compared with NoteFlight, MusicTXT is easier and faster to use when typing the same music and (2) Task2 (Fur Elise) is harder than Task1 (Twinkle Twinkle Little Star), which seems reasonable.

7. Conclusions

In this paper, we present MusicTXT, an innovative interface for online music notation using plain text as the input. Our algorithm is designed to converting users' input of numbered-notation-like plain text into readable music scores in standard modern staff notation, we develop a computer program as the interpreter to achieve such a translation process. Where the major steps of our interpreter include: Lexical analysis, grammar tree parsing, and Lilypond code translation. To validate the efficiency of using our proposed user interface, we compared MusicTXT with another well-known music notation software-NoteFlight. Given two different tasks, by measuring how much time needed for users to finish typing the same music using different software, we statistically calculated the average finishing time. After applied two factors ANOVA tests, we concluded that MusicTXT is easier and faster to use than NoteFlight and the second task is harder than the first task which seems quite obvious given to the first glance.

According to these inspiring findings, in the future, we will move along this direction and propose more interesting music notation interfaces that are based on text. Some functions are expected to be integrated such as enabling midi input which can be converted into plain text according to our notation rules, handling Fugue, adding lyrics, and supporting complex rhythms. Also, there can be some other exciting explorations in the near future. For example, it can be incredible if we can write and send a piece of music on Wechat just like writing a text message, the user on the other side receives such message as a standard music score or a playable sound. Also, by taking advantage of AI music composition technology, when people write their own music like writing text, the system can automatically suggest the chords beneath the text, this working process looks just like when someone is using the google doc there is another collaborator writing the comments at the same time. Rich text can be explored to simplify the current grammar by adding underlines or bold font to specify particular meanings. Also, given the rich text-based interface, custom-designed graphic notations can be introduced to help users define their own notations through graphical symbols designed by themselves. Further more, in the future our proposed grammar and syntax can be extended to be capable of coding contemporary music such as Xenakis and Ferneyhough, etc. Overall, there can be a couple of more directions to explore given to our interface of MusicTXT, this will cast a light upon the future as the text-based music notation is easier to use.

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Beat Byte Bot: A Chatbot Architecture for Web-based Audio Management

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***Abstract.** The use of chatbots for content management and creation is pervasive. From the collaboration promoted by the web and its community, this paper presents research done on chatbots, content management architectures and web audio. Building on the universal use of social platforms for audio recording and transmission, as well as the robustness of chat platforms to handle microphones and audio uploading, a new architecture for sharing music content using the cloud is proposed. It promotes a path of sharing, inclusion and above all fosters a new way to establish audio communities with the help of chatbots. A functional multi-server chatbot-based architecture is presented with a multitrack audio editor as web application.*

1. Introduction

The use of chatbots promotes a new paradigm in human-computer interaction [Følstad and Brandtzæg 2017]. These define software that simulates human behaviour conversationally, and through the way they exist in programming interfaces eventually help people in certain tasks. Its use allows users to ask questions about a specific topic, ask for references or news, as well as to assist in the treatment of the most varied types of media files [Brandtzæg and Følstad 2018]. There have been research proposals from conversation-based music recommender systems [Jin et al. 2019], serverless computing [Yan et al. 2016] and even in routine teaching [Bii et al. 2018]. As management systems, chatbots can be programmed to undertake almost any task in the platform they exist, which offers multiple opportunities for the digital music community. Building on previous research [Adamopoulou and Moussiades 2020], this paper presents a modular and functional architecture of a system entitled *Beat Byte Bot*. A web-based system composed of several servers that in turn allows users to make music together on a multitrack browser application with the assistance of a chatbot. Its structure as a computational system is described, why some paths were taken in the development, iterations are proposed as well as discussed directions for other platforms of this type.

2. Web-based chatbots for music

Given the existing services that allow the creation of chatbots, it is accessible for all developers to create quickly and from scratch [Adamopoulou and Moussiades 2020]. There are even platforms – as services – dedicated to providing specialised infrastructure for this purpose,

which is the case of *Microsoft Azure* [Tajane et al. 2018] and *IBM Watson* [Godse et al. 2018]. The number of chat services that enable the connection with these platforms is also large e.g. *Facebook* and *Slack* [Kozhevnikov et al. 2017]. More and more chat services evolve and provide dedicated application programming interfaces (APIs) with multiple methodologies for developers to interact with [Shakhovska et al. 2019], and this demonstrates functional plurality and a greater and greater web ecosystem. In the particular case of chatbots in web-based audio applications, we propose a conceptual division into two major areas important for the present research: 1) audio recognition and analysis, where we have e.g. *AudD* bot and *Tadam* bot¹ made with the *ACRCloud* music recognition toolkit [Medina et al. 2017]; and 2) music recommendation [Kozhevnikov and Pankratova 2018], where we have e.g. *Groovy* bot [Sari et al. 2020], *Jukebot*² and *MusicBot* [Jin et al. 2019][Yucheng et al. 2019]. There are also a large number of web services regarding music production workstations, given the potentialities of the browser – e.g. *Soundtrap* [Lind and MacPherson 2017]. This is a fertile field to the application of chatbots, and that is where part of the proposed architecture focuses, featuring a connection point to the audio managed by the chatbot from the various users on the system.

3. *Beat Byte Bot* architecture

Today, almost all chat platforms have audio upload and record functionality and this demonstrates an opportunity for file processing, orchestration and management [Zimmermann et al. 2004]. This opportunity, thanks to the public access to source code and APIs [Stallman 2002], allows creative communities to create new networks and systems that deal with audio on the web. From the ubiquitous possibilities provided and the potential scientific contributions, the *Beat Byte Bot* system was developed as an example of a possible architecture that can be used in the future of web-based digital music services. A centralized architecture [see Kim 2021 for decentralization] that connects different cloud services, built to work with web technologies, with five distinct components [Samizadeh et al. 2021]. These have been developed to provide system modularity in order to coexist together – one of which belongs to the chosen chat platform, *Telegram* and its instant messaging servers³ [Hasyim and Pramono 2021]. The four remaining components are divided in: 1) the chatbot; 2) a middleware API; 3) an external storage database (DB); and 4) a multitrack audio editor as a web application. All research development is publicly hosted on *GitHub*⁴ interfacing with the other needed services [Daniel et al. 2019]. As shown in Figure 1, there are several links between modules, and the same is done given the specifics of the platform on which they run. In the following sections the functionalities of each part of the system are detailed.

¹ <https://audd.io/>, https://telegram.me/Tadam_bot.

² <https://groovy.bot/>, <https://getjukebot.com/>.

³ *Telegram* was chosen due to its openness and potential practical applications given the access to chatroom content by bots. It allows us to work with e.g. files, albums and live locations [Kozhevnikov et al. 2017].

⁴ <https://github.com/gilpanal/beatbytebot>.

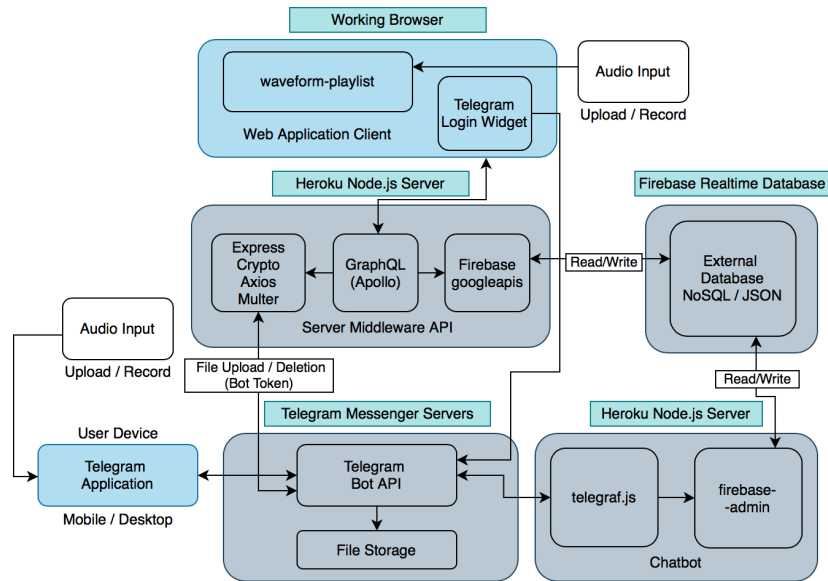


Figure 1. Beat Byte Bot architecture. Outlined in grey are the four major parts of the system, in blue are the connection points – via mobile or desktop, using the web app or Telegram itself – and in green the infrastructure.

3.1 The Telegram servers and the chatbot

Telegram’s message servers are the main point of data management, as they are the ones that originate and record the data in the first place. The developed chatbot exists completely interconnected with the provided API. It is implemented in *Node.js* [Jannat et al. 2018] and deployed using the *Heroku* platform, a cloud service that provides Unix machines [as in Arandas et al. 2019]. When a user is connected to a functional chat with the bot and uploads audio – either in direct recording or by the file system – it is connected with the *Telegram Bot API* and hosted on its servers. From there, and whenever functional within a chat room, the bot continuously receives messages and then analyses them to know if they are audio messages. This is done real-time through a communication established on *Heroku* using the library *telegraf.js*⁵ [Mardan 2018]. Based on chat administrator permissions, a metadata-based analysis is then made to the content [Saribekyan and Margvelashvili 2017]. Here we directly identify and transmit the uploads of the users to other modules of the architecture⁶. When successful, a connection is made with the next module, an external DB (see section 3.2). Using *firebase-admin* software development kit, the chatbot has instant control to this DB for reading and writing, allowing it to orchestrate the data from the detected audio files. The *Telegram API* maximum limit file size is of 20Mb for downloads, and the server can handle a maximum of 2Gb independently of the number of files, which makes *wav* format and others without compression or lossless not suitable to exchange due to its large size [Harchol-Balter et al. 2003]. The chatbot is the fundamental connection point between the users in the chat, what they type and record, and the rest of the architecture.

⁵ <https://telegraf.js.org/>.

⁶ At this point, there is no instant access to the audio buffer, only data about the post and specificities of the file. Something based on the type of response obtained by *Telegram*, not defined by our code.

3.2 *Firestore* realtime DB storage

As mentioned, every time the chatbot detects an audio file, information is retrieved from the message – e.g. file identification (ID), name of the *Telegram* channel or group and file format – in *JavaScript Object Notation* (JSON) format [Smith 2015]. Here, the nested data structure is automatically parsed and attributes are checked such as its duration, file size, title and *mime type* (e.g. *mpeg* and *ogg*) [Freed and Borenstein 1996]. After parsing, it is saved in a container in *Firestore Realtime DB* [Moroney 2017]. An external NoSQL DB hosted by *Google* services [Khawas and Shah 2018]. By keeping this module dedicated to recording data from the various audio files – given the capabilities of the platform in question – we can quickly expand the system without worrying about computing power [Tanna and Singh 2018]. In order to structure the data with the collaborative use of *Beat Byte Bot* in mind, when creating a new group or channel in *Telegram*, adding the chatbot means that we can start creating a *song*. That *song* is composed of multiple audio files, recorded or uploaded, that will be detected by the chatbot to follow the flow of the proposed architecture (see Figure 2 for the data structure).

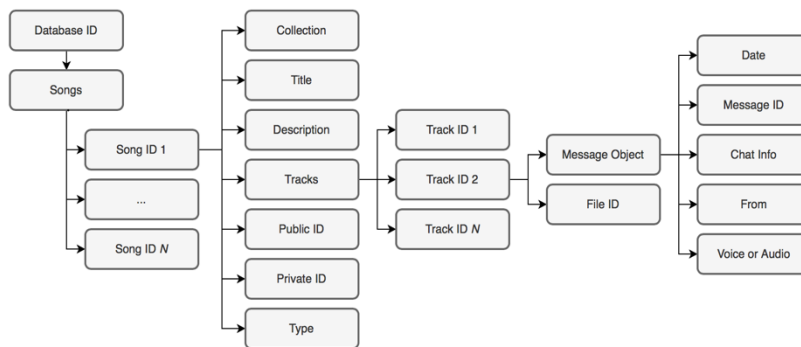


Figure 2. Data structure parsed by the chatbot to distil the message received from *Telegram* servers.

3.3 Server middleware API

In order to integrate the DB with the web application (see section 4), a dedicated middleware API was developed. Also made in *Node.js* and hosted on *Heroku* [Andersson and Chernov 2016] with a different instance than the chatbot, containing libraries such as *Express.js* [Liang et al. 2017], *Crypto*, *Axios* and *Multer* [Wittern et al. 2016], *GraphQL* (Apollo)⁷ [Porcello and Banks 2018], *Firestore* and *Google* APIs, allows data management between the *Telegram* servers and the DB with the ability to write and erase. It extends possible connections to the system being an independent module. This middleware ends up being a bridge to the chatbot, also being able to deal with *collections*. This is an implemented feature offered to increase the relationship between *songs* users make. As a *song* is composed of several audio files, a *collection* is composed of several *songs* and can be initiated in the chat using the user command – *collection: <collection name string>*⁸. It is a specific server connected to the other modules that can establish links with

⁷ <https://www.apollographql.com/>.

⁸ Collections are presented as a functionality although no spam control structure has been made.

other web applications. Some of its functions – providing bidirectionality – are listed in the following table.

Table 1. Proposed API used to link the middleware with *Telegram* and the DB.

Programmed Function API	Result
GetSongs()	Returns all songs from the DB with the parameters: ID, title and collection.
GetSongsByCollection("collectionName")	Returns all songs belonging to a specific collection. Same kind as the <i>GetSongs()</i> callback.
GetTracks("songID")	Given a song ID (long integer) it returns all tracks included in the song.
GetUserPermission("songID", "userINFO")	When a user is logged in, using <i>Telegram</i> widget, it returns whether the user has admin access to the given song or not. The ID is similar to <i>GetTracks()</i> and the <i>userINFO</i> is a JSON object, also used in <i>DeleteTrack()</i> .
fileDownload("fileID")	Given a unique file identifier it will send to the client the buffer of the file. This option has been implemented in order to not expose the bot token used at file URL. Currently the any way to access the audio buffer is in the front-end.
fileUpload("chatID", audio, "userINFO")	For a registered user with admin permissions to the song, it uploads a file automatically after drag-and-drop on the input box, or when a new track is recorded using the microphone – access permission must be granted to the web browser. This method internally calls <i>sendAudio()</i> , a <i>Telegram</i> API function which has a limit of 50Mb size for files.
DeleteTrack("trackINFO", "userINFO")	Erases a track from the external DB by passing its ID – by a user with permission. The current <i>Telegram</i> Bot API does not provide an update to receive notifications when a message (e.g. text or audio) is deleted from the chat. Currently, the provided solution is triggered by the <i>edit</i> event on a message, if that <i>edit</i> has a <i>delete</i> caption, then the chatbot removes the track from the DB.

4. The web browser application

As a practical example of the application of this chatbot, a web-based multitrack audio editor is presented. Extending the presented functionalities, we promote a collaborative ecosystem [Lazzarini et al. 2015], as well as a use case for music management, production and listening. A type of web application that uses the various functionalities provided, in which several users can collaborate, listen and compose. The client side is built with standard web languages, *JavaScript*, HTML and CSS [as in Werner et al. 2017] with the library *Bootstrap* 4 [Krause 2016]. For the multitrack editor the library *Waveform Playlist*⁹ v.3.2.4 [Pauwels and Sandler 2018] is used, with features such as: 1) a timeline-based interface; 2) the ability to solo or mute each track; 3) time control and visualization; and 4) track markers [Mahadevan et al. 2015]. Using the automatic decision taken by the various modules, this multitrack editor presents a way for multiple users distributed around the world to contribute to the same end, adding content to a *song*. There are three pages: 1) the *landing* page with several buttons for each *song*; 2) the *collection* page which offers the possibility to see to which *collections* a specific *song* belongs to; and 3) the *detail* page which has the multitrack editor and a *drag-n-drop* zone allowing the web user to add audio files to the session then subsequently added to the DB. It is possible to record or upload audio but it is not possible to create a *song* project or a *collection*, that is just done in the *Telegram* application through the chatbot. Also, on each page there is an implementation of the *Telegram* login widget¹⁰ that allows each user to connect – if administrator of the chat group in question, enabling file upload or delete. When using the widget, the *bot token* (illustrated in Figure 1) is used in the

⁹ <https://github.com/naomiaro/waveform-playlist>.

¹⁰ <https://core.telegram.org/widgets/login>.

middleware to verify the hash obtained from the widget and it is also possible to locally search for *songs* or *chat groups* in the webpage – see Figure 3 for a diagram and two screenshots of the web application.

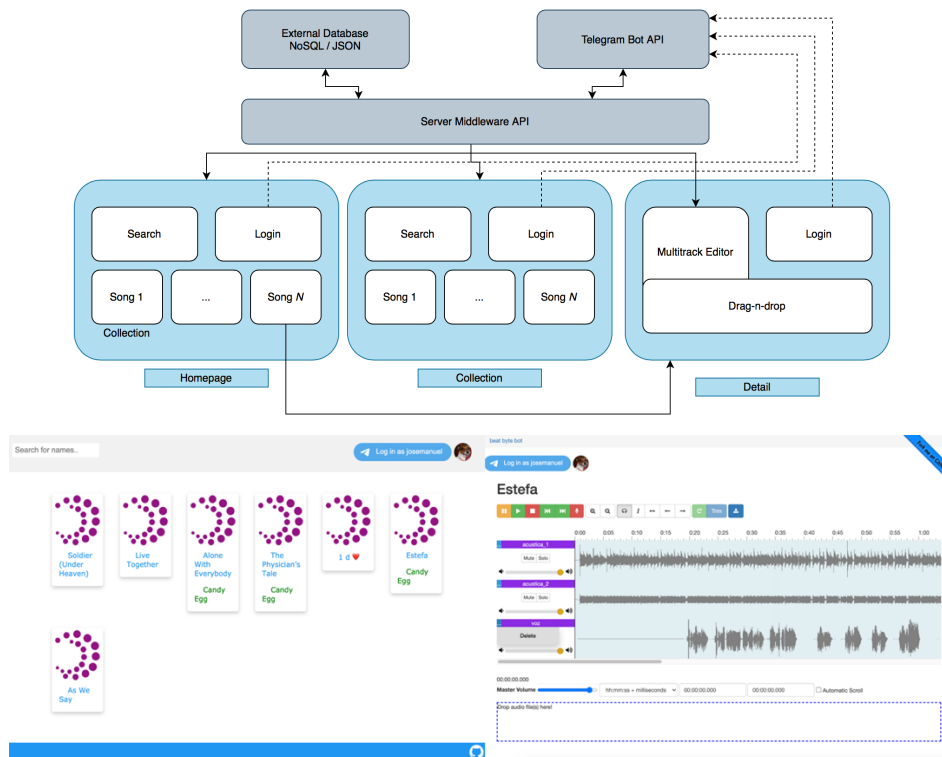


Figure 3. Diagram of the contents of the web application with links to the middleware API and two screenshots, the landing page and the multitrack editor.

4.1 Tests and Compatibility

In order to provide data regarding the use and support of the proposed software on common platforms, tests were developed. Focusing on the type of audio files and potential errors between the various modules, we used a *Telegram* application version 7.6.1 on an *iPhone 7* running iOS 11.4.1 and the desktop version 2.7.1 on a macOS *Mojave* version 10.14.6. The multitrack tests were developed on a staging environment, version 0.0.1¹¹. Results showed that the *.oga* file type is the default format used in *Telegram* applications for the voice recording option with the internal microphone, and for the browser is *wav* given the *MediaRecorder* API. The major browsers – *Firefox* 87.0, *Chrome* 89.0.4 and *Edge* 89.0.7 (on a Windows 10 Pro v.1909) – show the capability to present the multitrack editor apart from *Safari* 13.0.4, detailed in the next table. Regarding audio file types, the files: *mp3*, *ogg*, *m4a*, *acc* and *flac* show full compatibility with the upload both from the desktop application as well as through the multitrack editor. Issues show us that the *wav* type file when uploaded from the *Telegram* desktop application is recognized but doesn't play in the multitrack as well as *aiff* and *wma* that do not play and are not recognized – the main issue is that the library *telegraf.js* (version 3.38.0) recognizes them as documents instead of audio so they need

¹¹ <https://bunchofsongs.web.app>, https://github.com/gilpanal/beatbytebot_webapp.

a proper store in *Firebase*. As for the multitrack upload of *wav* files no problem is detected, *aiff* files are unable to decode using the *waveform-playlist* and *wma* is an unsupported file type.

Table 2. Compatibilities and issues regarding the platform.

Browser-based Issues				
Platform	Multitrack Audio Controls and Visualization	Multitrack Audio Recording	Telegram Login Widget	
<i>Safari</i> Build Version 13.0.4	1) .ogg and .oga audio format not supported when received from Telegram voice recording 2) Download .wav mix not working: error AudioContext()	Not working: error in <i>MediaRecorder</i> API	No user's profile preview	
Audio Upload Issues from Telegram Desktop Application				
Platform	Format	Recognized as Audio in <i>Telegram</i> ?	Played at Multitrack	Error
<i>Telegram</i> MacOS 2.7.1	.wav	Yes	No	Telegraf
	.aiff	No	No	Telegraf
	.wma	No	No	Telegraf
Audio Upload Issues from Web Application Multitrack Editor				
MacOS <i>Chrome</i> v. 89.0.4389.90	Format	Uploaded and Played in Multitrack?	Played in <i>Telegram</i> App?	Error
	.wav	Yes	Yes	-
	.aiff	No	No	Decode
	.wma	No	No	Type

Features found in other web-based multitrack editors [Buffa et al. 2015] can be implemented given the open nature of the libraries used, as well as trying to solve in our system, some of the problems found in decoding files [Jillings et al. 2016]. However, given the functionalities already presented and its cross-platform support, the web application proves to be a functional solution for the proposed chatbot, allowing several people to contribute, interact and make music together [Xambó et al. 2019]. We also underline that for a positive scalability, it will be necessary to develop adaptive processes of rules [see Arandas et al. 2019].

5. Discussion and future work

From the potentialities of the web, we can promote collaboration and interaction not only on a large scale but also ubiquitously [Stolfi et al. 2017]. As an augmented space for creation – given its network effect [Aggarwal and Philip 2012] – as well as the current technological advancement of its infrastructure, we developed research directed to a field that unites chatbots,

automatic data management and collaborative music applications [Roberts and Wakefield 2013]. An architecture designed to allow multiple users to interact together is proposed, taking into account previously proposed theories of ubiquitous music systems [Flores et al. 2009]. Given the lack of chatbots applied to the management of audio files, the proposed architecture links a virtual chat room – one of the most crowded places these days [Shih 2020] – with a platform for consumption and manipulation of audio material. This is done from a chatbot, an agent that exists in these same chat rooms and promotes all the structural manipulation of the data that users upload to participate. Taking advantage of the existing quality of the microphones in mobile devices, the quality that chat services put in audio recording, as well as the open APIs in the platforms used, we propose a collaborative and distributed system that can be used around the world, as a collaborative music platform. Users can use it in an open and inclusive way, democratising the system as a music platform through chat rooms.

The various services used for the prototyping and implementation of *Beat Byte Bot* serve as proof of concept, offering a starting point for future research. However, these should not be taken as the only option, as some of their development comes from the specificities of each platform and API. The architecture should be perceived as modular, extensible and changeable to other cloud platforms that minimally match the desired effect. In order to propose future work, we divide the proposals into two major paths: 1) compare with other platforms – both chats and server providers – that share similar characteristics, where we can raise e.g. quantitative tests in speed; and 2) the development of novel features in the project already developed, such as 2.2.) automatic signal processing in *Heroku* servers or in the front-end e.g. applying filters on the multitrack; 2.3) applying machine learning for better data clustering in *Firebase*; 2.4) the possibility of applying labels from the users to the various audio files in the collection they have access to.

6. Conclusion

This paper presents and discusses research into web audio music systems, chatbot architectures and data management. A review of relevant literature and web services matching the objectives of the explored solutions is made, a web system promoting collaboration and music assisted by chatbots and the cloud is proposed, the process is described and results are presented. It is on the pervasiveness of chatrooms and the possible musical applications to develop from them that the presented research focuses. A new extensible architecture is created and proposed – *Beat Byte Bot* – that helps to push the boundaries of what is normally thought of as musical collaboration by bridging different platforms in the cloud. Focusing specifically on the *Telegram* services, the various modules presented were developed with extensibility in mind, as well as the possible integrations with other web services. The proposed system that can be used from anywhere in the world promoting a valid ecosystem for music creation in an area with both scientific and creative potential.

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Enhancing DIY musical instruments with custom circuit boards

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Abstract. *This paper explores the use of bespoke printed circuit boards (PCBs) for enhancing Do-It-Yourself (DIY) making of electronic sound devices. With the tools and manufacturing costs now within reach of amateur makers, the production of PCBs for DIY projects can add stability and reproducibility to the growing number of custom instruments used in ubiquitous music projects. The article discusses the impact of maker culture on the custom development of electronic musical instruments, and how incorporating PCB design can extend these developments. Several case studies are described and lessons from these for DIY makers are outlined.*

Resumo. TBA

1. Introduction

In recent years the process of having custom printed circuit boards manufactured has become more accessible with free open-source tools and inexpensive production of small runs. These developments bring the process within the reach of DIY electronic instrument makers, including the authors.

Our objectives are similar to others in the Ubiquitous Music (UbiMus) community; to enable access to music making using affordable and non-complex technologies (Lazarini et al. 2020, Brown et al. 2018, Schmeder and Freed 2009). A tension when trying to promote access to music making is that one barrier may simply be replaced by another. This could be the case, for example, when moving from acoustic to electronic instruments as acoustic instrumental skill requirements are replaced by the need for engineering skills. We feel that the barrier to entry for PCB design and production has reached a point where its value is worth the additional investment in skills.

PCBs can be useful for any electronic circuit but provide most utility for moderate to complex ones. In any case, PCB production requires prior developmental steps that are already part of DIY audio electronic workflows. Software-based prototypes are often a starting point for instrument development (Lazarini et al. 2015), they are then typically prototyped on a solderless breadboard with components later soldered together for use in workshops and performances. The reliability of handmade devices made through this process is quite variable, depending on the engineering skills of the maker. We have found that the use of custom PCBs has made our DIY instruments more reliable for performance, and construction in maker workshops easier and faster.

2. Background

The making of DIY instruments has a long history as summarised by Timoney et al. (2020). The more recent history of DIY electronic music making has been greatly influenced by the publication of the book *Handmade Electronic Music* (Collins 2006/2009/2020). Microcontroller platforms such as Arduino and Raspberry Pi have been central to enabling these activities since their introduction in the mid 2000s. More recently music-specific design such as Bela (McPherson and Zappi 2015) and Daisy¹ underscore the popularity of DIY audio. A wide variety of sensors can be integrated into circuits for various types of gestural or environmental control over audio signals. In addition to DIY activities, the development of new electronic musical instruments using these materials has been the focus for academic explorations as presented in the *New Interfaces for Musical Expression* conferences, and elsewhere, since the turn of the century. Music and sound related projects have been a staple of maker workshops and of introductory coding courses in both community and educational settings (Tanenbaum et al. 2013).

2.1. DIY and Maker cultures for music

Music composers in the 20th century began the turn to everyday objects for music making. Examples include John Cage's use of paper, screws and other objects for prepared piano works and his use of radios, watering cans and kitchen appliances as sound sources. Since the 1990s the DIY movement in electronic music making has adopted arts and craft approaches to working directly with materials for the making of sound devices and new instruments. These activities have benefitted from a broader push for reducing the costs of small-run electronics, and the accessible production of custom PCBs is part of that trend.

PCB-based kits, such as the Atari Punk Console from Yeovil Hacker Space (Whiteford 2015) have been the basis for community music workshops. Thus far, these have typically been designed and created by relative experts for use in community situations and reveal the potential for the extended use of PCB by amateur engineers, as advocated for in this article.

DIY electronic music tends to focus on live music making using handmade instruments. Often these are noisy or low-fi—partly out of necessity given the materials available—but this has often become a deliberate aesthetic choice and stylistic characteristic. As technologies have improved and costs reduced, the devices made by DIY music makers have expanded in sophistication and musical scope. The access to small-run PCB manufacturing is another step in this evolution.

2.2. Accessible tools and services

The manufacturing of PCBs for electronic music is not new. PCBs were used in the earliest commercial synthesizers from the 1970s and one look at the prevalence of modular synth components, each of which includes a PCB, shows their commercial ubiquity. There is even a strong hobbyist market in the design and distribution of PCBs for music devices on sites such as SynthCube² or Nonlinear Circuits³ and by

¹ <https://www.electro-smith.com/>

² <http://synthcube.com>

³ <https://www.nonlinearcircuits.com/>

organisations such as Dirty Electronics (Richards 2013a). Like many technologies, the printing of circuit boards has recently become much more refined and inexpensive, although it is still not trivial. A range of low-cost tools and services has made this possible.

The manual production of PCBs by hobbyists has been possible in the past, but the etching process involves toxic chemicals and can be messy, if not dangerous. Outsourcing production to professional PCB manufacturing opens up the process to many more makers.

The tools and manufacturing support for PCBs have become more accessible. Free software for PCB design includes Fritzing⁴ and KiCad⁵. DIY makers may already be using Fritzing for designing or documenting breadboard electronics, and these projects can be extended to PCB design as well. KiCad is an open-source project for designing schematics and circuit boards. It is a bit more complex than Fritzing, but also has more features. The applications KiCad and Eagle were used for the case study examples in this article.

Having designed the PCB using software tools, these can be exported to Gerber files for sending a professional PCB manufacturing service such as PCBWay (China), OSHPark (USA), AISLER (Germany) and more. A price comparison from various international manufactures can be accessed at PCBShopper.com. Production and shipping typically take about two weeks.

2.3. PCBs for DIY

There are some considerations for utilising PCBs in a DIY electronic music making process, compared to their use in commercial settings. Simpler boards will use through-hole components, like those used for breadboards, so the PCB layout needs to allow spacing for ease of hand soldering by non-experts. Automated assembly of surface-mounted components is also possible and reduces hand soldering but adds some complexity to the design process. Establishing optimal circuit tracks between components can take some time, but fortunately PCB design software often includes auto-routing tools, and free external tools such FreeRouting⁶ can be very useful.

There are many online resources to assist with undertaking the process of PCB design and manufacture. While a full tutorial is well beyond the scope of this article, to give the reader a feel for the process here are the basic steps involved.

- 1) Prototype the project on a breadboard.
- 2) Draw a schematic in software.
- 3) Use the schematic to design a PCB layout.
- 4) Route connections between components and establish a ground plane.
- 5) Export Gerber files.
- 6) Upload files to a PCB manufacturer and place an order.
- 7) Solder components onto the delivered PCB.

⁴ <https://fritzing.org/learning/tutorials/designing-pcb/>

⁵ <https://www.kicad.org/>

⁶ <http://freerouting.org>

3. Exemplar projects

To illustrate what is possible we will describe three examples of music projects the authors have taken through to the stage of PCB design and build.

3.1. The Sonic Frisbee

The Sonic Frisbee (Figure 1) is a six-voice portable and battery-powered synthesiser based around a CMOS 40106 (Hex Schmitt-Trigger) and a LM386 (amplifier) integrated circuit (IC), there is no computer involved. This makes for a very low-cost instrument overall. It is designed for improvised real-time performance and the PCB is designed to facilitate hand-held interaction and gestural freedom.

Three of the synthesizer voices are operated via “resistive-touch” on the MuTec lettering where there is a physical gap in the signal path of each voice and oscillation only occurs when the gap is bridged. This element of the instrument is performed using fingers to touch metal pads so electricity flows across the gap and human flesh becomes part of the circuit. The result is a tactile but unpredictable relationship between human input and sonic output given that it is difficult to perform exact pitches but the sonic response to touch is instant. The remaining three voices are either controlled by a light dependent resistor (LDR) or a potentiometer.

The pitch range of each voice is switchable high/low, which can lead to dramatic shifts in musical character. LDR/pitch control is laid out horizontally across the board while output of the instrument is divided in half with two separate volume controls: one for the three touch-sensitive voices and the other for the three light/potentiometer voices. The three individual voices that make up each of the two halves of the instrument can either be mixed via diodes or resistors (switchable), this offers further timbral manipulation. Sonic output is switchable between a mono jack socket on the rear and the onboard amplifier/speaker combination. Power is provided by a 9-volt battery that clips into a socket on the rear, this also makes the instrument stable and sets the sit-angle towards the performer when used as a desktop instrument.

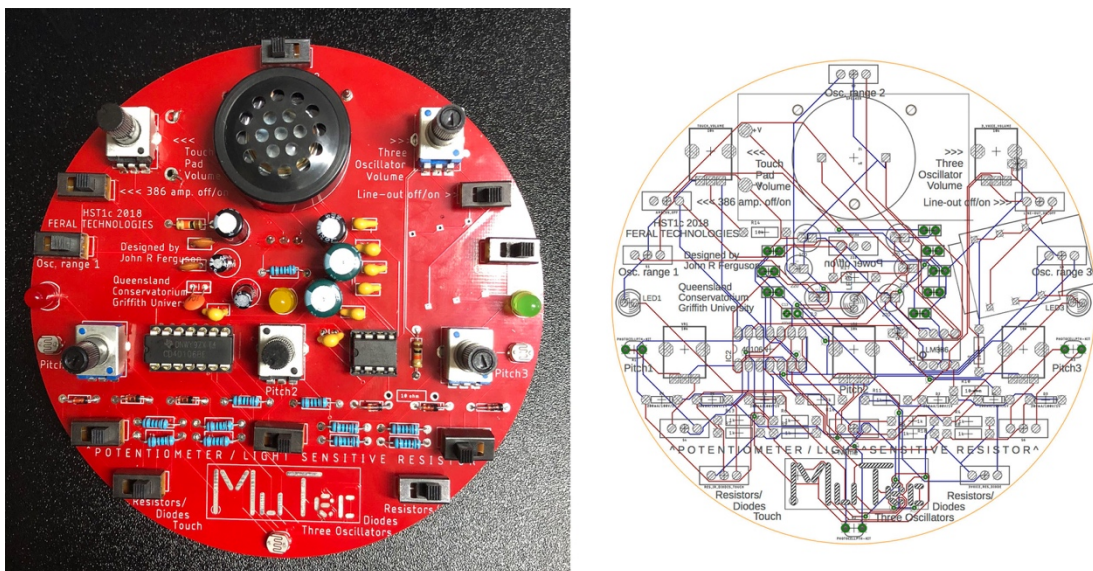


Figure 1. The Sonic Frisbee and its PCB layout

The design of the Sonic Frisbee was prototyped on a solderless breadboard and the PCB design was done in EAGLE⁷.

A significant advantage of the PCB design for this instrument, rather than alternative DIY methods of laser-cut box or solderable breadboard, was the combination of neatness and compact design. As can be seen in Figure 1, the wiring is quite complex, and the PCB provides a compact product easily manipulated in live performance without the risk of wiring disconnects.

3.2. The Beat Machine

The Beat Machine is a 16-step sequencer and 3-voice synthesizer controlled by 10 potentiometers, 19 buttons, and an accelerometer (Brown and Ferguson, 2020). The Beat Machine is designed to be hand-held, like the Sonic Frisbee, but can also be operated resting on a tabletop. The PCB facilitates a lightweight design that is compact enough to operate in the hands and movement-oriented features such as accelerometer control of parameters encourage expressive gestural performance.

The controls are connected to two Arduino Pro Micro microcontrollers that communicate via the I2C communications protocol, one microcontroller handles the sequencing and the other functions as a synthesizer using the Mozzi library (Barras 2020). There are three layers of control, one for each voice. Low-cost tactile switches are used to enter step-sequences and to access the various layers of control. A ring of programmable LEDs (light emitting diodes) indicates sequence pattern and layer information so the user can see where steps have been programmed to sound and which synthesizer voice these correspond to. The red voice is optimised for a bass drum-like tone (noise source has high frequency rolled off), the blue voice is optimised for a high-hat like tone (noise source has low frequencies rolled off), the green voice is full-range and is intended to approximate a snare drum.

Each synthesizer voice is made up of two elements that can be blended together or sounded in isolation using the balance control, the first is a sine waveshape and the second can either be a sawtooth waveshape or a noise source. When using sine and saw these can be detuned by up to an octave and then pitch-fall and the attack/release controls can be used to sculpt the overall sonic character of each voice. Pitch, volume, and distortion controls are also available, see Figure 2 for an overview.

⁷ <https://www.autodesk.com/products/eagle/free-download>

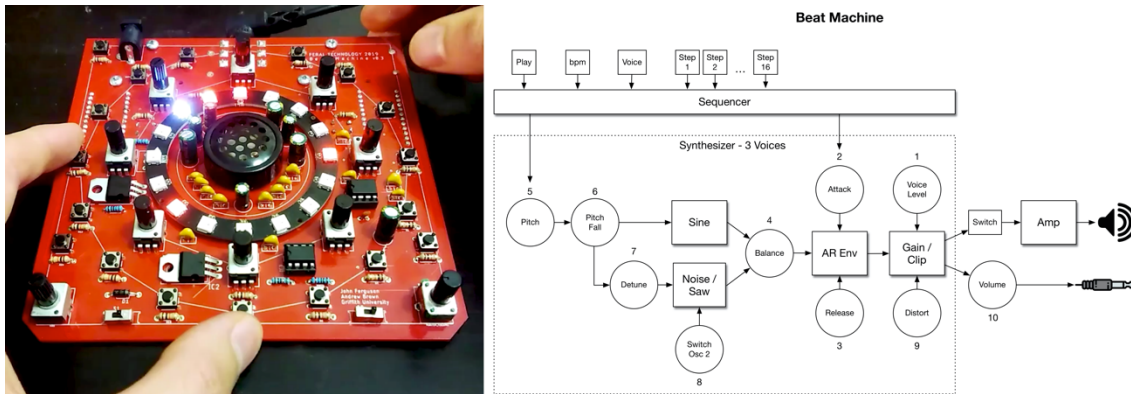


Figure 2. The Beat Machine and its software overview

A two-axis accelerometer on the rear of the beat machine is set such that the Y axis (forward and back) controls the chance of changing the probability of sequence steps, while the X axis (left and right) effects the blend between Osc. 1 and Osc. 2 and can thus be used as a timbral control. A video demonstration of the Beat Machine by students of 2710QCM Electronic Instruments class at Griffith University in 2021 is at <https://vimeo.com/534756472>.

The Beat Machine was prototyped on a large solderless breadboard and PCB design was done in EAGLE. However, the authors have since adopted KiCad as their preferred software for schematic design and PCB manufacture.

A significant learning from the development of the Beat Machine PCB was the need for attention to power circuit design. The combination of Neopixel LEDs and audio running on an Arduino microcontroller led to disruptions and audio crosstalk from power fluctuations. The PCB design enabled parallel power circuits and distributed decoupling capacitors throughout the board to keep sensitive and power-hungry elements apart.

3.3. The Micro Mono Control

During COVID-19 lockdowns in 2020 some music students we taught needed an inexpensive MIDI controller to continue their studies remotely. This prompted the design of the Micro Mono Control (MMC), the components for which cost around \$20 USD. The MMC is a MIDI controller with onboard monophonic synthesis capability (Figure 3). The MMC can be operated at rest on a desktop or held in the hands like a game controller. Serval continuous controllers—joystick, light sensitive resistor, and accelerometer—encourage real-time gestural interaction.

The MMC sends continuous control messages from 5 potentiometers, a light sensitive resistor (LDR), 6-axis accelerometer, and an XY joystick. It has 5 buttons that trigger MIDI note messages. The MMC includes a monophonic subtractive synthesizer and arpeggiator modified with the onboard controls or via external MIDI input. Audio level is set by a dedicated potentiometer and output is switchable between an onboard loudspeaker (buzzer) and 3.5mm audio output socket. The MMC is driven by an Arduino Pro Micro microcontroller running the USB-MIDI and Mozzi libraries⁸. It can be USB powered or run from batteries.

⁸ <https://sensorium.github.io/Mozzi/>

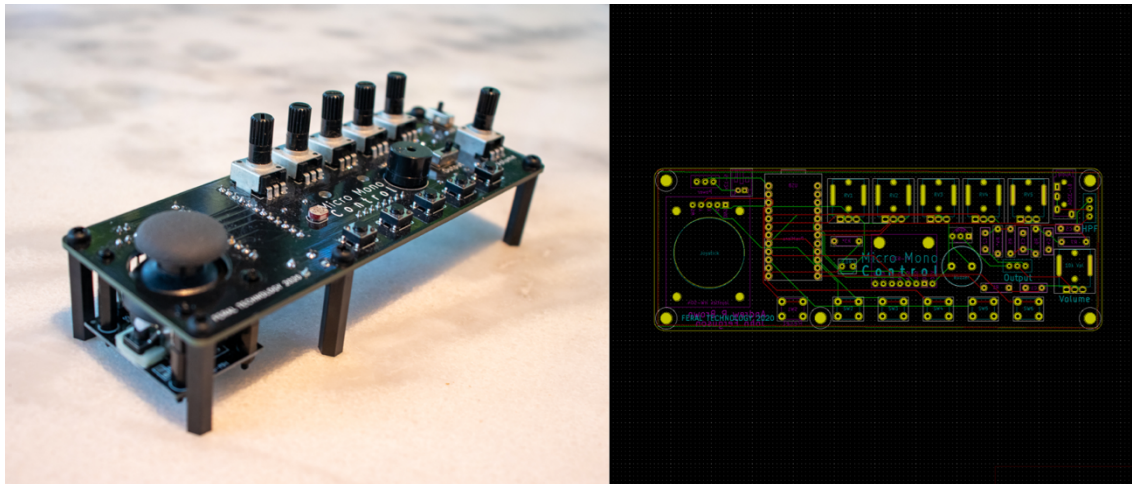


Figure 3. The Micro Mono Control and its PCB layout

The design of the MCC was prototyped on a solderless breadboard with programming done in the Arduino IDE⁹. Once the circuit was finalised, the PCB design was done in KiCad.

The PCB enabled the MMC to be both lightweight and robust. The fact that the board also acted as a case, especially for the joystick, minimised the number of fabricated parts required. Doubling down on featuring the PCB, the decision was made to go with a black colored PCB which looked more finalised and polished than the typical green or red PCBs that are typically designed to be out of sight inside a product.

4. Reflections on the exemplar projects

The design of PCBs for an instrument is a task that requires a solid background in breadboard prototyping. Although software applications, such as KiCad, include useful default settings that minimise decisions and have tools to check the validity of circuits, the PCB design process is somewhat abstract (being entirely digital) and is best grounded in an understanding of the breadboard prototyping activity.

Learning about PCB design process and software takes time but is rewarded with neat and robust infrastructure for novel electronic instruments. Iteration and mistakes are inevitable and need to be considered part of the design process. Printing PCB designs on paper for checking against component fit is a useful strategy to locate issues before manufacturing.

The use of PCBs implies that makers solder components to the boards. Often soldering is already part of DIY electronic music processes, but for those who may have only employed solderless breadboard circuit design processes the addition of soldering to PCB design skills may present an additional hurdle and/or learning opportunity.

While one aspect of the maker culture is to embrace technologies, there is also an undercurrent of technological critique in the DIY movement. For some, the use of

⁹ https://www.arduino.cc/en/Main/Software_

manufactured PCBs may be seen as giving into the professional and commercial world of technology, and they may prefer the deliberate messiness of roughly soldered components or even deliberately unruly PCB designs like those of Gijs Gieskes (2018). There is also the consideration of resource usage and environmental impact of the PCB manufacture and shipping to take into account.

5. Conclusion

This article has outlined a case for the addition of small-run PCB production as a viable addition to existing DIY electronic music making activities for use in UbiMus contexts. PCB design and manufacturer seem like a next-step skill for those looking to move beyond breadboard-based methods.

Three example projects were described that show some of the potential use of small-run PCBs. These examples were created by reasonably skilled individuals who were new to PCB design processes at the time. We suggest there is scope for digital fabrication processes, such as PCB manufacturing, to be further incorporated into bespoke instrument building processes, especially where outcomes require multiple devices as employed in workshop-based events and Do-It-Together (DIT) approaches to DIY advocated by Spencer (2008) and Richards (2013) and already a feature of many UbiMus activities.

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Functional Musical Sonification for Chronic Pain Support

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Abstract. *Chronic pain causes substantial disability, and people living with chronic pain often use protective behaviours and movements to minimize pain and worry about exacerbating pain during everyday activities such as loading the washing machine. We present work in progress on ubiquitous interactive sonification of body movement to help people with chronic pain to understand and positively modify their movements in clinical and functional situations. The sonification blends informational and aesthetic aspects and is intended for daily use.*

1. Introduction

People with chronic pain experience long-term pain that is not associated with ongoing tissue damage (Raja et al. 2020). This pain can have significant impacts in day to day functional situations. We undertook a survey of people living with chronic pain and respondents (n=37) identified varying extents of difficulty (including total inability) in a range of activities involved in daily life e.g. lifting things, bending, turning while sitting, and ascending and descending stairs. Respondents indicated difficulties in everyday tasks such as shopping, laundry, and cleaning.

Previous work has shown the potential of movement sonification to increase self-efficacy and pain management for people living with chronic pain (Singh et al. 2016, Newbold et al. 2016). It showed that movement sonification could variously increase confidence, relaxation, and self-regulation in individual instances of painful or protective movement. Other work found that music can be effective in reducing pain, depression, anxiety, and feelings of powerlessness in study participants with chronic pain (Guetin et al. 2012, Siedliecki & Good 2006). The distracting power of music was also somewhat evidenced in our survey results: Of the respondents (n=30) who reported that time passes less quickly for them when their pain is more than usual, the majority (n=25) reported that listening to music during this period made time pass the same as or more quickly than on a usual day.

The work we report here is focused on combining generative sonification of body movement with music, to support affective use of the sonification in day to day functional situations. This might be seen as a form of eco-composition (Flores et al. 2009): bringing together agent (the person living with chronic pain), tools (body-worn sensors, mobile phone, headphones, sonification algorithms/apps), and environment (the home). Whilst

the activities (day to day tasks like loading the washing machine or unpacking shopping) are not artistically-focused (e.g. performance, composition (Flores et al. 2009)), the result of using such a sonification in task support will result in ‘informational music’ created by the user’s interaction with the system (the kind of sonic by-product Flores et al. identify, except that here the music itself aims to change the affordance of the environment and activity from which it is being created). Keller et al. (2019) note the potential for well-being and health applications of ubiquitous technologies, citing the Beathealth project (Timoney et al. 2014) as an example. Like the Beathealth project, our work is not directed primarily at musically-creative outcomes, but aims nonetheless at everyday music-making irrespective of musical expertise (see Keller et al. 2020).

We envisage multiple linked use-cases: in therapeutic situations where an individual is working with a physical therapist to understand, review recordings of, and improve movement confidence and quality; working with a partner to support movement practice; and when alone, drawing on the music and sound developed in these other situations to stimulate and give confidence to tackle functional tasks.

2. Sonification

An initial prototype designed to sonify simple arm extensions was followed by a more complex sonification of a daily task (unloading the washing machine). We used Notch¹ sensors to measure rotation and/or tilt angles of shoulder, knee and chest. Data from the sensors was then downloaded and sonified using SuperCollider². At this stage of our work, the data is simply recorded and replayed to the sonification engine as if in real-time (to minimize the need for participant involvement in each execution and to overcome some current technical limitations). In future we intend the tool to function interactively in real-time to support the range of use-cases identified above.

The sonification design drew on Hunt and Hermann’s (2011) criteria for interactive sonifications, considering the system and user as a “closed loop”, each influencing the other’s reaction and behaviour. We developed four behavioural goals and corresponding sonic mechanisms, drawing on the findings of previous research into chronic pain sonification design (Singh et al. 2017). The result is a multi-layered musical soundscape, with morphing harmonic sounds and individual chiming chords playing over a slow-moving generative bassline. The behaviour-sound mapping is shown in Table 1.

Several videos show the sonification of movement data captured from one of the authors and from study participants. In the first, a series of isolated crouch movements clearly demonstrate the “threshold chimes” when the figure bends their knee past a certain point³. The other videos demonstrate the full washing machine task, but with the sonification of “threshold values” taken from different dimensions of movement: knee bend⁴; chest lean forward⁵; and reaching (shoulder extension)⁶. Additionally in each animation, the movement of the band-pass filter frequency and the texture of the ambient melodic sound change as the velocity of the participant’s movement changes.

¹ <https://wearnotch.com>

² <https://supercollider.github.io>

³ <https://youtu.be/RPhH8NTUhyI> - Video of isolated crouch movements

⁴ <https://youtu.be/JuNyJpaPLcY> - Unloading the Washing Machine, Study Participant, knee bend

⁵ <https://youtu.be/Mv3TuWPIGhE> - Unloading the Washing Machine, Study Participant, lean forward.

⁶ <https://youtu.be/TEp66ysbIKo> - Unloading the washing machine, researcher

Table 1. Sonification Design Factors

Goal	Rationale	Sonification Design
Reduce anxiety	Movement can exacerbate pain leading to significant anxiety about movement.	Generative, slow-tempo, ambient sounds with long attack/release times provide a foundation to reduce anxiety.
Foster feelings of achievement/progress	People living with chronic pain can benefit from an awareness of progress in range of motion over time.	“Positive” (major, chiming) sound triggered when reaching a pre-defined movement threshold (set by the user and/or therapist in advance). Thresholds can be set to reflect gradual changes in range of motion.
Objective self-monitoring	Agency over the sound is needed, thus some sonification elements must directly map to movements.	1. Angular velocity is mapped to the frequency of a band-pass filter (100Hz-3kHz) applied to a pink noise generator, to indicate when motion is taking place. 2. The “energy function” (see Fod, Matarić & Jenkins 2002) of a user’s movement is mapped to the trigger rate, grain duration, and amplification parameters of a granular synthesizer, resulting in the texture (smooth vs. grainy) of the sound varying in response to the dynamism of movement.
Promote exploration	To motivate continued use, the soundscape should encourage playfulness and creativity.	The integration of the sonic layers is designed to promote fidelity of sonic outcome in response to movement but remain interesting to the user.

3. Conclusion

This paper has reported work in progress on a musically-oriented movement sonification to support people with chronic pain. Future work will include empirical evaluation of the sonification in a range of settings to investigate the balance between information and musical coherence, investigating more advanced movement recognition, and considering possible applications beyond chronic pain.

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Work-in-progress Paper Submission for Ubimus 2021:
**Blanket Sounds: An Acoustemological Account of Immersive
Audio and Memory**

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***Abstract.** This project explores the function sound plays in the formation of memory in Ubimus contexts and what influence immersive audio could have in mediating sonic encounters. This is accomplished through the creation of a VR adaptation of a multimedia sculpture called, “The Witness Blanket,” made to memorialize experiences of indigenous survivors of Canadian Residential Schools. This research presents a novel way of communicating auditory information in educational settings through the sonification and musication of sounds that lack real-life sonic equivalents, drawing upon what I call, ‘the semiotics of nostalgia,’ to question the many factors which colour our experience of sound and how our sonic perceptions shape our reality.*

***Keywords.** Sonification, music in education, immersive audio, social interaction in sound and music computing, indigenous cultural preservation, sound and music for VR, timbre in Ubimus contexts.*

1. Introduction

I am the principle sound designer, producer, and engineer for a project creating a virtual reality (or VR) adaptation of a multimedia sculpture called “The Witness Blanket” (or “blanket” for short). Created by artist and indigenous scholar, Carey Newman, the blanket memorializes experiences of indigenous survivors of Canadian Residential Schools. While assembling the blanket, Newman received hundreds of artifacts, stories, songs, letters, and other symbolic pieces from survivors, as well as physical remains from several schools in varying states of neglect, decay, or repurposed use. He collected doorknobs, floor panels, and other remnants from the buildings and surrounding premises. After collecting and organizing these artifacts, he meticulously fit pieces of all different shapes and sizes together to form a complex mosaic panel, visually reminiscent of a quilt, except made out of wood, ceramic, metal, paper, and all manner of other materials aside from what one would expect from an actual blanket.

The piece toured all over Canada for six years, but in light of its physical complexity and the work required to construct, deconstruct, and transport the blanket from one location to another, one can easily begin to see the appeal in a VR version. Aside from the ease of setup (or lack of setup entirely), the other obvious benefit to adapting the blanket for VR is that it allows the piece to become accessible to a global audience.

However, before any attempt can be made to reconstruct the blanket in VR, it is necessary first to deconstruct and examine the nuances and subtleties of the constituent parts that make the analog blanket experience in an effort to identify what makes it sound unique. Those concepts will then be used to design a conceptual framework through which the rest of the audio can be conceived of, produced and organized, and can later help guide the incorporation of audio into the complete VR blanket.

This framing process revealed three central questions about sonic experiencing around which the resulting inquiry has been organized. First, I investigate how sound can be used as a vehicle to facilitate the creation of memory and emotional connection by identifying the variables that influence those connections, as well as researching how, if at all, VR as a medium and 3D audio spatialization techniques can more effectively and/or more powerfully catalyze that process.

Second, I study the ways sound informs our perception of the world by highlighting the effects environmental factors have on acoustic dynamics. I then consider how these dynamics apply to the conceptualization, design, and production of audio for the VR blanket, and finally how the resulting audible products will be used in the subsequent design process. This phase presents opportunities to explore novel representations of music information and challenges notions of agency in performance when the human-machine relationship in a creative and experiential context is blurred and it becomes unclear if the machine is driving the human experience or the human controlling the experience of/in/with the machine. This also raises questions about creative ethics and artistic practices and how to address the implications of our rapidly evolving understanding of human-machine dynamics in the age of AI.

Third, this project contemplates the temporal and ephemeral aspects of sound by studying the fluid relationality of listening, using theories like critical listening positionality and acoustemology to question the many factors that color our experience of sound.

2. Consideration of Auditory Variables

How do we experience sound in the world, and the world through sound? In other words, how do we come to know (and experience) the world through sound, and what can sound tell us about our environment? Sound helps us get oriented in our surroundings and provide us clues about the nature of the place, time, and space we're in. Take for example, the sonic environment of a forest. The sounds of splintering wood could hold a lot of information that had important implications regarding your safety. For example, the quality of the sound would tell you how far you are from the sound

source and the direction it's moving, hopefully giving you enough time to get out of the way of a tree before it falls. But what are we actually hearing when we talk about these functions of sound? What we listen for differs according to the context in which we're listening. For example, direction and movement are helpful considerations when trying to locate sound sources, like with our tree example. If we are able to hear the trunk just as it's beginning to splinter, we will know that the tree is some distance away, but it's not until it starts to fall that we're able to identify that it's falling in our direction.

Changes to Sound Behaviour. So, what variables account for noticeable changes in sound dynamics? The physical environment around a sound directly impacts how the sound behaves and changes depending on the characteristics of the space. Dimensions are one of the primary influences, but the physical materials used in the construction of a space also matter a great deal. Construction style, floor and ceiling materials, and additional nearby matter all affect sound in a space. The physical characteristics of the sound source, its material, size, shape, weight, texture, density, etc. also impact acoustic dynamics. Think of the difference between the sound produced by a falling twig and that made by a falling log. What else or who else is around can also make a big difference, as it certainly does in case of this project. These sounds are subject to the same dynamics and will vary according to a person's size, like their weight or height, the clothes they're wearing (pants versus shorts), the types of shoes they're wearing, their pace or gait, and that's not including spoken sound.

All of these variables become design considerations in the blanket VR adaptation process. How do we deal with the presence of others? Do we design for it and allow the sounds of other to simply become part of the sonic environment, or do we limit the experience to one person at a time? The analog blanket experience obviously involved sounds made by others because others were always present, but here we have the power to exclude that form of sonic interference from a VR adaptation, but think of the significance such a decision would have on the experience. Decisions of that magnitude should not be made without careful consideration and also consulting the artist, as the differences between the two experiences would be profound.

3. Designing Sound Dynamics

Having explained some of the dynamics that influence sound, we can begin thinking about what types of sounds we want to use and how we want them to behave. In attempting to recreate the sonic atmosphere of the original blanket, I first needed to find needed an audible metaphor to link everything together, something to communicate the presence and movement of others. It needed to be personal, intimate, and responsive. My first instinct was to explore the idea of using footsteps. Keen to find ways to embed cultural learning opportunities, I decided to look up footsteps in the Kwakwala language. Kwakwala is spoken by the indigenous people of the north eastern coast of Vancouver Island and blanket artist, Carey Newman. I discovered four separate words

related to the sound of footsteps which suggests a potentially more complex and nuanced understanding of footstep sounds and could be a good opportunity for cross cultural learning. While I haven't yet had an opportunity to consult an expert in this language about the differences in usage, footsteps are easily identifiable, personable, and provide an interesting opportunity for using sound. Footsteps are also a good example because they're universally acknowledged as sounds resulting from our own movement and therefore easily assigned agency to highlight cultural parallels.

Machines Mediating Sonic Experiencing. The consideration of how machines mediate the experience is when things start to get interesting. Firstly, this project begins with the production of audio which is virtually unheard of in VR design. The rationale behind an audio-centric workflow in this case is that it allows for sound to drive other design considerations rather than simply providing auditory fixes to visual cues.

We begin by imagining sounds for things which are naturally silent, and this is where things start to get interesting. By starting the design process with sound, the design of interactions follow naturally. What sound does a braid of hair make? What might you do with it, and what sounds would result from that movement?

The plan is to use eye-tracking data to not only follow the gaze of participants in order to learn about their perceptual instincts within the space, but also allow the system to capture eye-tracking data and use it to guide participants through the space by highlighting objects visually, or even by using sound to call out to people, literally.

4. Creative Implications of the Project

In the introduction to his book, "Hungry Listening: Resonant Theory for Indigenous Sound Studies," Dylan Robinson introduces the concept of colonial listening, and the ways the Canadian residential schools were used to mandate or override culture through listening that he calls the "civilizing sensory paradigm" which he says can be defied through the creation of "culturally immersive learning environments." This is the precise goal of this project: to create a culturally immersive learning environment to foster healing through reflexive listening to indigenous voices telling their own stories.

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bandy - an interactive performance system

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Abstract. *bandy is an interactive performance system that lets participants play a simple game to collectively create music on real musical instruments over the internet. Players can join together on a video chat application to see and hear the band of acoustic, electric, and electronic instruments respond in real time.*

1. Motivation

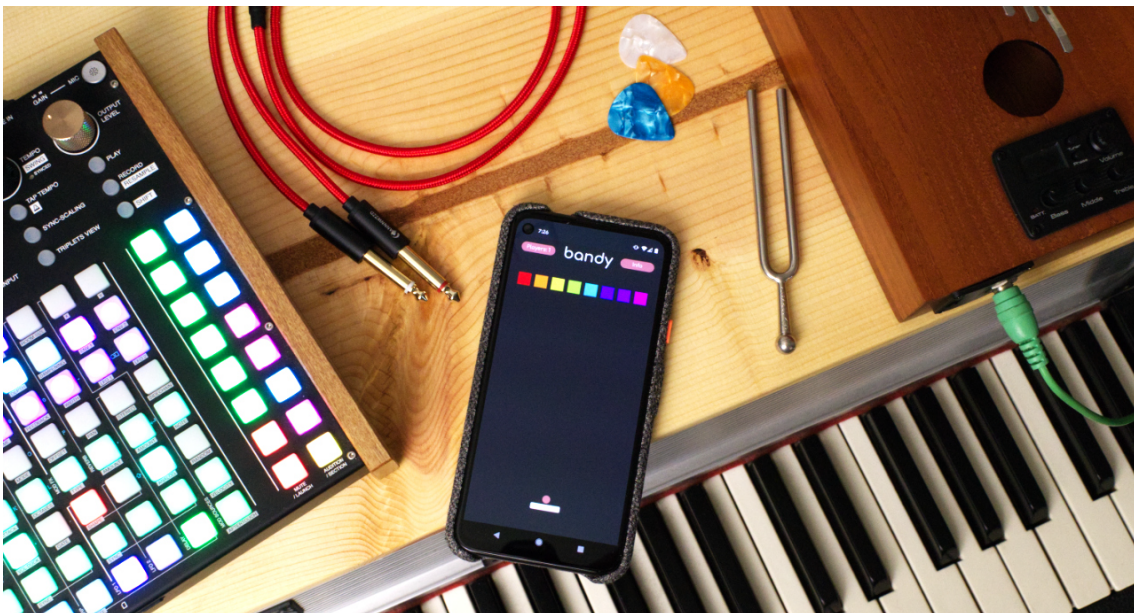


Figure 1. bandy web application

Over the past few years I've moved geographically further away from my friends and musical collaborators. I was missing making music with them and looking for ways to play music remotely. Our past year spent inside has given me the opportunity to experiment with some new available internet technologies and see how they could be used to maintain the sense of connecton and the joy of discovery in playing and improvising together.

As a composer I explore stochastic and chance determination of the traditional elements of music, pitch, duration, dynamics, and tempo, within controlled systems. The aesthetic choices of composition are then ones of level of control over the stochastic processes, sources and qualities of sound, density of musical information, performance, and interaction. I combine these elements into systems which define individual pieces of music; often using novel physical and digital interfaces.

Groups of performers can be used as random event generators in such a musical system. They exert influence over the resulting sounds but not control. In bandy, performers' actions determine the density of events but they don't have direct choice over the notes or the instruments on which those notes are performed. Those are instead determined by the compositional parameters and machine learning algorithms. Performers are then free to play within the system and create music without the need for specific musical training. We all, composer, performers, and audience, are surprised by the results. This form of playful music generating is inspired by historic, indeterminate, compositional processes (Cage, Xenakis, etc.) as well as complex emergent systems as in Céleste Boursier-Mougenot's from here to ear series.

2. System Description

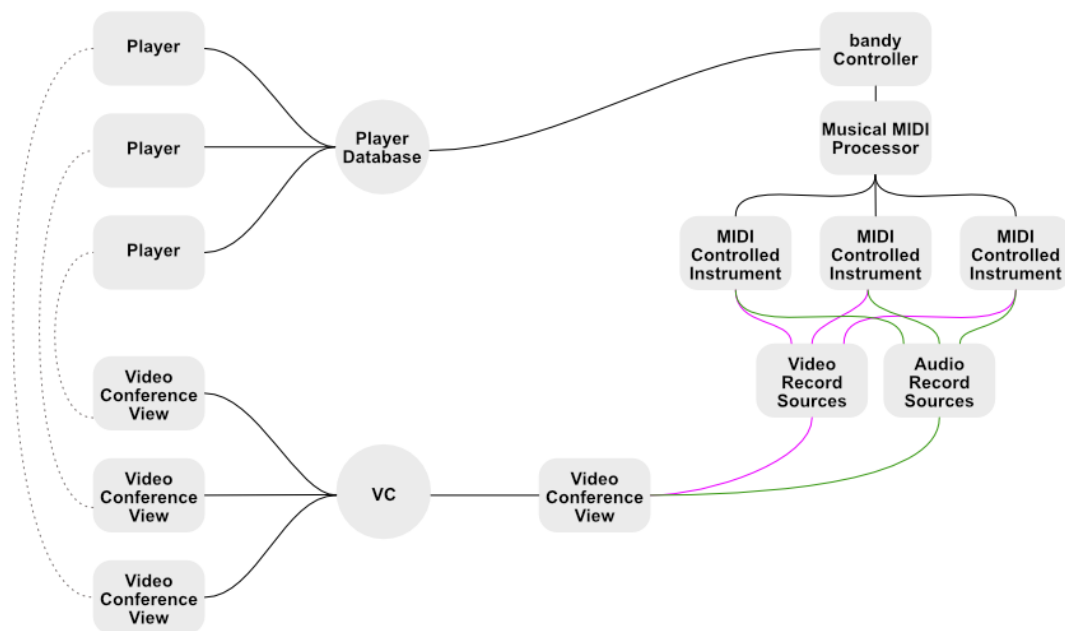


Figure 2. bandy system diagram

A set of simple mobile web games allow players to influence the creation of a musical composition by bouncing a ball against colored boxes. Each time a box is hit it generates an event that is collected in a real-time database and sent to a piece of software that acts as a performance controller. The performance controller uses Magenta machine learning libraries' Piano Genie to create musical information based on the events from players' games. Aggregated events from all players are translated into note sequences by the algorithm, which has been trained on 1400 western classical piano compositions. These note sequences are represented in MIDI format and can be filtered and sent to a set of controllable instruments. My choice and design of instruments and application of filtering and audio effects create specific compositions. The band of instruments can be viewed via video conference so players can see and hear the music they are creating in real time and interact with their bandmates.

The number of players can have a significant effect on the musical result. Limitations are intentionally imposed by the game mechanics allowing many players to

interact at the same time while keeping the musical result varied and dynamic. There are moments when the system breaks out of its western harmonic patterns and modulates seemingly at random or breaks into a streaming cadenza when a player's ball gets stuck between blocks and creates a flurry of events. It is the balance and contrast between these two states that is the artistic goal.

Players can access bandy using modern web browsers on mobile or other computer platforms at <http://www.bandy.camp>

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Modulation Synthesis in Digital and Analogue Computing Environments

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Abstract. *This paper surveys the area of modulation synthesis for digital and analogue computing applications. We explore the key definitions, classic methods, and some more recent developments. The key points for digital and analogue implementations are discussed, with examples in the form of diagrams. Modulation synthesis is shown to be an important resource for ubiquitous music composition and performance.*

Modulation synthesis is a class of techniques that employ the combination of a few simple waveforms (often sinusoidal) in order to produce complex spectra with dynamic characteristics. Among these, we find several methods, some of these based on various forms of amplitude modulation (AM), and others based on frequency or phase modulation (FM/PM) of signals. This survey paper aims to provide an overview of such techniques, focusing particularly on the non-linear distortion-based techniques of FM and PM and their extended forms. These may find important applications in various ubiquitous contexts, both in the context of digital environments (e.g., microprocessor-based embedded systems, music programming languages) and in analogue music computing (modular systems, DIY electronics, etc., as outlined in [Lazzarini and Timoney 2020]). The text is mostly non-mathematical, but a complete theoretical treatment of these methods can be found in [Lazzarini 2021].

1. Modulation

It is possible to describe all forms of modulation synthesis as variations of a basic arrangement consisting of the product of two signals [Bloch 1944]. We can represent modulation synthesis in this way as the action of a modulator on a carrier, through some means of amplification, which effects a multiplication operation (real or complex). This is defined in a very simple signal flowchart, shown in Fig. 1, where the triangle symbol stands for a black box product operator. In simple forms of modulation synthesis, the carrier takes the form of a real sinusoid, but this restriction is not imposed more generally. The modulator signal, on the other hand will depend on the type of modulation that is employed.

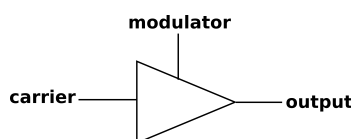


Figure 1. Modulation Synthesis as the product of carrier and modulator signals

The simplest configuration employs a sinusoidal wave, and the result is called *sinusoidal ring modulation*. This is in fact a specific instance of a more general method

of amplitude modulation. The resulting spectrum, in the case of a sinusoidal carrier, is composed of the sum and difference of the carrier and the modulator frequencies. On the other hand, if we employ analytic signals for both carrier and modulator, it is possible to produce single-sided spectra. These will contain either the sums or the differences of the carrier and modulator frequencies. For this to be implemented, real-valued input signals need to be placed in quadrature before complex multiplication is applied. In the case of sinusoids, this means employing complex sinusoids as carrier and/or modulators. A typical application of the single-sideband is in the frequency shifter effect, where the frequencies of an input signal are shifted upwards or downwards by a complex sinusoidal modulator.

1.1. Phase Modulation

In PM, the modulation signal that is applied to a sinusoidal carrier is put first through a *waveshaper*. This is a very important element of a synthesis system: it allows an input signal to be mapped by a given function, producing a non-linear modification of that signal. In its simplest form, we can describe the output of an oscillator as a waveshaper acting on a linear phase function, producing a waveform that is defined by a particular waveshaping function. Figure 2 (left) shows such a representation of a cosine wave oscillator, as a waveshaper mapping an input phase. Normally such a signal is a periodically-repeating ramp defined within a certain range (e.g. 0 to 2π in the case of the cosine wave oscillator example), but can also be obtained by direct integration of a frequency input¹. Waveshapers may be constructed for various other periodic functions, and in general we can describe it as an arbitrary function $f(x)$ defined over a given range of inputs. In the case of PM, the modulation signal in the Fig 1 flowchart is taken from a complex-valued sinusoidal *waveshaper*, as shown in Fig. 2 (middle). The input to this waveshaper can be any signal, but in simple PM we use a sinusoid. So, in this case, the waveshaper signal is in fact a mapping of a sinusoid by a complex sinusoid. If we take the carrier signal to be again analytic, in its simplest form another complex sinusoid, then the result of the complex product of the two signals is equivalent to the modulation of the phase of the carrier signal. In practice, we can avoid the complex multiplication since we want a result that is real-valued, by rearranging the operations (Fig. 2, right). Furthermore, this also means we can also apply the input signal directly to offset the phase of the carrier signal. For this, of course, we need to have the means of such fine control over the carrier phase. If this signal is a sinusoid, all we need to do is compute its phase as the sum of the phase and modulator. This can also be represented by a waveshaping expression, where the input is the modulator input offset by a linear phase function, and the waveshaper is a sinusoid. This is the form that is usually implemented in most cases. However, the form given above using the general modulation synthesis flowchart is important because it can lead to interesting variations of the PM synthesis method. From the generalised modulation description of PM we can derive the resulting synthesis spectrum. As we have noted, the ring modulation of a sinusoid and an arbitrary waveform with many harmonics produces the sums and differences between the sinusoid and the frequencies of each partial. In the case of PM, the output of the waveshaper, the modulation signal, is a waveform with a well-defined spectrum composed of several harmonics of the modulation frequency f_m , including a DC term at 0Hz. Therefore the carrier-modulated output will be composed of frequencies at $f_c \pm n f_m$, for $n = 0, 1, 2, \dots$. There are actually an infinite number of components, but since the higher harmonics of the modulation signal have little energy,

we can consider only a certain number of them to be significant. In simple PM, where we have a sinusoidal modulation source, the number of significant sideband partials is directly related to the peak amplitude of the modulator. We call this parameter the *index of modulation* z . We can estimate the bandwidth of the signal according to it: the upper sideband will extend to $f_c + kf_m$ for $k \approx 4z$ [Corrington 1947], beyond which any signal components have very little audible significance. In any case, we can use the index of modulation as a direct means of controlling the spectral distribution in a PM waveform. The relationship between f_c and f_m is also significant. Chowning ([Chowning 1973]) made an interesting analysis of the ratio of these two frequencies and came to a number of general conclusions, which are very useful in sound design. He noted that If the ratio $f_c : f_m$ can be put into a fraction of two small integers, $a : b$, then resulting spectrum will be perceived to be harmonic, with fundamental frequency set to $\frac{f_c}{a}$ or $\frac{f_m}{b}$. If $b > 1$, then all harmonics that are integer multiples of b will be missing from the spectrum. On the other hand, if the ratio cannot be put into such a fraction, or if a fraction of larger integers results, then the spectrum will be perceived to be inharmonic, with no defined fundamental frequency.

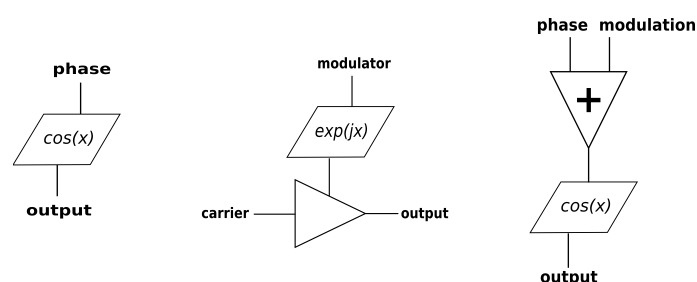


Figure 2. Cosine oscillator (left), phase modulation using a complex exponential waveshaper (middle), and phase modulation using a cosine wave carrier (right)

1.2. Frequency Modulation

Frequency Modulation is often confused with PM. While there are many similarities and in general we may state one in terms of the other, they are actually distinct methods with different implementations. Using the general modulation synthesis model, FM employs an integration step prior to the waveshaping step, which is normally built into a unit called the *oscillator*. The integrator actually makes the frequency modulation signal into a phase modulation input. Following it, the two techniques are identical and can be treated using the same theoretical tools. However, we should not neglect that there is an integration involved, because there are important consequences that follow from it. As with PM, the usual implementation of FM is more direct: we apply the signal to modify (additively) the frequency of an oscillator. For this to be implemented, the oscillator takes a variable frequency as input, which may be positive or negative. We can describe such a unit using a flowchart where it produces an arbitrary periodic waveform, whose frequency is offset by a modulation signal. The significance of these differences will play out when the methods are deployed in either digital or analogue computing environments, and also if we attempt to expand FM or PM beyond their simple forms. For now, it is important to note that the integration step through which the modulation signal is put in FM will cause a phase delay, which in some situations can be significant. Another important consideration is how to

determine the peak amplitude of the modulation signal to obtain a given spectrum. Due to the integration, the index of modulation needs to be scaled by the modulation frequency to define the modulator amplitude. This is sometimes defined as a frequency deviation value, which gives the minimum and maximum values of the instantaneous frequency of the carrier. In any case, to determine exactly the output spectrum, it is always needed to take the integration into account and put FM in terms of PM, as the theory has been built around the latter, not the former. Figure 3 shows flowcharts for simple PM and FM side-by-side, which are designed to be equivalent in terms of output waveforms. Note that in order to having matching spectra, the modulator phases are offset by $\pi/2$, and their amplitudes differ by an f_m factor, due to the phase shift introduced by integration.

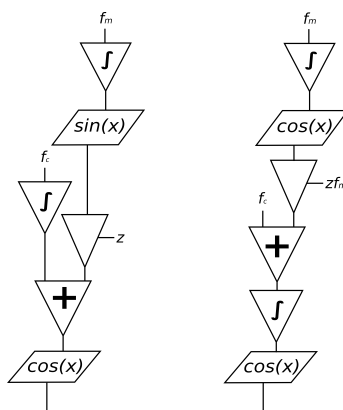


Figure 3. Simple PM (left) and FM (right) synthesis flowcharts

2. Digital Computing Environments

While FM was possible in analogue contexts prior to the introduction of direct digital synthesis, it was within a digital computing environment that it first flourished as a practical means of producing dynamic spectra. Chowning's description of FM [Chowning 1973], in fact using the theory of PM, led to its implementation in various computer music systems of the 70s (MUSIC 5, MUSIC 10, MUSIC 11, to cite but a few), and most notably in some of the first dedicated digital hardware synthesisers, such as the New England Digital Synclavier, and the Yamaha DX instrument line (who patented their version of PM based on Chowning's method). An important aspect of any digital implementation of FM/PM is the fact that the method does not produce bandlimited spectra in theory, although in practice higher-order sidebands are have very little energy. Therefore, it is important to be mindful of this and control the modulation in such a way that any significant partials are contained within the digital baseband. This means that we should set our sampling rate to provide a reasonable value for the Nyquist frequency, which defines the limits of the baseband. The typical sampling rate of 44.1 kHz should be sufficient in most cases (the original DX7 ran at 49 kHz), but if there is enough computing resources to set this at higher values, we should avail of it. With certain hardware such as field-programmable gate arrays (FPGAs), it is possible to use sampling rates in the MHz range, in which case for all practical purposes we may consider the synthesis process directly in terms of its non-bandlimited continuous-time equations.

2.1. Implementation

In systems where oscillators are readily available as black boxes (e.g. in Csound, as op-codes), FM is generally the most straightforward form to be implemented. Although this poses issues for further extensions using higher order modulation or feedback topologies, it is perfectly applicable to simple carrier-modulator arrangements. When implementing these techniques from first principles, however, it may be more advisable to opt for the PM form, as it allows a far more flexible approach, and the possibility of further extensions. Given the interest, within the context of ubimus, on small computing devices, embedded systems, and do-it-yourself (DIY) hardware [Timoney et al. 2020], it is worth discussing the general lines of a PM implementation that may be deployed with such resources. This only requires a couple of components, which may be constructed in different ways depending on the capabilities of the hardware. The first one of these is the phase generator, which consists of a feedback arrangement taking the ratio of the fundamental frequency and the sampling rate as input, and producing a normalised phase signal in the range $[0 : 1)$. It requires one addition and a modulo operation, which in a system with a floating-point unit (FPU) can be implemented by taking the fractional part of the number. The flowchart for a phase generator is shown on Fig. 4. It is also possible to implement this component with integer mathematics, with a few modifications. The phase generator performs the integration needed to determine the instantaneous phase from a frequency input, and so it takes over the role of the integrator described in earlier examples.

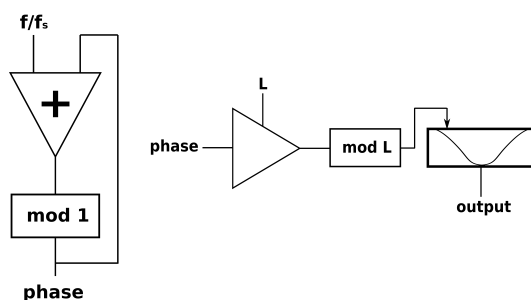


Figure 4. A phase signal generator (left) and table lookup operator (right)

The other component is the waveshaper, which maps the phase to a given waveform (in the case of simple PM, to a sine or cosine wave). This is typically implemented using a function table lookup. One cycle of the waveform is pre-computed and stored in an array (the table) of a given size, and then looked up according to the phase signal. The table lookup operator flowchart is shown on Fig. 4. The normalised phase is scaled up to the table size L , and the modulo is applied. Note that if L is a power-of-two, then the wrap-around operation is simply to apply a bitmask $L - 1$ with a bitwise AND, which is fairly inexpensive. The wrapped-around phase is then used in the table lookup. Given the symmetries in a sinusoidal wave, it is often possible to save memory space (at the cost of a few operations) by storing one half or one quarter of the waveform. This was the strategy applied, for example, in the early DX synthesiser circuits, where PM was implemented with discrete logic components (instead of code running in a microprocessor). With these components in hand, it is fairly straightforward to implement digital PM synthesis (Fig. 5). In addition to the modulator and carrier, it is also common to provide envelopes for both the index of modulation z and the output amplitude. In fact, with the

addition of an envelope to control the signal amplitude, each oscillator, constituted by the phase and lookup components can be considered a separate unit called an *operator*, which may be combined in various ways with other similar components to extend the synthesis method into more complex configurations.

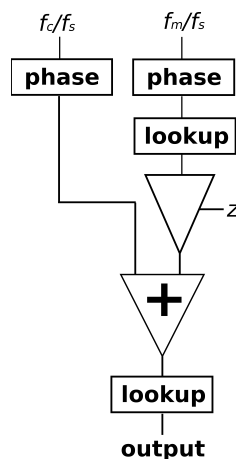


Figure 5. Digital PM synthesis

2.2. Complex Modulation

The first form of such extensions to simple FM/PM is to consider the use of a complex modulating wave, with more than one partial. It is important to note that the meaning of *complex* here has nothing to do with complex numbers, but it is used to mean a signal with more than one component, that is, not sinusoidal. A derivation of the complex modulation PM spectrum [LeBrun 1977] indicates that it is composed of partials at the sums and differences of the carrier and integer multiples of all modulation frequencies, $f_c \pm n_1 f_{m_1} \pm n_2 f_{m_2} \pm \dots \pm n_k f_{m_k}$, which can make it very dense if more than a few partials are present with significant energy in the modulator signal. One useful aspect of this arrangement is that only small indices of modulation z are needed for a sufficiently complex output, and for these values, the behaviour of the Bessel coefficients is more controlled (without the bipolar fluctuations seen with higher values of z). This produces much more smooth and natural spectral evolutions as the index of modulation is changed. In order to implement complex wave modulation, it is possible to take the two-modulator PM arrangement of Fig. 5 and add one or more further modulators, with their own individual z and f_m . Furthermore, if we consider an operator as described above, we can use two or more of these as modulators. We could go even further, and stack them to produce higher-order modulation arrangements, or use multiple carriers (Fig. 6). This is a very useful design, introduced in the DX series of synthesisers, which is only possible in such a straightforward way by the fact that we are implementing PM instead of FM.

2.3. Feedback

In fact, not only it is possible to combine operators to produce various topologies, we can also feed the output of an operator back to its input (Fig. 7), in this case with an additional envelope controlling the amount of feedback. For the system to be stable, we need to keep the index of modulation below or equal to unity. The carrier to modulator frequency ratio of course will be locked into a 1:1 relationship, and the resulting spectrum will have

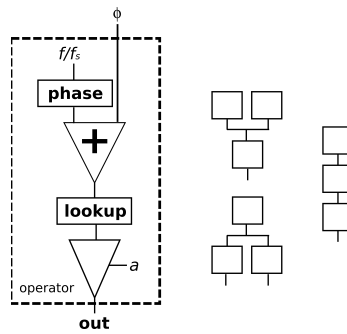


Figure 6. A PM operator with envelope a , frequency f , and three different example topologies

a decaying curve, close to $\frac{1}{f}$, producing an output that is very similar to a sawtooth wave (with maximum modulation). There is an implicit one-sample delay between input and output as this is designed to be implemented within a digital environment.

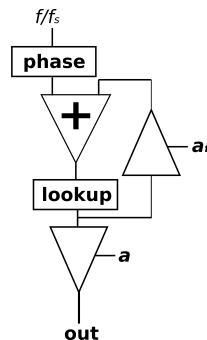


Figure 7. A PM operator using feedback modulation

2.4. Complex Carriers

Using a complex carrier wave instead of a sinusoid is another possible variation on the simple PM arrangement. Note that this is different to using several separate sinusoidal carriers; the resulting spectra is different, even if we match each harmonic of the complex carrier with an oscillator at that frequency. The somewhat surprising result is that the higher partials of a waveform will receive more modulation relatively to the lower order harmonics. The modulation index acting on each component of the carrier is actually scaled by the harmonic number, and so we end up with a very rich spectrum, where aliasing may be an issue (depending of course on the sampling rate, carrier waveform, as well as the modulation index, f_c , and f_m). In any case, we can implement the modulation of any waveform by storing one period of it in a function table and then using table lookup as before.

2.5. Delay-line PM

Alternatively, we can dispense with the carrier wavetable and replace it by a variable delay line [Lazzarini et al. 2008a]. In this case, the phase modulation signal is applied to the delay time. Since this is positive-only (a negative delay implies being able to predict the future!), the modulation signal needs to be given a DC offset. In that case, it makes

the delay time vary from a minimum (near zero, but taking account of interpolation may require it to be one or two samples) to maximum of perhaps only a few milliseconds. The carrier signal can be any arbitrary input, which is placed in the delay line, and the same principles outlined above for a complex carrier PM may be applied. If we can estimate the fundamental frequency of the input, then it is possible to set a given $f_c : f_m$ ratio to produce different types of harmonic and inharmonic spectra. This method is also known as *adaptive* FM (although PM is actually employed).

2.6. Splitting Sidebands

If we return to the generalised modulation arrangement shown in the flowchart of Fig. 2, then it is possible to split the spectrum into even and odd sidebands by taking the product of two separate real-valued waveshapers (driven by a cosine and a sine waveforms) and a sinusoidal modulator. Furthermore if we employ analytic signals, then we can split these two outputs once more into upper and lower sidebands. This is called split-sideband synthesis (SpSB) [Lazzarini et al. 2008b], which is an extended form of phase modulation. In order to produce the four outputs, we need to combine the two waveshapers, their Hilbert transforms (which shift their phases by $\pi/2$), and an analytic sinusoid modulator (effectively a cosine and a sine pair of signals) in a matrix product. The Hilbert transforms can be computed using an allpass filter (which shifts the phase but does not affect the amplitude signal). The flowchart in Fig. 8 shows the complete structure for SpSB, with the H boxes denoting the $\pi/2$ phase delay produced by a Hilbert transform operator. The four output signals then can be recombined or spatialised as desired. This approach provides another timbral dimension to PM synthesis, beyond the simple manipulation of z and $f_c : f_m$.

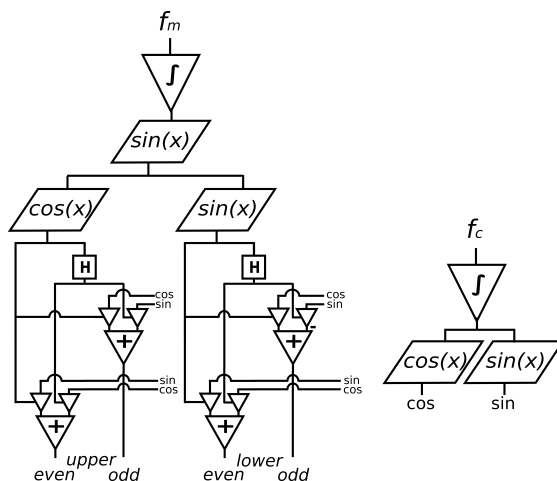


Figure 8. SpSB synthesis flowchart

2.7. Modified FM

We can also modify the PM equation so that it takes in a purely imaginary index of modulation, giving rise to Modified FM synthesis (ModFM) [Lazzarini and Timoney 2010]. In this case the spectrum amplitudes are similar to PM, but defined instead by a set of scaled modified Bessel coefficients. ModFM is implemented via the ring modulation of a

sinusoid mapped by an exponential waveshaper and a sinusoidal carrier (obtained by modifying the PM arrangement of 2, middle, so that it uses only real signals). An extended form of ModFM can be designed by combining it with the original PM arrangement, and defining two new parameters to control the transition between the different states of the synthesis, as shown in Fig. 9. The interesting aspect of this is that, with certain combinations of these two parameters, it is possible to create single-sided spectra (either lower or upper), which are not scaled by Bessel coefficients (but follow another expression based on the modulation index). This allows for various other timbral transitions that are beyond the typical PM spectra.

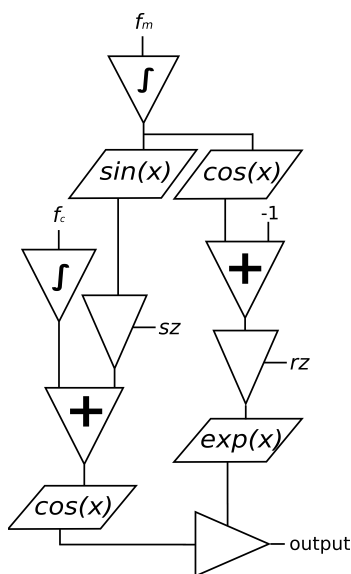


Figure 9. Extended ModFM synthesis

3. Analogue Computing Environments

Modulation synthesis within an analogue computing environment has a number of differences to the digital implementations discussed above. Two of them are fundamental: (a) signals are continuous in time and amplitude; and (b) precision is dependent on circuit design and electronic component characteristics and tolerances. The first of these points exempts us from worrying about aliasing: within an analogue environment, there are no absolute theoretical frequency limits. The second tells us that achieving the type of precision warranted by a digital environment may be hard. We should also bear in mind the fundamentally different characteristics of an analogue programming environment. Instead of a set of stored instructions which are executed step-by-step, a program is a circuit patch, an *analogue* of the problem we want to simulate [Lazzarini and Timoney 2020]. The programming environment is typically given by a modular synthesis system with several units (oscillators, amplifiers, envelope generators, etc), and we are dependent on what these may offer in terms of signals and control. Of course, a bespoke circuit may be designed for a particular application (and such approach is fairly common in DIY/maker communities). Another possibility is the use of programmable analogue circuits, which have been introduced in recent years [Lazzarini and Timoney 2020]. Within an analogue audio computing, signals are usually carried by varying voltages. Such signals may be

unipolar (non-negative) only or bipolar; generally the former is reserved only for controls, whereas the latter can be used to carry either audio or control information. Module parameter voltages may be set by potentiometers, by control signals, or a combination of both. It is far less common to see the use of varying electric currents as a means of passing signals, even though internally, in the circuitry of synthesiser modules these are important but not normally exposed by their interfaces.

3.1. Implementation

As we noted before, the basic component used in FM is the oscillator, and this is applicable to both digital and analogue systems. Within a modular environment, the voltage-controlled oscillator (VCO) is the module that normally implements the generation of waveforms which are employed in modulation synthesis. In these, voltages can be used to control the fundamental frequency of a carrier signal, and their output can be used as a modulation source. They typically generate the classic waveforms defined by the sawtooth, pulse/square, and triangle shapes, as well as sinusoidal waves. We can delineate a VCO from fundamental building blocks. The first aspect we need to note is the form in which the voltage control is given to (or taken by) a VCO for its fundamental frequency. While in a digital environment, we just present the frequency in Hz, here we need to define what voltage represents a given frequency. There are two basic options: a linear map, where we apply a given voltage level directly to a frequency in Hz; and an exponential, where changes in voltages are proportional to an interval, typically 1V representing an octave interval (a frequency ratio of 1 : 2). This latter is far more common, and in many ways more reasonable, and so we should adopt it as the standard approach. This gives us the first requirement for a VCO circuit, an *exponential converter*, which will take a linear input in the form of a voltage level V , and convert it to an output frequency, $2^V f_r$, where f_r is an arbitrary frequency reference (defining the lower point of the scale). Exponential converters can be constructed using semiconductor technology, namely transistors, which give an exponential response in current to changes in input voltages [Chamberlin 1985, 184]. The oscillator proper then is composed of the two basic elements we have seen before, an integrator (with a reset circuit) and one or more waveshapers. The role of the integrator is produce a varying phase, as we saw in digital synthesis program, which is a ramp or a unipolar sawtooth wave. This is a periodically repeating signal with the frequency defined by its input voltage. The actual operation of an analogue integrator is fairly straightforward; if implemented using an operational amplifier [Lazzarini and Timoney 2020], it can be simply described by an inverting amplifier to which a loop including a capacitor is added (Fig. 10). This circuit will integrate any voltages presented at its input up to the saturation voltage limit of the operational amplifier. The slope of the voltage change, and therefore the time that it takes to reach saturation, is proportional to the input voltage.

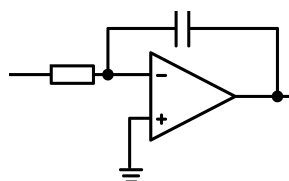


Figure 10. A typical inverting op amp voltage integrator.

In order to produce a repeating waveform, we need a reset circuit which can discharge the capacitor so that the voltage can rise again at the output. This is equivalent to the modulo operation employed in the digital oscillator. The reset circuit can be implemented by a timer integrated circuit (IC) which fires a pulse that can close a switch to discharge the oscillator. Alternatively, we can use a comparator, for example in the form of a Schmitt trigger, which will fire once the waveform crosses a certain threshold. The reset in fact can take the form of a square wave signal, which when integrated produces a triangular output. In this case we have a *triangle core* oscillator. The ramp integrator output, however, yields a *sawtooth core* oscillator which uses a pulse as a reset signal [Chamberlin 1985, 183]. A waveshaper is then used to produce the final waveform signals. Starting with a sawtooth phase signal, we can apply a DC blocker in the form of a resistor-capacitor circuit (also called an AC coupler) to produce a bipolar output. From this sawtooth, employing full-wave rectification, where the negative voltage is mirrored as a positive value, we can obtain a triangle signal. From the phase input, using a comparator we can produce a pulse wave signal with variable width (or duty cycle; a square wave being represented by a 50% duty pulse). Finally, using a more complicated waveshaper we can shape a sinusoidal signal to various levels of precision or purity. A general schematic of the standard VCO is shown in Fig. 11

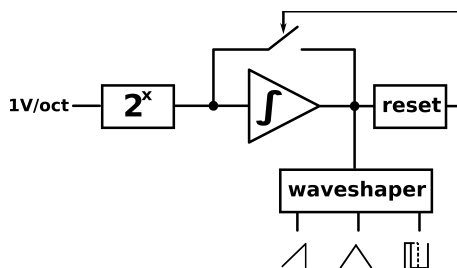


Figure 11. A standard VCO with sawtooth, triangle, and pulse waveform outputs

With regards to modulation synthesis, there are two aspects that are important to note about a standard VCO: (a) It takes in a frequency input, so FM, not PM is available; (b) The frequency input is exponential. Therefore, with a standard VCO neither PM nor FM in the form that we have so far seen can be implemented. For the former, we would need access to the integrator output, so that the signal at that point could be modulated. While this is not offered in the typical VCO, there are specialist modules that provide a means to do PM in this form, with voltage access to the circuitry after the integration point. In order to implement FM as it is done in a digital environment, we would need a linear (Hz/V) input that is added to voltage applied to the integrator (or another modification to the circuit with similar effect). That is more commonly offered by enhanced forms of VCO. Moreover, for FM to be properly implemented such modules need to allow bipolar signals to be fed to the integrator, as per the FM synthesis equation. Without these, some sort of misshapen frequency modulation signal is employed, with less well-defined results. For a proper FM implementation, the VCO requires a *through-zero* operation, that is, it can work in reverse phase [Hutchins 1981].

3.2. Exponential FM

Exponential FM (xFM) is therefore the typical mode of operation in an analogue environment with standard VCOs, and is generally contrasted with the additive form of FM

(which is referred to as *linear* FM). In xFM, since voltage signals are put through an exponential converter, the result is that any input modulation is multiplied by, rather than added to, the VCO frequency. Also, the current or voltage feeding the oscillator core is never going to be negative in this case. If compared to linear FM, this is equivalent to a distortion of the modulation waveform, as the signal is effectively passing through an exponential waveshaper. If a cosine wave is applied, then the resulting modulation is similar to that observed in ModFM, with modified Bessel coefficients defining the amplitude of the various partials of the waveform [Hutchins 1975]. One of the difficulties of xFM is that the modulation signal will most likely have some amount of energy at DC, which is going to be proportional to the Bessel coefficient of order zero (as a function of the modulation index). In this case then, changes in modulation amount would lead to an upwards pitch glide, since the modulation signal is applied to the frequency of the VCO. In fact, this is a general (less desirable) characteristic of FM versus PM, in that any DC component in the modulation wave will cause the carrier frequency to drift as opposed to just causing a phase offset in the waveform. So, while various inharmonic and even harmonic spectra may be tuned in with specific parameters of xFM (z, f_c, f_m), dynamic modification of spectra always has the subsidiary effect of a carrier frequency glide. This may or may not be an issue, depending on the musical application.

3.3. Stacked FM

As we saw earlier, within a digital environment, higher-order modulation may be successfully accomplished by stacked PM operators, producing a generally well-defined and predictable output spectrum. Since FM is the usual method employed in analogue systems, we may wonder whether some equivalent form of stacked modulation is possible, using a linear form of the method. The short answer is yes, but there are some complications due to the fact that DC components in a modulating signal are problematic. So, if we are considering simply a second-order (linear) FM arrangement, where we have two stacked modulators, it is possible to determine parameters that will not lead to the presence of 0 Hz partials in the modulator. For example, while a m ratio of $f_c : f_m = 1$ will lead to a DC component (by the virtue of the first lower sideband frequency being $f_c - f_m = 0$), an arrangement employing $f_c : f_m = 1 : 2$ will be guaranteed not to produce a 0 Hz partial. Alternatively, it is also possible to ensure that the modulation applied is mathematically equivalent to PM, leading theoretically to nothing but phase shifts, but this would require a more complex implementation. In any case, with simple or stacked FM implementation it is always important that we observe that the modulation signals have no DC applied to them at any stage of the circuitry, as otherwise we would not be able to dynamically control the modulation amount without the subsidiary effect of frequency glides.

4. Conclusions

In this paper, we offered a survey of the various traditional and more modern formulations of phase and frequency modulation. We have also looked at their deployment in digital and analogue computing environments, noting the specific aspects and conditions of each. In particular, we saw that PM is more suitable than FM in terms of generality of implementation, particularly within a digital environment, while FM is more common in analogue systems. The rationale behind is that it is much more flexible to modify the phase of a carrier without having to take account for the integration step built into an

oscillator. This allows for stacking and feedback to be arranged more freely. While this should also be the case in analogue computing, it is far less common to find oscillator circuits that allow phase to be modified directly. We also noted that the modulation methods discussed here are particularly suited to limited computing resources, as they are very economical. Nevertheless, they can also benefit from devices that support extremely high sampling rates, as in this case their results can be derived directly from the continuous time equations that define them, without concern for aliasing distortion.

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Tumaracatu: An Ubiquitous Digital Musical Experience of Maracatu

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Abstract. *We present Tumaracatu, an application for fostering a performative digital experience of maracatu. Our work's main contributions are curating an adaptive user experience of maracatu with ubiquitous off-the-shelf technology and advancing a new digital shaker model using physics-based concatenative sound synthesis. We developed the application in PureData for both Android and iOS smartphone devices using MobMuPlat. A preliminary evaluation by expert maracatu performers has shown that Tumaracatu simultaneously serves as a performance, entertainment, and learning tool.*

1. Introduction

Maracatu is a ritualistic performance from Recife, Brazil, which combines dance, music, and religion. A rhythmic choreography of primitive expression, rooted in African traditions, centers on the embodiment of musical performance gestures and dance movements as inextricable manifestations [César 1955]. The percussive-only nature of maracatu music unravels in time as rhythmic variations from baseline patterns. Current maracatu practices adopt a combination of the following percussive instruments: gonguê, agbê, timbau, tarol or caixa de guerra, alfaias, and ganzá, also known as mineiro. Each instrument has a specific function in the resulting polyrhythm of the *baque*. The Portuguese word *baque* is widely used in the musical universe of Maracatu to mean beat, blow, or touch and will be used hereafter in its original language due to its idiosyncratic nature [César 1955]. The musical performance of maracatu is the *baque*. Moreover, this word is present in two types of Maracatu existing: Maracatu Nação (Baque Virado) and Maracatu Rural (Baque Solto). The differentiation between styles of each *baque* is made by musical characteristics that invoke sound quality and quantity. The quality explains the rhythm, timbre, harmony, and volume, classifying the different types of toques of the maracatu. The most observed distinction is the musical rhythm of each group, some slower and others faster. The Baque de Luanda and Baque de Arrasto are considered slower; and the de Martelo, faster [De Carvalho 2007]. The timbre is perceived mainly through the sound of the alfaias. Variations in timbre performed simultaneously by a group of alfaias are of primary importance to maintain rhythmic coherence [Albernaz and Oliveira 2015].

The quantity refers to the numerous maracatu groups, given the greater volume of the performance sound. Fundamental to the structure of Maracatu are three specific layers that can be related to the gonguê, ganzá, and alfaia instruments. Figure 1 shows some

prototypical rhythmic patterns for each of the above instruments. The rhythmic patterns were inspired by the first author own experience and musical practice with Maracatu.



Figure 1. Representative baseline and variations rhythmic patterns for the gonguê, ganzá, and alfaia instruments in maracatu.

The gonguê is the highest-pitched instrument in the baque. Its musical function is to establish the pulse by a uniform rhythmic pattern to which the remaining layers (and instruments) articulate polyrhythms [César 1955]. The instrument has two steel-cast iron grooves with different tones, called positive (lower tone) and negative (higher tone). The first is generated over the instrument’s body; the second is near the base [César 1955]. The ganzá is a cylindrically shaped idiophone instrument constructed as a hand-woven basket or a metal canister filled with beads, pebbles, or other similar items. It is played by shaking the arm to produce a rhythmic pattern that is typically steady, e.g., a set of four quarter notes with accents on the first and fourth notes, orally taught as TU-ma-ra-CA-TU. The alfaias are drums, traditionally made of barrels with animal skin, and produce the lowest-pitched tones in the baque. They provide the main rhythmic ‘melody’ and are typically in larger numbers, the so-called *batuqueiros*. A typically African organization of high, medium, and low alfaias are adopted and referred to as *repiques*, *meião*, and *marcantes*, respectively. The variations are rhythmic patterns created by the alfaias, which break the constant repetition of the beat by creating intricate polyrhythms. They are the faster patterns in maracatu and require a virtuosic movement of the arms.

The performers’ movements in maracatu summon different corporeality that occurs in synchronization with and response to the metric properties of the music. For example, arm movements required to play the ganzá will equally impact the movements of the lower limbs, such as the legs [Afonso 2017]. The performed movements accumulate musical, visual, social, and ritual functions. The pulse marking on the body unifies internal tempos, facilitates the execution of syncopated rhythms, creates a ‘music of the bodies,’ and defines visual references for instrumental execution [De Freitas 2009]. Based on the corporal importance of this ritualistic practice arises the primary rationale of our work: listening to maracatu does not capture the practice. Maracatu needs to be experienced as a music-dance ritualistic symbiosis.

Leveraging on current ubiquitous digital technology, we propose *Tumaracatu*, a digital mobile application to promote a performative maracatu experience. It relies on the accelerometer sensor of a handheld mobile device (e.g., smartphone) to drive the control of the physics-based concatenated sound synthesis of the ganzá and an adaptive map-

ping of alfaías and gonguê loops. The physical dynamics of user movement control the mechanics of the generated maracatu rhythmic patterns beyond a passive listening experience. While advancing on the maracatu experience using off-the-shelf ubiquitous technology [Friedewald and Raabe 2011], Tumaracatu encompasses a contribution at the sound synthesis level, which seeks a computationally efficient technique compromising the quality of the interaction control and sound synthesis. The remainder of the paper is structured as followed. Section 2 reviews related work along three main lines of research: the application of ubiquitous digital technology for augmenting musical experience and two of its main underlying mechanics: the physical interaction modalities and sound synthesis for digital music instruments. Section 3 details the proposed mobile application for maracatu experience. Section 4 provides some preliminary evaluation of the Tumaracatu prototype application, and Section 5 summarizes the main conclusions of our study and avenues for future work.

2. Related Work

The domain of the current study accounts for multiple areas of knowledge related to the design of digital musical instruments and its multiple implications in listening and musical practices, namely what concerns the embodiment of the musical control gesture and its sonic feedback. For example, when listening to music, the body responds to the stimulus and allows the mind to recognize the music according to the resulting physical interaction. This physical response is strengthened in instrumental music practice due to the interaction between the musician, the instrument and the feedback loop that is established [Jensenius et al. 2009]. In this context, musical gestures have different functions, such as communicating musical intentions or producing sound [Leman et al. 2008]. A parallel could be established to the conductor role in communicating with the orchestra through a specific set of gestures and the performer role, which execute gestures that produce sound. Next, we survey related lines of research to the above-identified musical intentional and sound-producing roles in the digital domain, namely on what concerns the physical interaction and synthesis models in digital musical instruments.

2.1. Physical interaction

Music and movement support each other during a musical performance, and the musical gesture is a visible indication of this intimate relation [Zelechowska et al. 2020]. People tend to associate musical gestures with different sound features [Eitan and Granot 2006]. Sound features such as dynamics (i.e., the difference between the highest and lowest amplitude peak) can be associated with a particular movement's speed. In short musical gestures facilitate music understanding and expression [Meimaridou et al. 2020].

A relevant area of knowledge to the purpose of our study is the control of musical instruments through air gestures. Traditional musical instruments are manipulated with physical contact through the body movement of specific parts, such as the hands. Electronic and digital instruments also require physical contact to actuate on a key or push a button to generate sound. An exception is the theremin [Theremin and Petrishev 1996], an instrument played with air gestures controlling pitch and volume as a result of the proximity to two antennas. More recently, with the advancement of motion sensing technologies, such direct physical connection has become more diffuse. Motion sensing in mobile devices promotes the musical exploration of digital instruments through a set of

meaningful movements performed *in the air* [Dahl 2015]. The author conducted a series of experiments on sensorimotor synchronization to understand what people do when performing air gestures in time to rhythmic sounds and how their movements correspond to the sounds. The results showed that acceleration peaks yield the best results in sensorimotor synchronization for a real-time musical system because they occur on average before the audio event and do not vary as much with note speed. In summary, the study revealed that people prefer to execute a movement first and hear sound next.

2.2. Sound Synthesis of Musical Shakers

The sound synthesis of the ganzá, a fundamental instrument to our work and a pervasive instrument across different music genres fits within the broad category of musical shaker. The digital sound synthesis of musical shakers has been prominently pursued by physical modeling synthesis emulations, which allow the generation of a variety of timbres and the intuitive parameterization of the algorithm to accommodate its multiple material size manifestations.

In [Cook 2002] presents the Physically-Informed Stochastic Event synthesis Model (PhISEM) containing several controllers, such as accelerometers or force-sensing resistors, generating MIDI data to parameters for a synthesis model which translates shaking and scraping gestures into sound. Based on this model, the author developed the *Haptic Maraca* [Cook 2003], which adds a haptic layer to reinforce the sound-gesture connection. The *bEADS Extended Actuated Digital Shaker* [Williams and Overholt 2017] expands the *Haptic Maraca* with a loudspeaker embedded and modeled after a shaker's generic form. The high computational expense of these digital instruments required an external computer to run the audio engine and the high complexity of the model in capturing the involved non-linear control gesture and sound response relationships. Moreover, these physical simulation challenges simplify the continuous-time model into a discrete approximation at the expense of the expressive realistic result. Recently, [Piepenbrink 2018] developed the *eShaker* and *eChocalho*, which are self-contained instruments, battery-powered, and can synthesize various shakers, rattles, and other handheld shaker percussion. Although the graphical user interface parameters and preset selection can be configured wireless through a computer program, the instrument has an embedded sound synthesis engine. More recently, there has been a development of commercial mobile applications of shakers. *The Salt Shaker* is a musical instrument built upon ideas of tangible and embodied interaction [Craig and Armen 2020]. It uses acceleration to encode shaking gestures into digital information, thereby translating these gestures into a rhythm and humanizing the digital audio synthesis process. Furthermore, commercial applications such as the music game *Shakers*¹ an Android application that emulates different with ten different percussion instruments, including a shaker; or the *RealShaker*² which explores a real shaker's dynamics and physicality as the user moves, tilt, and shake his device to generate sound.

3. Tumaracatu: A Digital Mobile Application for Maracatu Experience

The application Tumaracatu, named after the underlying phonetic accents used to learn the ganzá, aims to foster an performative digital experience of the maracatu practice beyond

¹<https://play.google.com/store/apps/details?id=com.bti.shakers>

²<https://apps.apple.com/us/app/realshaker-highly-realistic-responsive-shaker-rattle/id1062454423>

passive listening. To this end, Tumaracatu mimics the ganzá music-movement expression from instantaneous user actions to create a digital ganzá shaker and provides two additional layers of gonguê and alfaia rhythmic patterns that gradually adapt to long-term user actions.

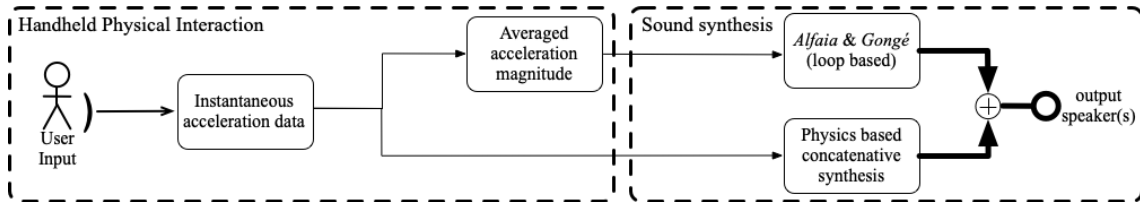


Figure 2. Architecture of the Tumaracatu application. Dashed lines isolate its two major components for physical interaction and sound synthesis. The solid rectangular blocks denote the processing blocks of the application. The flux of control data and audio signals is indicated as solid thick and bold arrows, respectively.

Tumaracatu was deployed as a mobile application for off-the-shelf handheld devices, namely smartphones running Android and iOS. Employing handheld devices, we target a broad audience which has facilitated access to these devices. Pure Data [Puckette et al. 1997] was adopted to design the application, which we later ported to mobile devices using MobMuPlat [Iglesia and Intermedia 2016]. The architecture of Tumaracatu is shown in Figure 2. It features two main modules for physical interaction and sound synthesis (dashed lines in Figure 2), each with two primary processing modules (solid rectangular blocks). User input gestures controlling a handheld device are captured by accelerometer sensor technology, embedded in the vast majority of current handheld devices on the market, and aim to promote a feedback loop between the user’s movements and the maracatu musical counterpart. In greater detail, the instantaneous and (long-term) averaged acceleration magnitude is used to control two sound synthesis processes: ganzá physics-based concatenative sound synthesis and the adaptive loop-based gonguê and alfaia playback.

3.1. Handheld physical interaction: Capturing Performative Gestures

To capture user input gestures, we use the triaxial accelerometers embedded in handheld mobile devices. Accelerometers are technological devices that allow obtaining a measurement of linear acceleration in a certain spatial axis. There are various mechanisms to measure this magnitude. Common strategies adopt mechanical (dynamometers), electromechanical (piezoelectric), electrical (capacitors), or magnetic (hall effect) components. Accelerometers in handheld devices are often embedded in chips to measure acceleration for each spatial dimension (x, y, z). Although each chip computes the mechanical, electrical, or magnetic transduction to obtain the magnitude of the acceleration in each axis, according to the manufacturer’s own criteria, accelerometers usually report the acceleration based on the acceleration of gravity (g) on the planet earth ($1g = 9.81m/s^2$), in a range between $\pm 2g$ and $\pm 24g$. In both cases, the chips can typically sample acceleration in the range between 100 MHz and 400 MHz. For example, the default accelerometer sample rate on an iOS devices is the range $\pm 2g$ at 100MHz with a nominal resolution of 0.018g. In the $\pm 8g$ range, the resolution would be four times higher [Allan 2011].

To capture the accelerometer data, we adopted MobMuPlat, which normalizes data to the range ± 1 at a sampling rate of $\approx 100\text{Hz}$ (iOS) and $\approx 20\text{Hz}$ (Android). To account for velocity changes over time regardless of the direction in space, we calculated the magnitude of the triaxial accelerometer data using the Euclidean norm from the sensor data. Following [Van Hees et al. 2013], to separate movement and gravity components in the acceleration data, we subtract to the norm one. This strategy allows the acceleration magnitude value to be invariant to the device’s spatial position. The resulting value is considered our instantaneous acceleration magnitude, which controls the ganzá. An average value across a sliding window of 5 seconds provides a long-term indicator of user movement, which we adopt to control the loop-based variations of the alfaías and gongüê.

3.2. Physical Ganzá Control and Synthesis

To digitally emulate the continuous sonic interaction of the ganzá, we adapt the physics-based concatenative synthesis (PBCS), a recently proposed technique by [Magalhães et al. 2020] to model the interaction and synthesis of rolling objects. The motivation to adopt PBCS is due to 1) the expressive potential of the technique for fostering a high degree of correspondence across the physical and the experienced interaction, as it enforces, by design, the perceptual congruence through the capture and rendering from realistic sources; 2) the exemption of cumbersome mappings across input gesture and its sonic feedback; 3) its time and space computational efficiency.

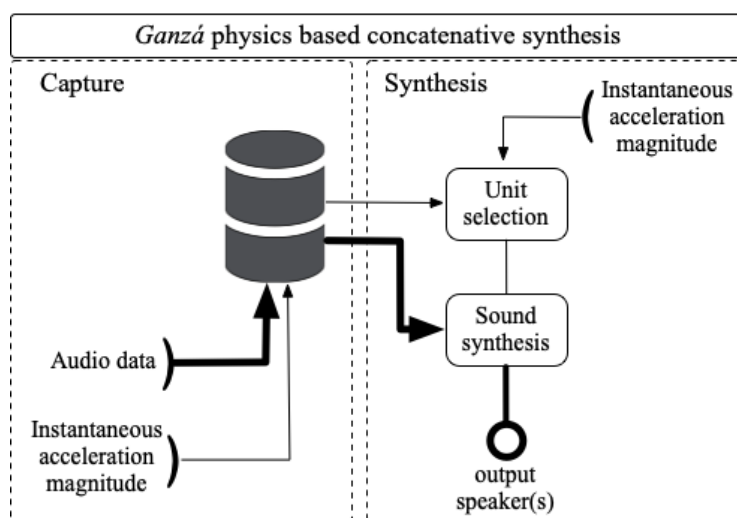


Figure 3. Architecture of the physics-based concatenative synthesis of the ganzá. Rectangular blocks indicate the main processing modules and arrows denote the data flux (dashed lines for control data and solid lines for audio signals).

Figure 3 shows the architecture of the proposed PBCS framework. It includes two major capture and synthesis components. The capture component assembles an annotated *corpus* of ganzá *units* of about $t = 93$ ms (i.e. 4096 sample window at 44.1 kHz sampling rate). Each unit is annotated with a value of acceleration magnitude. To collect the annotated corpus, a synchronous recording of audio and acceleration magnitude data was conducted. A single acceleration magnitude value per unit duration is adopted by averaging all values across the unit duration. An important design feature of the PBCS capture

is collecting sound grains for the most comprehensive array of acceleration magnitude values in the smallest duration for efficient computational memory space management. The audio and acceleration captured data consisted of ≈ 30 seconds including a large set of typical ganzá gestures (e.g., *toque seco* and *cambinda* – see Figure 1 a musical notated representation of these rhythms), silence, and free exploration of movements at various velocities.

Figure 4 shows the captured audio and acceleration magnitude data of a ganzá gesture. Of note is the non-linear relation between the two signals, which are typically misrepresented in techniques that manually enforce these relationships, such as in physical modeling. A great advantage of PBCS is the modeling of both control gestures and their resulting sonic feedback.

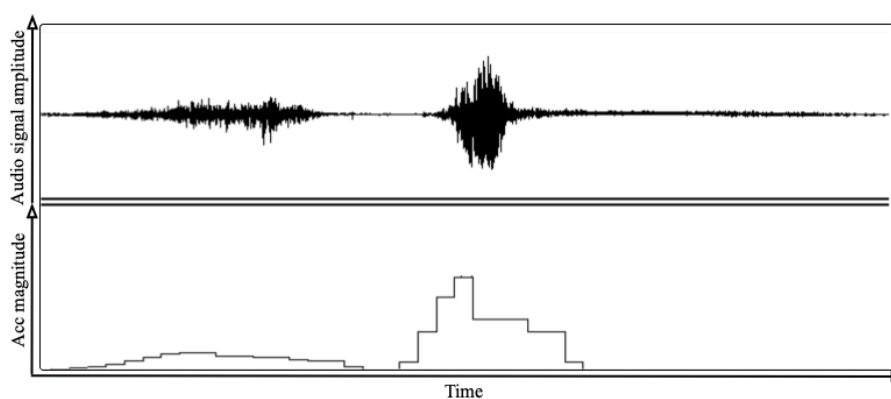


Figure 4. Synchronous audio and acceleration magnitude data for a maracatu toque seco gesture from the captured session.

The synthesis module generates the auditory feedback by concatenating short audio units from a corpus of ganzá recordings. The selection of a temporal sequence of units to be concatenated is driven by a target defining at each $t/2$ (i.e., an overlap of two sample windows). The real-time magnitude acceleration data defines the targets. In the feature space, audio units stemming from the same physical conditions during the capture stage result in neighbourhood locations. In other words, we ascertain that sound grains with similar acceleration magnitude values have a perceptual resemblance, thus a smaller distance in the feature space. Furthermore, audio source signals and annotations are captured in the same conditions as the rendering stage. Thereby, audio units' annotations and online target feature vector navigation occurs in the same feature space.

3.3. Gonguê and Alaias Adaptive Loop-based Variations

To emulate the ritualistic character of the maracatu performance in terms of embodied expression, we adopt a (long-term) average acceleration magnitude to adapt a set of loops for the gonguê and alaias. The audio loops for each instrument were designed to account for different degrees of density and complexity. The rhythmic patterns adopted are shown in Figure 1. The starting loops (numbered as loop 0) of gonguê and alaias establish a baseline pattern that defines the pulse. Once the user starts interacting with the application and gradually evolve the ganzá rhythms, the alaias and gonguê loops are equally adapted to respond to the continuous experience. The climax of adaptation results in a more dense rhythmic pattern with an intricate polyrhythmic structure and greater tonal

components resulting from the addition of a larger set of pitched (repique and meia) alfaias. Figure 5, shows the mapping between acceleration magnitude values (normalized to the [0-1] range) and the loops of the gonguê and alfaias.

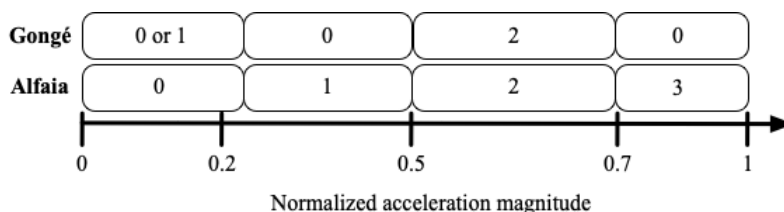


Figure 5. Adaptive Mappings between normalized acceleration magnitude values and the gonguê and alfaias loops. The numbering of the loops correspond to those shown in Figure 1.

The gonguê and alfaia loops were sequenced from existing recordings of maracatu de baque solto collected in a previous study [Davies et al. 2020]. Before the loop sequence, we isolated gonguê alfaia notes resulting from a large set of percussive strokes. Then, we arranged the sequences to comply with the rhythmic pattern shown in Figure 1, namely their accents and tone variation. Finally, we adjusted the loops using micro-timing deviations for accounting layered interaction.

We created three gonguê loops. Gonguê loop 0 established a baseline pulse, and it is widely adopted across many maracatu expressions and one of the most traditional patterns. Nação Elefante and Leão Coroado adopt this pattern. Gonguê loop 1, expand the set of tones notes a twofold higher and lower notes. The lower notes represent the ‘attack’ accented sound, and the higher notes can be understood as their response. This gonguê pattern is adopted by Nação Porto Rico. The gonguê loop 2 mixes the two previous loops to create an intricate response when combined with loop 2 of the alfaias (i.e., the martelo variation). For the alfaias, we created four loops. Alfaia loop 0 establishes the traditional *marcação* or baseline pulse, which all maracatu nations adopt when performing the alfaia with the right-hand only. The alfaia loop 1 is the *marcação* plus a convention. This convention will usually be repeated in the presentation being originated by the Nação Estrela. The alfaia loop 2 adopts the repique drums playing the *martelo* of Nação Estrela Brilhante do Recife, a rhythm known to be more accelerated. The alfaia loop 3 adopts marcante drums playing a bass pattern and alfaia meia drums playing the *arrasto* variation, resulting in a highly dense rhythmic pattern.

4. Evaluation

We conducted a preliminary qualitative evaluation to assess the musical affordances of Tumaracatu. Particular emphasis is given to the inextricable input and output (sonic feedback) modules of the application for the digital synthesis of the ganzá. Collected feedback will be used to improve the future design iterations of Tumaracatu. In greater detail, the evaluation consisted of a task-based online experiment followed by an interview. A purposive sampling of participants with previous musical expertise with maracatu and, in particular, of the ganzá in a baque was adopted. To reach eligible participants, we establish direct contacts with personal acquaintances and their network of performers to widen the sociodemographic of the sample.

4.1. Procedure

The conducted experiment had a threefold phase structure. The first phase aimed to install the application on the device and create some degree of familiarity with its mechanics. In greater detail, once user installed the application, they were asked questions about the maracatu universe and their experiences as a musician. Then the user was invited to experiment with the ganzá alone for about two minutes freely. No prior instruction was provided.

The second phase of the experiment included the completion of two tasks. The first task consisted of sequentially performing the cambinda, toque seco and tumaracatu rhythmic patterns (see Figure 1) ganzá with the application. No tempo, i.e., beats per minute (bpm), was imposed for the task, and for each pattern, participants could explore the rhythm for about two minutes. In the second task, participants were given the same instructions to be performed with the additional gonguê and alfaia rhythmic patterns and adaptive mechanics. Besides providing an encompassing backing track for the maracatu, the additional layers also aimed at further constraining the user to the given tempo, 90 bpm. This twofold design aimed at having participants approach the experiment in two different ways with increasing degrees of constraints, namely in terms of the tempo, which was imposed in the second task by the underlying gonguê and alfaia patterns.

In the third phase of the experiment, we conducted a semi-structured interview. By promoting an informal conversation with the participants, we prioritize their most immediate impressions and concerns about Tumaracatu. The protocol was also prone to guide the participant in providing specific details about: the implications of different rhythmic pattern densities in the sonic feedback of the ganzá and the recognition of the adopted rhythmic layers and instruments following the participant's practice.

4.2. Results

Three experienced musicians in the practice of maracatu completed the experiment (two females and one male participant aged between 28 and 25). Two participants used IOS, iPhone 6 and iPhone 11 PRO. Furthermore, one participant used Android, Samsung A8. All participants are active maracatu performers with at least eight years of performance practice. In the third phase of the experiment, we recorded a semi-structured interview for transcription purposes, for which consent by the participant was collected.

The participants were able to understand the underlying mechanics of the Tumaracatu, with few to no prior explanations, and were able to complete both proposed tasks. However, an overall comment on the need for an adaptation phase to learn finer degrees of control of the ganzá was pinpointed. Therefore, the results suggest some learning curve towards expressive performance. One participant highlighted difficulties in playing ganzá on a mobile handheld device due to its reduced dimensions compared to the acoustic instrument. All participants reported an overall enjoyment in conducting the experiment, mainly in phase two, where the gonguê and alfaia instruments were added.

Participants reported high degrees of control in performing the cambinda rhythm and toque seco. All participants reported challenges keeping a specific tempo with the ganzá without the two remaining gonguê and alfaia layers. Overall, the interaction of the ganzá and the alfaia was perceived as the most challenging. The participant using an Android device found greater difficulty controlling the cambinda pattern, which requires

greater degrees of freedom than the *toque seco*. The same behaviour was not perceived by participants adopting iOS devices. This behaviour is probably related to the rate at which the sensor data was acquired. Further research on the implications of each device's sensor technology and signal processing techniques should shed light on perceived differences.

One participant recalled that the *ganzá* is an instrument that requires an advanced performance technique, fundamental to the overall stability of the *baque*, namely in establishing a pulse. To this end, we conducted the tasks to pursue the right pulse, which aligns with the rhythmic pattern *toque seco*. In sum, the feedback collected from using Tumaracatu suggests it captures to a particular degree the challenges inherent to the acoustic practice of the *ganzá*, and that somehow the experience of performing *maracatu* was recollected in the digital domain.

5. Conclusions and Future Work

In this paper, we presented Tumaracatu, an application deployed as a mobile application for off-the-shelf handheld devices, namely smartphones running Android and iOS. The main goal of Tumaracatu is the digital emulation of the experience of *maracatu*, a ritualistic performance that inextricably combines dance music and religion. To this end, an experience of the *ganzá* performative gesture was our primary direction. In this context, two main contributions resulted from our work: 1) a physics-based concatenative synthesis model of the *ganzá* and 2) a curated digital experience for *maracatu* offering the possibility to experience the *maracatu* through a handheld mobile device. The code and multiple performance examples with the Tumaracatu, can be found online at <https://bit.ly/3tR84Gf>.

A preliminary evaluation of Tumaracatu consisting of a task-based experiment followed by a semi-structured interview was conducted with three expert musicians. Particular emphasis was given to the performance with the *ganzá* and its interaction with the remaining layers of *gonguê* and *alfaia* adaptive loops. Ultimately, the feedback collected during the experiment aimed to improve future iterations of Tumaracatu. Participants reported high degrees of control in performing both the *cambinda* and *toque seco* rhythmic pattern. The experiment denoted some challenges concerning the iteration of the *ganzá* with the remaining instruments, namely when the density of the rhythmic patterns increased. We can conclude that Tumaracatu provides a digital application to learn, perform and experience *maracatu*, beyond passive listening.

In the future, we aim to improve the design of Tumaracatu to tackle some identified limitations in the experiments: understand the different performance across iOS and Android devices and the fluency of gestures concerning sonic feedback. Future user studies shall equally inform optimal parameterization of the PBCS of the *ganzá*, namely the optimal unit duration, source requirements in terms of variation and duration for enhanced realism approximations and accurate sonic interaction. Finally, we will research novel mappings between sonic feedback and biosignals as control structures to promote an embodied experience of *maracatu* in the digital domain. Based on the biosignals' response, we intend to promote the creation of a feedback loop between the user's body and musical performance to reprogram the sound experience of that universe from an individual corporal perspective.

Acknowledgments

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Kaleidophone – A Collaborative Web-based Tool for Comprovization Based on Arithmetic Operation Grammar

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***Abstract.** Kaleidophone corresponds in concept to a previous work which found its way into the article "Composing by Laypeople: A Broader Perspective Provided by Arithmetic Operation Grammar" (G. Kramann, Computer Music Journal 44(1):17-34) as THE FLIPPIN POMPOMS' but is web-based and is collaborative by means of the internet. As the preceding work, Kaleidophone has two successively connected transformation layers responsible for generating the currently sounding music. Special attention was paid to easy usability in order to give all participants the possibility to influence the musical performance themselves.*

1. Introduction

Kaleidophone has two successively connected transformation layers responsible for generating the currently sounding music. On the first layer, a multicolored spatial figure is designed. This figure is projected twice into the plane. The contiguous colored areas in these two 2D projections are each translated into an arithmetic formula. These two formulas represent the second transformation layer and henceforth represent a generation rule for the tone sequences of two software-based musical instruments. Since all participants in Kaleidophone are not only listeners, but should also have and use the opportunity to change into a role in which they actively influence the musical performance, Kaleidophone itself is available as a web page under the link <http://kramann.info/kaleidophone> and an introductory video into its use is given here: <https://youtu.be/HzZjTQTjJko>. The name Kaleidophone comes from a special visualization option that can be selected by means of the button "KALEIDOSCOPIIC VIEW (passive)" and that has a certain similarity with looking into a kaleidoscope.

2. How is collaboration organized on the web at Kaleidophone?

The only difference in using Kaleidophone between now, when you are reading this text, and a targeted collaborative performance at Ubiquitous Music 2021 is that more people will probably come together using it. Thus, Kaleidophone is not only ubiquitous in space but – due to its durability – also in time and is intended to contribute to "Everyday Creativity" (compare D.Keller et.al.: "Ubiquitous Music", pp.29-30, Springer, Heidelberg 2014) with a special focus on laypeople in particular. To ensure this, no registration is required on the start page. Only a nickname must be entered before the start. When the START button is pressed, the view changes to a display showing a 5 by 5 by 5 grid with colored spheres on the left and two 2D projections of this structure next to it. Still further

to the right, a piano roll-like representation depicts the musical structure currently being created. The data describing the current state of this structure and the angles at which the projections are made are continuously downloaded from a central server and thus updated. Conversely, any user can add or remove a colored sphere at any time. This action is then stored on the server and is available to all users after some time. There is only one simple rule how the actions of the different users are handled: Each location in the 3D grid and each angle is considered separately. If a change is made at a particular location by user A, it will only take effect if either the last change at that location was also made by user A, or the last change made by a user B at that location was at least 30 seconds ago. Sound generation takes place locally at each client. Only the structural data of the 3D shape and its projection angle are exchanged between the participants. This data exchange takes place via the HTTP protocol. Although this has the disadvantage that changes sometimes only take effect with a delay of several seconds at all clients, it has the advantage that Kaleidophone is constantly available in its full functionality and the data exchange works very securely.

3. How Does a Collaborative Comprovization with Kaleidophone Work in Practice?

Kaleidophone was programmed in Javascript and can be used at any time by navigating to the weblink <http://kramann.info/kaleidophone>. The piano roll displayed with each change reacts immediately and visualizes the musical structure over several bars. In particular, this allows participants to quickly assess the musical result of their changes and thus opens up the possibility of quickly searching the parameter space in order to then remain with an appealing setting. It is possible to arrange to perform at a certain time with each other. Basically, however, a change of the persons handling kaleidophone is fluently possible and the duration of a performance is in principle unlimited. To enhance the feeling of creating together, the nicknames of the currently active participants are displayed in the order of their activity.

4. What sense does it make, as in Kaleidophone, to unfold a musical structure across multiple hierarchical layers of representation?

The layers of representation used are borrowed from a context of meaning from the life-world (in the sense of Edmund Husserl's phenomenology, see e.g. E.Husserl, D.Carr [transl.]: "The Crisis of European Sciences and Transcendental Phenomenology", pp. 48-53, Northwestern University Press, Evanston 1970.) of the users, which is familiar to them: because of their own corporeality and the corporeality of the world around them, users already know what it means to form a spatial gestalt and to project it into the plane.

The use of arithmetic formulas as a function of time on the underlying level, which finally lead to the generation of the musical events, was similarly done with the intention of referring to a familiar context of meaning from the users' lifeworld.

The point is not so much to actually fully comprehend the context, but to provide a plausible, compact, easy to survey and manipulate symbolic representation for the currently audible musical structure. The basic idea overall is that a comprehensible handling of Kaleidophone can be learned over time via the perception of the presented connection between figure and formulas on the one hand with the current sound events and their visualization as piano roll on the other hand.

Projeto OUIJA: Agenciamento e Relações Espaço-Temporais na Ecomprovisação

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Resumo: *Dadas as condições atuais de fazer música que envolvem práticas a distância, principalmente com o auxílio da internet, consideramos formas de produção sonora de forma a ampliar estratégias de apoio. Para contornar os atrasos decorrentes das práticas musicais via internet e não se limitar à baixa qualidade sonora, abordamos a interação musical coletiva com ênfase nas práticas gestuais e visuais. Com base em conceitos baseados no senso de agenciamento, construímos uma obra para cordas friccionadas, sons eletrônicos e interação online, o projeto Ouija (comprovisação de Luzilei Aliel). Nosso objetivo geral foi investigar o uso de conceitos usados no senso de agenciamento em práticas musicais que evidenciam relações gestuais e visuais. Num segundo momento, pretendemos desenvolver formas recentes de práticas musicais online. No projeto Ouija, as estratégias de agenciamento parecem apoiar o processo de tomada de decisão, ajudando-nos a compreender as relações entre improvisação e planejamento composicional. Nesse sentido, a proposta contribui para as práticas no campo da composição e improvisação musical (comprovisação), sugerindo novas possibilidades criativas para a interação entre músicos ou leigos em práticas musicais dentro deste modelo.*

Abstract: *Due to the current conditions of making music that involve distance practices, especially with the support of the internet, we propose other forms of sound production in order to expand support strategies. In order to avoid delays arising from musical practices via the internet and not be limited to low sound quality, we decided to approach collective musical interaction with an emphasis on gestural and visual practices. Based on concepts based on the sense of agency, we developed a work for strings, electronic sounds and online interaction, the Ouija project (comprovisation by Luzilei Aliel). Our aim was to investigate the use of the concepts of agency sense in musical practices demonstrating gestural and visual relationships. Secondly, we developed recent approaches to online musical practices. In the Ouija project, agency strategies support the decision-making process, helping us to understand the relationships between improvisation and compositional planning. In this sense, the proposal contributes to practices in the field of composition and musical improvisation (comprovisation), suggesting new creative possibilities for interaction between musicians or laypeople in musical practices within this model.*

1. Introdução

A produção musical pode ser atualmente dividida em duas categorias: pré e pós-2020. O impacto da pandemia foi imediatamente sentido pelos artistas e pelas comunidades que se dedicam à atividade musical, mudando a forma como as pessoas vivem e compartilham experiências musicais. Apesar de profundas, essas mudanças não são uniformemente distribuídas. Em alguns casos, suas consequências não são óbvias. Os países que adotaram medidas sanitárias precoces conseguiram recuperar uma aparência de “normalidade” em suas atividades culturais. Os países que investiram pesadamente na vacinação em massa estão lentamente recuperando o acesso às atividades culturais. Mas grande parte do mundo tem sofrido uma forte redução do acesso à fruição e criação musical, principalmente quando se consideram as modalidades adotadas até 2019. Outro fator relevante é que a maioria das ferramentas digitais existentes não foi projetada para suportar toda a gama de interações musicais que caracterizam experiências musicais compartilhadas pela comunidade.

As mudanças generalizadas que afetam o futuro das práticas musicais exigem novas formas de pensar sobre a música. Felizmente, parte dos cenários atuais já foram considerados a partir de perspectivas práticas e conceituais dentro do campo emergente da música ubíqua (ubimus). O conjunto de pesquisas sobre ubimus produzidas durante os últimos 14 anos pode fornecer vislumbres de como a produção musical pode ser adaptada para sobreviver e florescer em um mundo pós-pandêmico. Assim, um dos objetivos de nossa discussão é desvelar os limites das possibilidades atuais de ferramentas aplicadas à práxis musical pós-2020. Nessa configuração, o aumento do uso das tecnologias da informação e de estratégias de compartilhamento nas práticas artísticas precisa ser repensado. Paradigmas composicionais e improvisacionais anteriores são estranhos a este novo contexto. Assim, podem ser necessárias novas vias de investigação que forneçam alternativas ao discurso dominante.

É dessas premissas que surge o projeto Ouija. Diante de um mundo pandêmico onde as práticas musicais aconteciam por meio de plataformas Voip¹ (google meet, zoom, skype, etc.), os artistas buscaram uma correlação direta entre o modus operandi das práticas musicais tradicionais. No entanto, as limitações físicas e tecnológicas não permitem as mesmas ações. O atraso existente devido à conexão com a internet impossibilita o processo de sincronismo, limitando as práticas baseadas nesta situação. As transferências de dados de áudio via software Voip tendem a causar compressão e degradação da qualidade do som, afinal, utiliza formatos leves para melhor transferência (como MP3), empobrecendo o potencial do som, tão relevante para as práticas artísticas.

Assim, elaboramos o projeto Ouija, que visa utilizar mecanismos de composição e improvisação (comprovação) para oferecer novas possibilidades de criação artística em formatos que utilizam a internet e plataformas Voip, onde as práticas sincrônicas são ignoradas e as trocas sonoras entre os agentes inexistentes. Ou seja, embora haja prática musical, o foco é dado às interações gestuais e visuais, limitando as questões sonoras. Para isso, utilizamos o conceito de sentido de agenciamento para delimitar como os processos de percepção gestual e visual suportam estratégias de composição e improvisação. No entanto, primeiro precisamos estabelecer a comprovação dentro de

¹ Voice over internet protocol (Gray 2010).

uma perspectiva ecológica.

2. Comprovação desde a perspectiva ecológica

Desde o final dos anos 1990, diversas propostas baseadas em cognição ecológica vêm sendo aplicadas em múltiplos contextos artísticos (Burtner 2005; Keller 2000).² Nance (2007) propõe estratégias para a escrita instrumental acústica (partituras sonoras), ampliando assim o leque de recursos. Connors (2015) sugere o conceito de performatividade ecológica (*ecological performativity*), adicionando mais uma camada de técnicas às instalações artísticas. Numa série de obras performáticas, Aliel et al. (2015; 2018) fomentam a fusão entre a improvisação e as abordagens composicionais. Através de estratégias síncronas e assíncronas, as práticas comprovisatórias aplicam o pensamento ecológico para impulsionar novos comportamentos, visando o aumento do potencial criativo dos participantes.

A comprovação ainda não alcançou uma definição consensual. Em termos amplos, engloba composição e improvisação musical. Suas origens remontam às propostas de improvisação da década de 1960 - exemplificadas na prática de grupos como Scratch Orchestra e Musica Elettronica Viva (Cardew, 1969; Curran e Teitelbaum 1989). As abordagens comprovisatórias atuais envolvem o uso de recursos instrumentais e eletroacústicos (Bhagwati, 2013; Dudas, 2010; Hannan, 2006). Fujak (2011) argumenta que as atividades realizadas pelos seres vivos podem ser planejadas só parcialmente. Como os eventos e os fatores não controlados impactam os processos criativos e moldam o comportamento dos participantes, ele propõe uma perspectiva da comprovação a partir de metáforas de interação entre os seres vivos. Essa visão é consistente com os conceitos e métodos defendidos pelas práticas criativas cognitivo-ecológicas.

Na última década, o pensamento criativo ecológico ganha força com as iniciativas musicais ubíquas (*ubimus*). Apoiadas pela pesquisa *ubimus*, surgem novas formas de pensar e fazer música compatíveis com o distanciamento físico (Keller, Messina e Oliveira, 2020). Nessa diretriz, problemas como a baixa qualidade da conexão (*delay e jitter*), a dificuldade na captação de áudio e as limitações na largura de banda para a transmissão de dados tornam pouco sustentável a prática acústico-instrumental (inclusive as propostas pensadas como uma continuidade desse enfoque e em especial as baseadas na prática síncrona e presencial).³ Desta forma, a presencialidade e a sincronicidade perdem sua relevância para as práticas coletivas distribuídas perante a necessidade de encontrar outras formas de organização social e de suporte cognitivo para viabilizar tanto as trocas de recursos criativos quanto às modalidades alternativas de interação musical em contexto ubíquo.

² Veja-se em (Carson, 2020), uma conversa informal sobre essas iniciativas.

³ O impacto negativo da falta de infraestrutura e de suporte para as práticas musicais criativas não têm a mesma dimensão em todos os contextos sociais e econômicos. A tendência pós-2020 é o aumento das barreiras para o fazer musical das comunidades de baixos recursos, localizadas fora dos grandes centros urbanos ou com dificuldades de acesso a know-how e recursos tecnológicos. A popularidade da "live violãozinho" (tentativa de adaptação das práticas presenciais às restrições pós-2020) dá destaque para a falta de resposta da comunidade artística às novas demandas sócio-culturais (Faria e Neto, 2021).

3. Senso de Agenciamento

Propomos o estudo do *agenciamento*⁴ como método de análise das interações entre os agentes no contexto das práticas comprovisatórias. O agenciamento advém de experiências sensoriais ou da movimentação do corpo no espaço em relação a objetos do entorno. O senso de agenciamento refere-se à sensação de estar no controle em situações envolvendo fenômenos complexos.⁵ Algumas dessas relações tendem a vincular o fluxo de nossos pensamentos, os movimentos do corpo e os efeitos produzidos pelas nossas ações no mundo externo (Haggard e Tsakiris, 2009).

O senso de agenciamento depende das relações espaço-temporais entre as nossas ações e seus efeitos intencionais e não intencionais, incluindo a previsão de reações por parte de terceiros.⁶ Essas relações têm impacto na percepção de causalidade, sugerindo que o agenciamento é um caso especial de causalidade em que o próprio agente gera o evento (Sato e Yasuda, 2005). Como citado anteriormente, esses julgamentos são delimitados por previsões cognitivas e ações motrizes tendendo a consequências planejadas (Frith, Blakemore e Wolpert, 2000). Quando não há discrepância entre a previsão e o resultado esperado, o fenômeno é interpretado como sendo gerado pelo próprio agente.

Para Haggard e Tsakiris (2009), a previsão da ação é um mecanismo-chave para as interações. A previsão ou antecipação funciona como elo de ligação do grupo, possibilitando abordagens conjuntas e em alguns casos gerando conflitos. Tsakiris e coautores (2007) relatam que a conjunção de ações próprias com ações ou reações de outros agentes podem gerar confusão ou colocar em dúvida os processos de agenciamento. Nesses casos, os agentes buscam estratégias confirmatórias para determinar se as ações são próprias ou de outros agentes. A modalidade visual é a mais utilizada para corroborar ações. Porém, quando tratamos de músicos, as práticas musicais padronizadas (através da tonalidade, da organização temporal centralizada ou pela adoção de gêneros musicais preexistentes) podem servir de referência complementando as informações visuais. As relações inter- e supramodais constituem um campo que vem recebendo atenção renovada na pesquisa da última década.

Uma visão complementar ao agenciamento como antecipação, trata do senso de agenciamento como uma inferência: a cognição pode inferir e reconstruir um caminho entre a intenção consciente e o efeito, após o fato. De acordo com Wegner (2003) a inferência em ações coletivas fomenta a noção de que o agente tem controle completo sobre as ações, mas em alguns casos essa noção pode ser simplesmente uma "ilusão". Essa ilusão de controle está associada ao conhecimento prévio, que reforça uma lógica

⁴ O impacto negativo da falta de infraestrutura e de suporte para as práticas musicais criativas não têm a mesma dimensão em todos os contextos sociais e econômicos. A tendência pós-2020 é o aumento das barreiras para o fazer musical das comunidades de baixos recursos, localizadas fora dos grandes centros urbanos ou com dificuldades de acesso a know-how e recursos tecnológicos. A popularidade da "live violãozinho" (tentativa de adaptação das práticas presenciais às restrições pós-2020) dá destaque para a falta de resposta da comunidade artística às novas demandas sócio-culturais (Faria e Neto, 2021).

⁵ Destacamos a relação estreita entre o *agente*, como a entidade causal de um evento que não precisa ser necessariamente humana, e o *agenciamento* como processo de atribuição de causalidade do evento.

⁶ Aplicações musicalmente triviais, como o acompanhamento automático, o karaokê ou alguns exemplos recentes do uso de "inteligência artificial" para compor melodias tonais não são considerados neste artigo como exemplos relevantes do fazer criativo atual.

motivacional. É o tradicional vínculo sugerido por Descartes, “penso, logo existo”, que vem sendo questionado por múltiplos estudos nos campos da neurociência e da cognição corporizada (Damásio, 1994). É justamente nesse espaço entre intenção, motivação ou planejamento de uma ação e o resultado da decisão estética que entram em jogo os vieses cognitivos, a abertura para a inovação e o impacto da disponibilidade ou da falta dos recursos distribuídos.

Figura 1. Diagrama projetado por Haggard e Tsakiris (2009) descrevendo o agenciamento como a experiência de controle via ação. Nele, o plano material (A) e o plano cognitivo (B) durante a ação contribuem para o senso de agenciamento^{7, 8}.

Acreditamos que as perspectivas ecológicas sobre agenciamento são aplicáveis nas práticas solo e nas práticas coletivas de composição e improvisação musical. Quando os agentes precisam lidar com múltiplas tarefas, em contextos nos quais falta o suporte fornecido por uma das modalidades de interação, eles encontram estratégias para compensar essa redução através da predição ou da inferência. Nesse contexto, elaboramos o projeto Ouija para testar as relações entre agenciamento, antecipação e inferência nas práticas ecomprovisacionais.⁹

4. Estudo de caso: OUIJA - para Cordas Friccionadas e Sons Eletrônicos

O projeto Ouija é inspirado no tabuleiro Ouija, uma superfície plana com letras, números e símbolos. Em sessões Ouija, vários indivíduos sentam-se ao redor de uma mesa com a tabuleta à sua frente. Todos colocam suas mãos sobre um copo ou item similar que serve como referencial. Segundo a mística do ritual, espíritos ou entidades sobrenaturais entram em contato via a tabuleta respondendo perguntas em uma conversa entre planos existenciais diferentes que se comunicam através do movimento do copo.

Agentes: Os dois performers que trabalharam em Ouija são músicos profissionais, com curso superior e aperfeiçoamento na área da música contemporânea (doutorado). A idade de A (32) e de B (28). Agente A é de sexo masculino, violoncellista. Agente B é de sexo masculino, violista.

⁷ Conforme mostrado no plano A da figura 1, as ações são precedidas pela preparação neural, que inclui a motivação para a ação, a seleção de parâmetros de movimento apropriados e a ativação de redes motoras corticais. Preparação, movimento corporal e efeito sensorial são eventos objetivos que ocorrem em uma sequência temporal estrita. Em contraste com os eventos físicos, a experiência subjetiva da ação tem uma forte coerência e unidade. A experiência de preparar uma ação prediz o efeito da ação. As informações sensoriais do evento são comparadas retrospectivamente com a previsão do efeito pretendido.

⁸ Link da figura 1 em:

https://drive.google.com/file/d/1fwB9f3vltItRqpUGSK1xvu6lZ_SO7ulx/view?usp=sharing

⁹ O neologismo ecomprovisação (*ecomprovisation*) é resultado da abreviação a partir da junção de várias vertentes do pensamento criativo. A primeira é o enfoque cognitivo-ecológico, inicialmente denominado ecomposição e que hoje abrange múltiplas vertentes artísticas que conformam as práticas criativas cognitivo-ecológicas (Keller e Lazzarini 2017). A segunda são os enfoques surgidos na primeira década do século 21 que sugerem que composição e improvisação podem constituir um campo de pesquisa diferente do que a simples soma dessas práticas, a improvisação. Por último, os aspectos da ecomprovisação que atingem o campo do design de tecnologias para o suporte à prática criativa podem ter impacto na pesquisa ubimus.

Local e ferramentas: A sessão ocorreu entre duas localidades: São Paulo, Brasil e Bowling Green, Estados Unidos. O aplicativo Zoom¹⁰ foi escolhido devido ao suporte de gravação de áudio e vídeo.

5. Plano de diretrizes: Materiais eletroacústicos

Para simular a paisagem sonora da sessão de Ouija, foi elaborada uma trilha de sons gravados. A trilha visa estabelecer uma relação auditiva entre os performers, substituindo a escuta presencial. Aplicamos o conceito de espaços paradoxais (Coelho de Souza, 2013), envolvendo elementos sonoros eletroacústicos para criar relações auditivas impossíveis ou ambientes inimagináveis (Aliel, 2019). Essa técnica é uma expansão das partituras sonoras empregadas por Nance (2007). Três fontes sonoras foram utilizadas para a geração da trilha: ruído de rádio, sons de vidro (copo) e voz.

Tabela 1. Trilha Ouija: fontes sonoras e procedimentos.

Fontes sonoras	Descrição	Procedimento
Rádio	Sintonização e marco estrutural	Ruído branco granulado
Vidro	Sons curtos ressonantes	Unhas e dedos percutindo copo
	Sons curtos sem ressonância	Unhas e dedos percutindo o copo
	Sons longos de raspagem	Arrastando o copo sobre metal
Voz	Texto: /ressonante/, /vidro/, /raspagem/	Ferramentas: PHP Markov chain text generator, RandomTextGenerator
	Áudio: fala sintetizada, panorama estéreo, transposição de alturas	Ferramentas: Tradutor Google (Japonês), Audacity, Soundflower

Rádio. O ruído de rádio foi gerado a partir de ruído branco processado via granulação. Esse ruído representa a "sintonização" ou conexão entre os espíritos e os performers. Existe também uma função formal, o ruído determina o início e o fim da peça, agindo como pista temporal no plano de diretrizes.

Vidro. Os sons de vidro foram gravados utilizando uma taça de cristal e foram distribuídos e subdivididos em 3 tipos: curtos ressonantes, curtos sem reverberação, longos (raspagem). Foram realizadas sessões de improvisação para selecionar as de melhor qualidade e definição sonora.

Voz. Usamos três palavras para cada subgrupo: 1) /ressonante/, 2) /vidro/ e 3) /raspagem/. As três palavras foram adicionadas a um gerador de texto baseado em cadeias de Markov, na plataforma *PHP Markov chain text generator*.¹¹ Embora o sistema seja simples, ele fornece recursos rápidos para a construção de encadeamentos de texto. Durante o processo, as palavras podem ser "quebradas" ou aglutinadas. Para fins composicionais em Ouija, todas as palavras quebradas ou incompreensíveis são

¹⁰ <http://zoom.com.br>.

¹¹ <https://projects.haykranen.nl/markov/demo/>

excluídas do processo. Aquelas que são aglutinadas, são trabalhadas no plano sonoro via justaposições. Desta forma, criamos a mesma relação de escrita e de escuta que a aplicada aos sons dos objetos.

Figura 2. Demonstração de uma das variações fornecidas pelo PHP Markov chain text generator, das três palavras-chave utilizadas em Ouija.¹²

O posicionamento das palavras aglutinadas é mapeado no panorama estéreo. Por exemplo, na aglutinação /raspagemaspagemsonate/ o material /raspagem/ (3) inicia no lado esquerdo do panorama em estéreo e se desloca até o centro, o material /ressonante/ (1) surge no centro e se desloca para o lado direito. A voz é utilizada como metáfora do "espírito" invocado durante a sessão de Ouija. Como escolha estética alinhada à tradição da cultura japonesa, consideramos utilizar uma voz com características nipônicas. Entretanto, concebemos que apenas com a utilização da voz humana não haveria o efeito "fantasmagórico" exigido pela obra. Como a comprovação Ouija está baseada na máquina e na utilização da internet, concebemos uma voz "espiritual da máquina". A voz foi sintetizada usando a ferramenta google tradutor.¹³ Outro fator para a escolha do tradutor google foi a quase ausência de acentuação ou prosódia. Essa limitação da fala sintetizada gera estranheza: "o espírito da máquina", uma voz sem sentimentos humanos. No texto lido em japonês aplicamos um gerador de texto aleatório, o *RandomTextGenerator*.¹⁴ O procedimento foi executado duas vezes.

Para ampliar as possibilidades semânticas do material, o texto gerado foi processado via o *PHP Markov chain text generator* (citado anteriormente). O procedimento foi aplicado uma vez. O material textual finalizado foi adicionado ao tradutor google e executado como áudio. A gravação do áudio foi feita através do roteamento da saída de áudio do computador utilizando o software *Soundflower*.¹⁵ O editor *Audacity*¹⁶ foi empregado na manipulação do material sonoro, incluindo a inversão temporal e a transposição de alturas com o objetivo de reduzir a monotonia da fala automática. Para gerar expectativa através da interrupção das frases, aplicamos cortes no meio de palavras. Nas justaposições dos materiais utilizamos as mesmas técnicas empregadas na geração do material (vide acima).

Figura 2. Demonstração de uma das variações fornecidas pelo PHP Markov chain text generator, das três palavras-chave utilizadas em Ouija.¹⁷

¹² link da figura 2 em:

https://drive.google.com/file/d/1mOF-mDY_dXCkDLsH7KrS7VMY-i-hnnv/view?usp=sharing

¹³ O tradutor google é uma plataforma online que oferece recursos de tradução para diversas línguas com a possibilidade de escuta de pronúncias. Para Ouija selecionamos a língua japonesa.

¹⁴ A plataforma permite a geração de texto em diversas línguas. <https://www.randomtextgenerator.com/>

¹⁵ <https://soundflower.softonic.com.br/mac> - Utilizamos a versão para Mac. Não há opções do soundflower para outros sistemas operacionais, mas os mesmos resultados podem ser alcançados via jackaudio em outros sistemas, <https://jackaudio.org/>

¹⁶ <https://www.audacityteam.org/>

¹⁷ Link da figura 3 em:

https://drive.google.com/file/d/16-_bFSy1niUyVYygEijV7v541CcuSGpp/view?usp=sharing

6. Plano de diretrizes: Materiais instrumentais

O projeto Ouija foi desenvolvido através de arcabouços comprovisatórios que funcionam como *módulos de diretrizes*, representados por letras maiúsculas na partitura de Ouija (figura 4). Eles incluem aspectos técnicos e indicações de procedimentos. A execução inicia a partir de qualquer letra, o performer pode mudar de módulo ou permanecer no mesmo. Não há diretrizes sobre tempo de permanência nos módulos, nem um número predefinido de mudanças.

Cada módulo fornece escolhas diversas para os instrumentistas. Por exemplo, na letra B temos a técnica de *overpressure* e a frase "Toque até que o som não diga mais nada". O instrumentista pode escolher a indicação que for relevante dependendo do momento da execução. As interações entre os participantes podem ocorrer através de sons pré-gravados ou através de gestos. Conforme a vontade dos performers, a interação pode migrar entre sons pré-gravados e gestos ou pode combinar as duas estratégias. Também pode ser escolhida apenas uma única forma de interação a ser aplicada durante toda a comprovisação.

Assumindo que o agenciamento pode funcionar como ferramenta para analisar as possíveis ações dos agentes, a partitura de Ouija utiliza três tipos de diretrizes: 1) descrição de aspectos técnicos voltados aos instrumentos; 2) parâmetros musicais; 3) instruções subjetivas. No primeiro caso, as referências técnicas são comuns à maioria dos instrumentos de cordas friccionadas. Por exemplo, *sul tasto*, *pizzicato* e etc. No segundo caso, inserimos referências paramétricas, grupos de alturas ou valores de dinâmica. Por exemplo, na letra E indica-se uma escala musical e pede-se uma dinâmica geral em piano. No terceiro caso, criamos frases de caráter subjetivo para que os performers escolham livremente suas ações. Por exemplo, "toque como se o som contasse algo". Esse tipo de abordagem permite qualquer forma de interpretação. Porém, como exige escolhas consistentes com o contexto musical, demanda um investimento maior no trabalho de preparação.

Figura 4. Partitura de Ouija para cordas friccionadas e trilha eletroacústica.¹⁸

7. Procedimentos

A parte instrumental de Ouija é projetada para cordas friccionadas. Ouija requer uma forma de comunicação online via protocolo VOIP (por exemplo, Skype, Meet, Zoom). Os performers devem desligar seus microfones nas plataformas, mantendo as câmeras ligadas, ou seja, não devem ouvir os sons do parceiro mas devem ver a execução do outro instrumentista. A faixa pré-gravada é ouvida pelo instrumentista visando estabelecer um alinhamento mínimo entre os participantes.

O experimento foi realizado em duas sessões online na plataforma *Zoom*. A duração total de cada sessão foi de 15 minutos, sendo, 5 minutos de execução musical e 10 minutos de discussão sobre a sessão. Foi utilizado o relógio *Time.is*¹⁹ para uma

¹⁸ Link da figura 4 em:

<https://drive.google.com/file/d/1tSHQ6SrpXg5te81RKkkpzBiAoteRgPQ/view?usp=sharing>

¹⁹ <https://time.is/> - Time.is exibe a hora exata, de acordo com o relógio atômico oficial para qualquer fuso horário (mais de 7 milhões de localidades) em 52 idiomas.

sincronização aproximada (admitindo o atraso recorrente em conexões via internet) da trilha pré-gravada. Os agentes tiveram acesso a partitura e a trilha pré-gravada. Entretanto, não foi realizada nenhuma prática ou preparação prévia com os materiais do projeto Ouija antes das gravações.

As entrevistas foram realizadas com os dois performers logo após cada sessão, com o objetivo de colher informações in loco, focadas nas reações imediatas, ao invés de uma análise ou reflexão em um momento posterior em que eles pudessem reconsiderar e reinterpretar sua experiência (ver Menezes 2010 para uma perspectiva metodológica alternativa). As principais questões foram: como os performers se sentiam durante a execução e quais eram as principais estratégias utilizadas. As respostas aos tópicos serão descritas nos resultados e na discussão.

8. Resultados e Discussão

Editamos duas versões de cada sessão. Uma versão mostra como a sessão ocorreu entre os participantes, ou seja, sem os performers se ouvirem. A segunda versão inclui a mixagem dos materiais sonoros e visuais para avaliarmos os resultados.²⁰ Nas duas sessões, encontramos momentos de respostas similares entre os agentes. Tanto tecnicamente quanto sonoramente as interações parecem se conectar, dando a impressão de que estão executando um processo composicional. Como exemplos, podemos apontar na sessão 1: de 1:06 até 1:19 minutos, *contraponto melódico/tremolo*; de 2:01 até 2:21, *arco circular - spazzolato/pizzicato*; de 4:06 até 4:34, *pizzicato/ricochet*. Na sessão 2: de 1:07 até 1:42, *contraponto melódico*; de 1:50 até 2:04, *pizzicato*; de 2:26 até 2:46, *overpressure/glissando*; de 4:11 até 4:25, *pizzicato/ricochet*.

No projeto Ouija, a trilha pré-gravada acabou se tornando um elemento composicional relevante. A ênfase no processo da dinâmica sonora deu suporte para uma organização formal em duas sessões. Isso pode ser observado nos trechos: sessão 1, de 1:09 até 1:27 (aumento e diminuição de intensidade), de 2:47 até 3:34 (variações e relações associativas de dinâmica); na sessão 2, de 1:05 até 1:48 (variações de dinâmica), de 3:05 até 3:53 (variações de intensidade e dinâmica).

Depois do fim das sessões houve uma conversa com os dois performers. Eles apontaram algumas características das estratégias utilizadas nas tomadas de decisão. Os agentes utilizaram os módulos para guiar as decisões. Por exemplo, segundo o Performer A: *quando o agente B estava fazendo pizzicatos eu estava longe deles [NA: o módulo F contém pizzicatos em dinâmica pianíssimo] e fiquei pensando, para onde eu vou? E foi assim, eu fui meio que tentando me achar. O que eu posso fazer com as possibilidades perto de mim?* Interpretamos que o performer A conseguiu identificar a técnica que o performer B estava utilizando e usou os recursos materiais disponíveis para buscar uma forma de interação. Isso indica uma estratégia de interação baseada no *agenciamento* visando relações de imitação. Porém, não havia indicações prévias sobre a necessidade de estar no mesmo módulo que outro performer. Essa foi uma estratégia iniciada durante as sessões.

²⁰ Sessão 1 e 2 - Mixagem sonora e visual: <https://youtu.be/2H7kMc82MpU> e <https://youtu.be/UksUyIgHdG4>

Sessão 1 e 2 - Sem som e entrevista: <https://youtu.be/CF6azGz7-1w> e <https://youtu.be/firwqgWi760>

Também tiveram destaque as estratégias de interação dos agentes com a trilha sonora. O Performer A menciona: *Teve uma parte que... acho que a gravação não estava tão intensa mas o performer B estava aumentando a intensidade dele. Vai ser legal esse contraponto com a gravação.* Essas observações sugerem que as interações sociais têm maior impacto do que as interações com máquinas ou com recursos sonoros.²¹ A interação sonora ocorria com a trilha pré-gravada enquanto havia só interações gestuais e visuais entre os performers. Em tese, o foco deveria ser o som e não os gestos ou os elementos visuais. Isso sugere que a interação da peso para as trocas cognitivas envolvendo ação e reação, algo que não pode ocorrer com a trilha pré-gravada. Vemos aqui o princípio do senso de agenciamento: o agente valoriza as ações que podem causar algum tipo de reação. A atenção a esse tipo de eventos pode ser mais vantajosa em contextos nos quais precisa ser priorizada a troca entre agentes.

Quando perguntado sobre sua percepção das alturas e sobre a relevância desse parâmetro, o performer A responde: Performer A: *Havia bem pouca (relação de altura), só quando eu via a mão dele lá pra cima. Mas era mais o arco, mão direita que era a relação, ali eu vi que a coisa estava intensa, então vamos ser intensos também.* Esse relato indica que aspectos mais abstratos (como a relação entre o posicionamento e a execução de alturas) são substituídos por relações mais simples para viabilizar o senso de agenciamento (neste caso, os gestos relacionados às dinâmicas). Em termos amplos, em uma situação de "execução multitarefa" (que envolve partitura, trilha pré-gravada, interação social e execução instrumental) as escolhas priorizam as informações de mais fácil assimilação que dão suporte para a interação social.

O participante A é bem claro em relação ao processo de agenciamento quando questionado sobre a tomada de decisão nas relações complexas. Performer A: *O que mais me deu dúvidas foi assim... quando o Performer B "mandava ver" no arco se ele estava tocando "notinha bonitinha afinada", se estava fazendo "overpressure", se estava fazendo uns "slides". Aí eu falei, bom, vamos tentar adivinhar aqui, e sei lá, pode ser que o resultado seja algo "bizonho".* Ao se deparar com processos mais complexos de percepção (envolvendo mudanças rápidas de alturas ou técnicas específicas de execução) as decisões são baseadas no senso de agenciamento, descrito na ação de "adivinhar" o material. Nesse sentido, até o momento em que o agente adquire certeza do que está ocorrendo, são possíveis todas as opções compatíveis com o universo de conhecimentos prévios do performer.

Em alguns casos ficaram em evidência tentativas de "soluções" condizentes com um pensamento composicional. Quando questionado sobre as estratégias de "adivinhar", o sujeito A comenta: Performer A: *Eu tentei ver pelos dedos... teve um momento que eu consegui ver que ele (Performer B) estava fazendo uns slides... ah beleza, não tem notas fixas ali. Eu não estava necessariamente tentando fazer a mesma coisa que ele, mas pelo menos tentando imaginar como é que o som estava para fazer alguma coisa que casasse. Mas o resto foi meio... ah vou fazer uns overpressure aqui e vou ver se vai juntar com o que ele está fazendo ali. Porque se ele tiver tocando uma melodia bonita, não sei se vai casar muito não.* Aparentemente, as ações e reações indicadas na fala do performer A partem do pressuposto de um resultado "consistente" com suas expectativas. Desta forma, as estratégias aplicadas perante as inconsistências enfatizam

²¹ Sobre esse item, destacamos que o estudo não visa estabelecer comparações entre agentes computacionais e agentes humanos. Desde a formulação inicial feita por Turing nos anos 1950, esse tópico já foi abordado em contextos diversos, inclusive o musical.

a redução de fenômenos imprevistos e o alinhamento com o conhecimento adquirido anteriormente e aplicado. Assim, o performer busca estratégias alinhadas ao seu conhecimento anterior para determinar se os resultados musicais são "corretos" ou se são consistentes com sua bagagem de conhecimentos.

9. Discussão Final

Diante das condições atuais do fazer musical que envolvem práticas à distância e o acesso a materiais distribuídos através da internet, consideramos formas alternativas de produção sonora com o objetivo de reduzir a referencialidade da prática tradicional. As tentativas de sincronização sonora e características de empobrecimento sonoro via internet tendem a não permitir uma melhor adaptação dos modos tradicionais de se fazer música. Nesse alinhamento, a partir dessas premissas e de conceitos baseados no senso de agenciamento humano, construímos uma obra para cordas friccionadas, sons eletrônicos e interação online, o projeto Ouija. Este visa investigar a interação musical coletiva via práticas gestuais e visuais, propondo aplicações nas quais o som instrumental é totalmente silenciado durante a execução. Ao longo do projeto, investigamos como as interações musicais que não possuem o som como elemento fundamental agem. Ou seja, como os músicos lidam com aspectos gestuais e visuais para estabelecer uma perspectiva musical na qual a escuta é fragmentada ou completamente inviabilizada. Podemos apontar algumas conjecturas sobre as análises preliminares:

Contribuições. O projeto Ouija demonstrou que o conceito de agenciamento pode ser útil na análise de estratégias referentes às tomadas de decisão, ajudando-nos a entender como as trocas são conduzidas pelos performers e quais são as limitações do suporte fornecido pela tecnologia web. Esse tipo de análise ajuda no desenvolvimento de práticas situadas entre a composição e a improvisação musical, que configuram o campo de pesquisa em comprovação e apontam novas possibilidades criativas para a interação entre os músicos com potenciais aplicações para a inserção de leigos, afinal utiliza outras formas, além da sonora para criar interação.

Limitações. Podemos levantar uma tese em três níveis de análise dos eventos ocorridos em Ouija e projetar estratégias artísticas que podem trazer contribuições à pesquisa em comprovação. 1) *aqueles que podem ser facilmente observados - técnicas de execução.* Ex.: *pizzicato*. Através dessa abordagem o agente consegue saber com clareza que tipo de ação outro agente está executando. Normalmente, gestos musicais técnicos possuem características singulares que possibilitam uma rápida percepção dos eventos. A desvantagem é que essa forma é limitada aos músicos e especificamente os que conhecem a técnica, excluindo uma ampla gama de agentes. 2) *aqueles que têm um nível médio de dificuldade de observação - elementos paramétricos.* Ex.: *execução ascendente/descendente de uma escala*. Nesta abordagem, as características gerais deste tipo de elementos permitem um nível de observação geral do material a ser executado, assim, podem ser criadas padronizações. Entretanto, são limitadas a aspectos gerais, afinal a observação gestual e visual não permite percepções apuradas do material. 3) *os que estão baseados em interpretações livres dos participantes - indicações subjetivas.* Ex.: *“toque como se o som estivesse se mexendo”*. As inferências por parte dos agentes podem ser facilmente detectadas quando são utilizadas dicas técnicas ou elementos paramétricos. Porém, os fenômenos imprevistos tendem a ser difíceis de prever. Como em Ouija os agentes não utilizam a escuta mútua, isso aumenta a dificuldade de

estabelecer formas de organização via elementos paramétricos. Outros fatores podem influenciar essas observações. Por exemplo, se um agente decide aplicar uma indicação subjetiva a uma técnica paramétrica, essa nova camada de significados pode gerar vínculos complexos entre agenciamento, comportamento e interação.

De maneira geral, podemos apontar que as práticas ecomprovisacionais tendem a um nível de agenciamento complexo e adaptável a contextos diversos. Durante a performance do projeto Ouija, embora os agentes não se escutassem, os elementos visuais forneceram suporte para ações conjuntas finamente alinhadas. No campo das práticas improvisatórias, observamos que os fenômenos totalmente imprevistos além de serem raros não parecem estar necessariamente associados à improvisação. O projeto Ouija mostrou respostas alinhadas com o conhecimento prévio e indicou a geração de novas relações, a partir de decisões baseadas no agenciamento por imitação, antecipação e inferência. Essas vertentes da ecomprovisação podem fornecer alternativas interessantes para a pesquisa ubimus, especialmente no desenvolvimento do suporte para interação leigo-músico.

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RoboMus: Interfaces de Controle para Instrumentos Musicais Robóticos

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Abstract. *RoboMus is a software and hardware open framework that guides the development of musical robots. Conceptually, the framework is divided into three parts: a) the robots; b) the synchronization server (SSMM; and c) the robot's controlling interfaces. In this article, the first results and proposals for future developments of the controlling interfaces are presented, taking into account the required support for ubiquitous creative processes, accessibility strategies, and other issues related to the interaction design of an interactive programming language that allows interactive control of the robots.*

Resumo. *O RoboMus é um framework aberto de software e hardware possibilita a construção de robôs musicais que são controlados por humanos por intermédio de interfaces de interação. Conceitualmente, o framework se divide em três partes: a) os robôs (instrumentos musicais robóticos); b) Servidor de Sincronização de Mensagens Musicais (SSMM); c) interfaces de controle dos robôs. Nesse artigo, apresenta-se os primeiros resultados e propostas de desenvolvimentos futuros para as interfaces de controle considerando o suporte necessários aos processos criativos ubíquos, estratégias de acessibilidade, e demais questões relacionadas ao projeto de interação de uma linguagem de programação interativa para controle dos robôs.*

1. Introdução

O projeto RoboMus iniciou em 2015 [Camporez et al. 2015] como uma iniciativa educacional interdisciplinar que buscava possibilitar aos alunos dos cursos superiores de Engenharia e Ciência da Computação vivenciar os desafios de projetar e implementar robôs musicais. Em um primeiro momento, o assunto era tratado tão somente sob o prisma das disciplinas de Laboratório de Controle (Eletrônica) e Sistemas Multimídia. Tão logo os primeiros resultados surgiram, vislumbrou-se a possibilidade de abarcar novas áreas de conhecimento como Interação Homem-Robô, Redes e Comunicação de Dados, Música Ubíqua, Linguagens de Programação, entre outras. Dessa forma, uma série de contribuições vêm sendo feitas ao longo dos anos, principalmente no contexto da Música Ubíqua.

Desde o seu surgimento, o RoboMus foi pensado como um framework aberto de software e hardware que tinha como objetivo possibilitar a construção de robôs

musicais de baixo custo controlados por humanos por intermédio de interfaces de interação. Conceitualmente, o framework se divide em três partes: a) os robôs (instrumentos musicais robóticos), que incluem dispositivos comuns de controle a todos os robôs compatíveis com a plataforma; b) Servidor de Sincronização de Mensagens Musicais (SSMM), que executa o escalonamento de mensagens, empregando técnicas de compensação de atraso mecânico (macrossincronização); c) interfaces de controle dos robôs, que incluem a definição de linguagem de programação musical, interfaces colaborativas, pervasivas/ubíquas, tangíveis, gestuais, biossinais, entre outras; As propostas para as duas primeiras partes já foram tratadas respectivamente em [Camporez et al. 2018] e [Camporez et al. 2020]. O foco deste trabalho está na terceira parte, ou seja, nas interfaces de controle dos robôs. Ao embarcarmos nessa frente, nos é possível refletir tanto sobre os processos criativos que devem ser suportados (Seção 2) quanto sobre as questões de acessibilidade do projeto de interação (Seção 3). Sobretudo, é possível fechar o ciclo, verificar como as partes se interconectam, e testar o todo - desde envio do comando musical pelo músico até sua execução eletro-mecânica pelo robô (Seção 4). Para isso, os aspectos da programação de robôs e suas relações com a música ubíqua são respectivamente descritas nas seções 5 e 6.

2. Suporte aos Processos Criativos mediados pela Tecnologia

Uma das definições orientadas pelo pensamento filosófico grego sobre criatividade vem da crença à inteligência humana como divina e de natureza racional, também considerada forma de intuição advindas das experiências vivenciadas. Essa ideia de criatividade nos dá subsídio para fundamentar a perspectiva audiotátil – sentido simbólico da percepção auditiva e tátil, “tatilidade” [Caporaletti 2018] junto a ideia de ubiquidade. Assim sendo, como forma internalizada do saber, integra-se ao pensamento ecológico – onde o ambiente é fortemente determinante nas tomadas de decisões e, portanto, dos processos cognitivos, indicando pensamentos agrupados e multidimensionais, de significado plural e encarada de forma interdisciplinar.

A atividade criativa assinala constantes universais aceitas por uma ampla comunidade científica [Sanmartim 2014], no entanto, o tipo de comunicação presente neste trabalho se concretiza no próprio processo de desenvolvimento, ou seja, durante o ato criativo partindo da noção de colaboratividade.

Desta noção, se enfatiza a ideia de que nenhuma atividade é operar se não for também formar, e não há obra acabada que não seja forma [Pareyson 1993]. Para o autor, formar significa “fazer”, mas um fazer tal que, ao fazer, inventa o modo de fazer. A tarefa do grupo é então criar novos modos do fazer, simbolizar as ações desenvolvendo conceitos e significados. Os processos e operações adotadas nesta etapa de estruturação do projeto são caracterizados como fruto das experiências expressas, a qual chamamos de formatividade. Observado o crescente caráter interdisciplinar sobre processos criativos, e sobretudo, em processos criativos musicais, a “nova musicologia” permite um desenvolvimento conceitual em diferentes áreas – psicologia, antropologia, sociologia, ciência da computação e neurociência. Nesse aspecto é possível intercambiar as áreas dispostas de estudos e fomentar a intencionalidade em permitir a integralização do público como ativo na experiência de controle dos RoboMus, conduzindo deste modo, o pensamento da pesquisa ubíqua e aos processos criativos musicais de caráter antropológico.

A utilização de múltiplas interfaces para a manipulação de dados musicais que viabilizam o acesso simultâneo de usuários múltiplos conceitua o termo ubíquo e portanto, o próprio campo ubíquo concede os meios para que sejam incorporadas as concepções de mediação antropológica e cognitiva presente no princípio de audiotatibilidade (PAT) centralizando o interator (sujeito), a relação com a mediação e suas percepções à medida em que vão se estabelecendo, indissociavelmente, campos comuns entre os humanos e os robôs.

3. Estratégias para Acessibilidade

A utilização de tecnologias digitais na música coloca uma nova questão em relação aos instrumentos musicais [Iazzetta 1998] uma vez que, no instrumento digital, apenas selecionando algumas notas podemos criar sonoridades e ritmos diferentes rompendo barreiras e limitações físicas, tanto dos instrumentos convencionais como do corpo humano. Indivíduos com necessidades especiais físicas e cognitivas, apresentam dificuldades em aprender um instrumento musical convencional, tanto pelos desafios motores quanto pela característica cognitiva que é necessária para desenvolver a técnica instrumental, sendo assim, duas propostas de interfaces são postas para atender, em especial, esse público. Tais interfaces devem ser tangíveis, seguras, intuitivas (naturais e/ou transparentes), suportar interação e colaboração, e de baixo custo. Sobretudo, devem favorecer flexíveis para favorecer o exercício da imaginação e criação artística.

3.1. Dispositivo Hipotético 1: Boneco Sensorial

Uma primeira proposta perpassa pela utilização de massa modelar para tal interação, pois através do seu manuseio o público infantil poderia experimentar novas formas de expressão que incluem: desenhar ou contar histórias, fantasiar, imaginar e interpretar situações, música, entre outros instrumentos que caracterizam uma situação natural para a criança e um ambiente livre de censura para a exposição de seus sentimentos [Gadelha and de Menezes 2004]. Além disso, a modelagem é uma atividade que exercita a função sensorial e trabalha com a organização tridimensional. A pessoa estabelece um contato de forma inédita com o material e assim evoca sua criatividade, o que lhe permite criar novas formas e ampliar o mundo imaginário restrito ao seu usuário [Valladares and Carvalho 2005]. Nessa proposta, um pequeno microcontrolador *bluetooth* e seus sensores (ex. *Arduino Pico*) ficariam envoltos por massa amorfa e modelável protegida por um camada de látex (ex. balão de borracha), similar a um boneco sensorial (Figura 3). Tal artefato estimula o tato, o desenvolvimento motor e também auxilia na percepção visual. Cores, formas, pesos e tamanhos podem ser explorados fazendo cada boneco de uma forma diferente, trabalhando também questão de inclusão e aceitação social. Uma solução acessível, tanto do ponto de vista financeiro como da interação.

Esse dispositivo seria capaz de detectar os diversos movimentos no contexto da interação que seriam interpretados pelo Octopus. Ainda, o dispositivo permitiria manusear, experimentar ou brincar de forma natural, e em tempo real, possibilitando ao observador aferir a reação do público alvo possibilitando o desenvolvimento de novas metodologias no ensino de música, em especial, dois aspectos poderiam ser mensurados: a) a correlação de movimento com ritmo; b) a correlação do emprego de força com dinâmica e altura tonal.



Figura 1. Exemplo de Boneco Sensorial.

Esse artefato se destina principalmente ao público infantil com transtorno do espectro autista, baixa visão e dificuldades motoras.

3.2. Dispositivo Hipotético 2: Rodopios Imersivos

Uma segunda proposta, que visa estudar a construção do timbre e a combinação dos sons e silêncios, perpassa pela técnica da pintura por imersão (*swirling*). A criação de pinturas, formas e desenhos também podem proporcionar aspectos benéficos a pessoa que, ao experimentar, ativa seus sentidos criativos, possibilitando interações e criações artísticas.

Através das combinações das cores e movimentos na água trabalha-se principalmente timbre e efeitos. Para tanto, seria necessário somente um recipiente com água, tinta óleo solúvel, acrílica ou esmalte e borax. Os participante ficariam no entorno desse recipiente acrescentando e misturando as tintas. Essa dinâmica possibilita visualização dos atos dos outros colaboradores e, por consequência, uma sincronização mais natural entre suas ações (Figura 2).



Figura 2. Exemplo da técnica de pintura por imersão.

A prática é monitorada por câmeras e interpretada pelo Octopus (visão computacional), sendo cada cor representada por um timbre ou um som específico, e cada movimento representa uma intensidade, podendo ser fortes ou fracos, fazendo com que o som se intensifique ou suavize. Ao final, a performance é objetificada pela pintura de um objeto físico que será indexado ao vídeo da performance. Essa interface, por ser colaborativa e tangível, permite ao observador derivar experimentos para aferir a capacidade

de comunicação musical de indivíduos no Transtorno do Espectro Autista (TEA) assim como portadores de deficiência auditiva.

4. O Modo de Operação RoboMus

Na plataforma RoboMus, cada desenvolvedor projeta e constrói o seu robô musical. Nele, um software padrão de comunicação é instalado. Esse software permite a comunicação com um servidor central que atua como ponte entre as interfaces de controle e os robôs. A centralização da comunicação com os robôs se faz necessária para a implementação de estratégias de sincronização entre os diversos músicos e os robôs. É possível imaginar o servidor como um sequenciador multimídia que é alimentado por múltiplas fontes (Open Sound Control) estabelecendo o tempo de referência e fazendo o escalonamento das mensagens que são enviadas aos robôs garantindo, assim, a macrossincronização e compensação de atrasos mecânicos baseado no perfil de atraso de cada robô.

Uma importante atividade que todo desenvolvedor RoboMus deve fazer é garantir que seu robô consiga informar ao servidor que tipo de ação pode executar. Quando o músico habilita um RoboMus para uma performance ocorre o handshake e é nessa ocasião que o robô comunica as ações que é capaz de realizar ao servidor responsável que, por sua vez, informa as interfaces de controle.

O servidor pode gerir uma ou mais performances, que são representadas por “palcos” virtuais. Cabe ao servidor fazer o controle de acesso a esses palcos. Todo esse processo bem como o formato de mensagens de comunicação está descrito em detalhes em [Camporez et al. 2018]. Originalmente, vislumbrou-se que as performances ocorreriam presencialmente. Robôs, em uma visão mais conservadora, são objetos físicos que produzem som por meio de ação mecânica similar a instrumentos acústicos, ou seja, os músicos e a platéia deveriam estar próximos. Em virtude do período de isolamento social oriundo da crise sanitária do COVID-19 essa questão foi revista de modo que, não só os robôs pudessem ser controlados remotamente, como também a audiência pudesse acompanhar a apresentação remotamente. Logo, também compete ao servidor oferecer ao músico (operador) esse controle temporal do “futuro imediato” permitindo que tenha tempo de reagir/sincronizar ações com outras que estão por vir.

Performances musicais RoboMus, assim como na música ubíqua [Keller et al. 2014], não necessariamente seguem as convenções da música tradicional/ocidental. Cita-se como exemplo o fato das performances poderem ser contínuas, colaborativas, e assíncronas. Ainda, podem se basear em estruturas outras alheias à música tradicional - podemos pedir aos robôs que “toquem” uma gama de material multimídia explorando os diversos sentidos da audiência, muitos desses recursos produzidos por terceiros. Isso não implica dizer que também não possam tocar notas musicais organizadas em estruturas rítmicas baseadas em compassos. Para avançar na música ubíqua não é preciso negar a música tradicional ocidental e todo o conhecimento que ela produziu ao longo dos séculos em que foi praticada e refinada.

Uma vez que os robôs estejam postos e conectados ao servidor, compete às interfaces de controle possibilitar ao músico dar início a performance, e esse controle deve ocorrer em tempo-real. Note que, por tempo-real, não intenciona-se dizer que as ações devem ocorrer instantaneamente, posto que há atrasos tanto de origem telemática como mecânicos do robô. Ademais, por serem colaborativas, as performances também são assíncronas.

Logo, o termo tempo-real deve ser visto aqui com cautela. O objetivo é que o músico possa “programar” o robô assincronamente para que mesmo execute ações sincronamente em relação a outro robô.

As interfaces de controle podem variar desde um aplicativo específico criado pelo desenvolvedor do robô até uma linguagem de programação de uso geral, como Java ou Python. Neste trabalho, adota-se a segunda opção por ela ser mais flexível. Ademais, o “Live Coding” [Brown and Sorensen 2009][Collins et al. 2003] é uma prática já estabelecida na área e apontam caminhos para soluções de interatividade. Dito isso, a programação de computadores ainda não é uma prática ubíqua entre os músicos e o uso de uma linguagem de programação convencional pode atravancar o aprendizado e frustrar o usuário de origem menos técnica, deteriorando a sua experiência de uso. O uso de linguagens de programação de quarta geração já estabelecidas (ex. Super Collider, Pure-Data, Sonic Pi, CSound, etc.) como interface de controle pode ser um caminho, mas essas seguem o conceito da “unidade geradora de som” introduzida por Max Mathews [Mathews et al. 1974] no MUSIC I, ou seja, são voltadas a trabalhar o som e não as estruturas da música que mediam o desenvolvimento dos robôs. Há ainda a opção de usar simplificações de linguagens de uso geral, como propõe o *Processing*, que mesmo rodando sobre o Java, oferece uma IDE e comandos específicos mais amigáveis seguindo a metodologia da programação criativa proposta por Maeda [Maeda 2001]. As vantagens dessa abordagem é que não se abre mão de todo o poder e flexibilidade de uma linguagem de uso geral e suas bibliotecas [Costalonga et al. 2005].

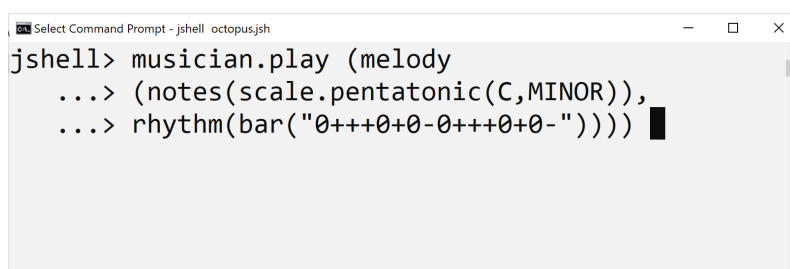
5. Programando uma Performance Musical com o Octopus Music

A *Octopus Music Library* [Costalonga et al. 2007][Costalonga 2009] é uma API Java projetada para ajudar desenvolvedores e compositores a lidar com elementos musicais em um ambiente de programação de alto nível. Diferentemente de outras APIs para desenvolvimento de software musical, o *Octopus API* tem seu foco na modelagem de elementos de performance musical, principalmente o intérprete e seu instrumento. Um possível uso dessa API é na recriação de uma apresentação musical para um artista específico em um instrumento musical específico. Conceitualmente as classes do *Octopus Music API* são classificadas em: a) Classes para estruturação da música (*Playables*); b) Classes para interpretação de dados musicais (*Musician*); c) Classes de Instrumentos; e d) Classes para comunicação. A música é formalizada usando classes de estruturação (a) de forma análoga a uma partitura, um arquivo MIDI ou MusicXML (MusicXML for *Exchanging Digital Sheet Music*, n.d.). As classes intérpretes (b) são equivalentes aos instrumentistas, e fazem uma adequação do que está na partitura para a técnica do seu instrumento (c) dentro de suas limitações técnicas/biomecânicas; uma característica marcante do *Octopus* é a possibilidade da modelagem de parâmetros de expressividade musical visando a simulação da humanização da performance. Essa metáfora empregada no *Octopus* faz da API uma candidata natural para ser usada como base para as modelagens das performances musicais robóticas. No entanto, o *Octopus* tem algumas limitações que precisam ser superadas.

Por ser uma biblioteca, precisa ser usada em Java o que, naturalmente, restringe a redigibilidade. Alternativas para superar tal dificuldade implicam no uso de estratégias por codificação em blocos, como no *Alice* [Cooper et al. 2000] ou *EarSketch* [Magerko et al. 2016], ou uma simplificação sintática linguagem como no *Processing*

[Reas and Fry 2007].

Mesmo utilizando um ambiente de programação simplificado e familiar aos artistas, como o Processing, ainda há a limitação de ter que “compilar” o código. As aspas foram usadas porque apesar do Java não ser tecnicamente uma linguagem compilada, ainda demanda um estágio de conversão para um código intermediário (bytecode) em momento anterior a execução do “programa/música”. Isso torna seu uso para atividades Live Coding desconfortável. Fortunadamente, o JDK 9 (2017) trouxe um ambiente interativo Read-Evaluate-Print-Loop (REPL) que avalia declarações, instruções e expressões à medida que são inseridas e mostra imediatamente os resultados. A ferramenta (JShell) é executada a partir da linha de comando. Através do uso desse ambiente, o Octopus passa a poder ser usado em modo interativo, mas ainda há o problema da baixa redigibilidade. Para superar essa questão, um estudo de usabilidade junto a comunidade musical está em andamento para determinar a melhor maneira de escrever código musical. A nova sintaxe é extensamente baseada em funções, simulando um paradigma funcional e buscando inspiração nos vários ambientes de ensino de programação e também nas linguagens para Live Coding. Os termos e nomes empregados na declaração das funções são familiares aos usuários da música, achatando a curva de aprendizado. Uma das vantagens dessa abordagem é o fato de poder oferecer suporte em vários idiomas, uma vez que o esforço de tradução se limita ao script usado pelo shell.

A screenshot of a terminal window titled "Select Command Prompt - jshell octopus.jsh". The terminal shows the following code being entered:

```
jshell> musician.play (melody  
...> (notes(scale.pentatonic(C,MINOR)),  
...> rhythm(bar("0+++0+0-0+++0+0-"))))
```

Figura 3. Exemplo de código produzido seguindo a nova sintaxe no REPL jShell. Uma melodia baseada nas notas da escala pentatonica em C menor sendo tocada pelo robô "musician" usando um padrão rítmico elaborado seguindo a mesma notação do EarSketch [Magerko et al. 2016].

Em resumo, oferece-se 3 opções para o desenvolvimento de interfaces de controle no contexto do framework RoboMus: 1) Java + *Octopus Music API* no desenvolvimento de um interfaces de controle específicas que rodam em desktop ou mobile; 2) *Processing* + *Octopus* for *Processing* para desenvolvimento de sketches interativos que também podem controlar os robôs e integram elementos das artes visuais; 3) Usando o *JShell* + *Octopus* for *REPL* que permite o controle dos robôs emulando um *Live Coding*. Nessa última abordagem estuda-se ainda a integração do *Octopus* com *JavaScript* para codificação na Web.

6. Programação com Suporte às Práticas Ubíquas

O Octopus Music API foi primeiramente liberado em 2007 [Costalonga et al. 2007] sendo fortemente baseado na modelagem de projetos ainda anteriores [Costalonga et al. 2003, Costalonga and Viccari 2004, Costalonga 2005]. Portanto, os conceitos e premissas da música ubíqua lhe é originalmente estranho. Destaca-se o fato da API ser fortemente baseada nos conceitos e estruturas da música tradicional ocidental, tais como notas, escalas,

barras, compassos, entre outras. Ainda, demanda de seus usuários conhecimento técnico de programação de computadores, programação orientada-a-objetos, além da própria linguagem Java. O Octopus Music foi concebido como interface e programação (API) para ser utilizado por desenvolvedores na criação de novos aplicativos musicais, e não para ser usado por leigos (tanto em música como em computação) na programação de música algorítmica.

Uma das primeiras definições de sistemas musicais ubíquos foi feita por [Pimenta et al. 2009] como sendo “Ambientes computacionais musicais que suportam de forma integradas múltiplos usuários, dispositivos, fontes sonoras, e atividades musicais”. Do ponto de vista tecnológico, sistemas musicais ubíquos devem suportar: mobilidade, interação social, independência de dispositivos e consciência de contexto. Ainda nesse sentido, [Costalonga et al. 2019] propuseram algumas *guidelines* para elaboração de projetos de interação de tecnologias musicais ubíquas baseado nos conceitos de (bio)musicalidade. As recomendações foram agrupadas nos seguintes grupos: a) Aspectos relacionados a materialidade e fisicalidade de instrumentos musicais; b) Controle e gerenciamento de estratégias assistenciais; c) Adequado uso de gestos e movimentos naturais; d) Mecanismos de sincronização e percepção de pulso rítmico; e) Uso de imitação para comunicação e imitação; Desse modo, o Octopus está sendo estendido para suportar as práticas ubíquas através das seguintes funcionalidade:

- Suporte a produção colaborativa e remota oferecendo aos usuário meios de apurar a contribuição mútua e aprender uns com os outros fundamentado no princípio de imitação verdadeira [Byrne and Russon 1998];
- Suporte a mecanismos de sincronização assíncrona baseada em eventos, onde a ação de um robô dispara programação prévia de outro;
- Suporte a conteúdo multimídia, com a utilização de *samples* de áudio, vídeo, ou qualquer outra mídia que seja suportada pelos robôs; isso elimina ou diminui a necessidade conhecimento musical avançado para operar o sistema, propiciando o uso por leigos em música; Tais mídias são utilizadas de forma integrada as demais estruturas musicais;
- Redefinição da sintaxe da linguagem para incorporar termos familiares ao contexto da música diminuindo o gap semântico com os usuários finais e sendo consistente com outras ferramentas (ex. *Processing*, *EarSketch*, *Alice*);
- Implementação de bibliotecas *snippets* de código adaptáveis (blocos de construção) de forma a diminuir o esforço de programação, compartilhamento de código e aprendizagem mútua;
- Implementação de entrada de dados baseada nos princípios da (bio)musicalidade e áudio-tatibilidade, por exemplo, utilizando voz para formalizar melodias, palmas para informar ritmo, ou dispositivos de entradas como os tratados na Seção 3;
- Implementação de mecanismos inteligentes de assistência aos usuários baseado no perfil de uso buscando ser sugestivo sem ser intrusivo.

É importante ressaltar que essas funcionalidades estão em desenvolvimento e testes. No entanto, para fundamentar essa proposta, buscou-se inspiração em algumas soluções já em uso pela comunidade, em especial nas linguagens de programação sônicas Sonic Pi [Aaron and Blackwell 2013] e CSound [Lazzarini et al. 2016] e ambientes de ensino de programação focados em programação criativa como Alice [Cooper et al. 2000]

e *EarSketch* [Magerko et al. 2016]. Antes de avaliar as características dessas ferramentas, é preciso identificar os objetivos de cada uma. O *Sonic Pi* é uma linguagem que prima pela facilidade de uso, particularmente para educação e composição/performance. Não objetiva ser uma linguagem de uso geral. Possui boa redigibilidade sendo possível estruturar uma música com poucas linhas de código, uma característica desejável no *Live Coding*, provavelmente sendo esse seu principal uso. Não possui suporte para web e também não oferece uma forma nativa de performance colaborativa, embora seja possível fazê-lo utilizando ferramentas externas em associação com o *Open Sound Control*. É relevante a esse trabalho a forma como *Sonic Pi* lida com o *Live Coding*, em especial, seu poderoso mecanismo de processamento paralelo. O *Csound* é uma linguagem consolidada, possui vasta documentação e utilização em projetos acadêmicos; Pode ser utilizado para desenvolvimento de instrumentos musicais e aplicações diversas, incluindo software embarcado, dispositivos móveis, e até no navegador Google Chrome através de ferramentas como o *Csound PNaCl* [Lazzarini et al. 2014], o que é de particular interesse a esse projeto. Oferece, assim como em outras linguagens, a possibilidade de ser utilizada como ferramenta de composição e também em *Live-Coding*, porém não suporta colaboração nativamente.

Ambas linguagens citadas oferecem um poderoso motor de síntese de áudio (*SuperCollider* e *Csound Engine*). Nesse sentido, nossa proposta está mais alinhada ao *Sonic PI*, uma vez que não se objetiva a criação de um motor de áudio já que a unidade geradora de som são os próprios robôs. Dessa forma, quando for o caso, será utilizado um motor de áudio terceiro, tal qual o *SuperCollider* ou *Csound Engine*. Essa opção mostra-se especialmente promissora com o uso de simulações robóticas [Michel 2004] que, além de permitir a prototipação colaborativa remota, ainda reduz os custos e contribui para questões ligadas à sustentabilidade ambiental.

O *Processing* [Reas and Fry 2007] é definido por seus criadores como um “software sketchbook” para codificação no contexto das artes visuais. Surgiu do MIT Media Lab e foi inspirado em uma linguagem mais simples desenvolvida por John Maeda denominada *DBN* (*Design by Numbers*) [Maeda 2001]. O *DBN* foi desenvolvido como uma prova de conceito, uma vitrine para demonstrar a abordagem à programação criativa e forneceu lições importantes para o desenvolvimento inicial do *Processing*, que por sua vez foi criado como um ambiente de programação completo para a programação criativa. Essas mesmas lições são premissas no desenvolvimento de nossa proposta, ademais, assim como no *Processing*, nosso desenvolvimento se baseia nas potencialidades e limitações do Java. Destaca-se os seguintes princípios norteadores compartilhados:

- Simplicidade: Interface mínima favorecendo a flexibilização e criação de algoritmos complexos;
- Ambiente robusto, intuitivo, de fácil uso para escrita, teste, execução de código. O *Processing* é *self-contained* e não é necessário configurações rebuscadas para iniciar a programação, o mesmo é válido no *Octopus for REPL*. Se optar, o usuário pode ainda usar o *Octopus for Processing* dentro no ambiente do *Processing*;
- Abordagem convidativa e divertida a iniciantes através do suporte ao método de programação criativa, ao invés do tradicional “*Hello World!*”. Com foco em multimídia, o *Processing* se esforça para mostrar toda a diversão da programação Java e esconder as partes mais frustrantes. O mesmo princípio foi utilizado na

especificação da linguagem aqui proposta, inclusive muitas vezes indo em direção oposta aos padrões da orientação-objeto;

- Software gratuito e aberto para favorecer adoção mundial e contribuição da comunidade através do desenvolvimento de bibliotecas que estendem os recursos do *Processing* em todas as áreas, como conectividade, banco de dados, visão computacional, e inclusive áudio e música. O *Octopus* também é gratuito e *open-source*.

Um outro ambiente que também é focado na programação criativa é o EarSketch da GeorgiaTech University [Magerko et al. 2016], porém esse ambiente é voltado para o ensino da programação através da criação de sketches sonoros e suporta tanto JavaScript como Python. Os desenvolvedores divulgam que o ambiente tem sido usado por mais de meio milhão de alunos em mais de 100 países. Para diminuir a curva de aprendizagem, emprega funções específicas para organização, efeitos e análise dos *samples*. Há vasta documentação e possibilidade de compartilhamento de código, que é facilitado por rodar em uma interface Web. O EarSketch inspira a corrente proposta principalmente na forma de formalizar algumas notações musicais, como estruturas rítmicas (ex. função *makebeat*). A programação no ambiente web também é algo que se busca em trabalhos futuros.

Por fim, cita-se o Alice [Collins et al. 2003], um projeto da Carnegie Mellon University, que também foca no ensino da programação, mais especificamente, no ensino de Java. O Alice é um ambiente de programação baseado em blocos que permite criar animações, construir narrativas interativas ou programar jogos simples em 3D. Ao contrário de muitos aplicativos de codificação baseados em desafios, o Alice motiva o aprendizado por meio da exploração criativa. No entender dos autores, a estrutura de codificação de blocos utilizada no Alice é pertinente ao corrente projeto, mas limitada por ser somente *desktop*. Ainda, é de particular interesse o modo como o Alice lida com processos paralelos com estruturas de desvio de fluxo simples, como o “*Do..together*” e “*Do..in order*”. O uso de tais estruturas são desejáveis em versões futuras das interfaces de controle.

7. Palavras Finais

O presente trabalho discorre sobre questões de controle de instrumentos musicais robóticos compatíveis com o *framework* RoboMus. Apresentou-se um referencial teórico sobre os processos cognitivos que embasam o desenvolvimento de tecnologias ubíquas bem como a aplicação de estratégias de acessibilidade, em especial, de uma estratégia de programação que permita o controle de robôs emulando o *Live-Coding*. Tal estratégia perpassa por 3 vertentes: a) Utilização de uma linguagem de programação de uso geral em conjunto com uma API que suporte OSC e siga o formato definido no *framework*, como por exemplo, a *Octopus Music API*; b) Utilização do Processing em conjunto com a biblioteca *Octopus for Processing* que permite o controle do robôs em conjunto todo o potencial deste ambiente voltado, em especial, a artistas digitais; c) Utilização de um editor *REPL* em conjunto com uma shell (*Octopus for REPL*) que simplifica e possibilita a programação em tempo-real de performances musicais. Para essa última vertente, foi apresentado um caminho de desenvolvimento baseado nos princípios da música ubíqua, do projeto de interação centrado em (bio) musicalidade, bem como inspirações oriundas de linguagens de programação sônicas já estabelecidas e ambientes de ensino de

programação que adotam a programação criativa. O desenvolvimentos futuros perpassam pela validação experimental do projetos e interação das interfaces de controles e o uso de simuladores (*Webot*) desenvolvimento de novos robôs. Uma vez maduro o projeto, retoma-se a ideia original de organização do festival de música robótica visando resultados mais artísticos.

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Telefone sem Fio

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Abstract. *Thinking about the phenomena of mass communications and the effects that the reproduction of a message can create, we present here the work called Cordless telephone, a composition for networked cell phones that uses the environment to create sound layers. Phones still use their screens, flashlights and vibracall to help the public understand communication today. The piece also has a set of acoustic amplifiers made in ceramic that serve to amplify the voices of cell phones and help us compose the scenography of this presentation.*

Resumo. *Pensando nos fenômenos das comunicações em massa e nos efeitos que a reprodução de uma mensagem pode criar, apresentamos aqui o trabalho chamado Telefone sem fio, uma composição para celulares em rede que utilizam o ambiente para criar camadas sonoras. Os telefones ainda utilizam suas telas, lanternas e vibracall para auxiliar o público a compreender a comunicação nos dias atuais. A peça conta ainda com um conjunto de amplificadores acústicos feitos em cerâmica que servem para amplificar as vozes dos celulares e nos ajudam a compor a cenografia desta apresentação.*

1. Introdução

Desde a invenção do aparelho telefônico em 1870 por Alexander Graham Bell (1847-1922) que a comunicação humana passou a ser mediada pela tecnologia. O advento desta tecnologia permitiu que a voz viajasse muitos quilômetros e alcançasse pessoas em locais distantes. Também trouxe mudanças na comunicação já que apenas a voz viaja pelos fios, limitando a comunicação aos sons e impedindo outras formas de expressão como os gestos, as linguagens faciais e corporais. Ao mesmo tempo, devido a decisões técnicas e limitações na transferência, a qualidade das comunicações telefônicas nunca foram próximas da qualidade do som acústico comprometendo o entendimento e a compreensão.

O telefone também dá o nome para uma brincadeira infantil bastante popular, o chamado Telefone sem fio. Esta brincadeira consiste em colocar as crianças em uma espécie de linha e cochichar no ouvido da criança em frente à linha uma frase, que será repetida para a segunda e assim por diante, até que a mensagem chegue na última criança. O efeito desta mensagem ser passada de criança em criança gera uma distorção na mensagem fazendo com que a mensagem final seja bastante diferente da original.

Nos tempos atuais, os telefones são portáteis, de bolso, capazes de acessar a Internet e trocar mensagens em grupos. No entanto, junto com o avanço tecnológico veio também a possibilidade de espalhar notícias falsas, as chamadas *fake news*, transformando esta ferramenta de informação em uma ferramenta de desinformação. Tais notícias falsas foram e estão sendo usadas como ferramenta política para sustentar governos autoritários em uma nova onda conservadora que vem crescendo em vários lugares do mundo.

É pensando nestes conceitos que a Orchidea[Schiavoni et al. 2018] apresenta a peça **Telefone sem fio**, que mistura a possibilidade de transmitir e gravar áudio em telefones celulares, trocando mensagens pela rede e sincronizando estes dispositivos de maneira a distorcer a comunicação que ocorre em um ambiente comum a estes dispositivos. Nesta peça, uma mensagem inicial é dita em uma sala e alguns celulares dispostos neste ambiente gravam esta mensagem e passam a retransmitir a mesma ao ambiente, como na brincadeira infantil, recortando e reproduzindo a mesma de maneira entrecortada e transformando propositalmente a informação em desinformação desconexa. De maneira similar à peça “I am sitting in a room”, de Alvin Lucier [Lucier 1969], a cada gravação e reprodução a mensagem vai sendo deformada e perdendo sua característica original. Para garantir a comunicação e a amplificação dos dispositivos móveis no ambiente, a peça conta ainda com amplificadores cerâmicos, desenvolvidos para a mesma, que permitem amplificar de maneira acústica as vozes dos telefones. Os telefones ainda utilizam seus vibracall, luzes do flash e mudanças nas cores das telas para convidar o público a tentar compreender os efeitos desta comunicação em massa em nossa sociedade, as vezes informando e as vezes desinformando, e também a pensar no conceito de que “o meio é a mensagem”, de Marshall McLuhan[McLUHAN 1974].

Técnica/Formato: Esta peça foi criada para ser apresentada ao vivo pois a participação do público no som do espaço pode ser fundamental para a modificação da mesma. No entanto, devido ao momento pandêmico que nos encontramos, acreditamos que o ideal é enviar apenas um vídeo da mesma para este evento. Trecho em vídeo disponível em <https://alice.dcomp.ufsj.edu.br/en/projects/telefone.html>.

Tempo de duração: 10 minutos.

2. Agradecimentos

Agradecemos à Pró Reitoria de Extensão da UFSJ, por financiar toda a pesquisa e também, a todos os membros do laboratório de pesquisa, ALICE, que contribuíram para a evolução desse trabalho. Em especial, aos colegas João Teixeira Araújo e Rafael Alves Soares de Andrade, que realizaram as análises acústicas dos amplificadores cerâmicos.

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Sinógeno

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Abstract. “Sinógeno” is a visual mini-album, made from samples of the afro-catholic brazilian bell’s tradition. The album, mixes traditional bell rings, with electronic music and other elements, as well as uses images of the cultural manifestation with an edition that highlights the anthropophagic aspects of the project.

Resumo. Sinógeno é um mini-álbum visual, feito a partir de samples da tradição sineira de São João del-Rei, reconhecida pelo IPHAN como patrimônio nacional. O projeto mistura os toques tradicionais dos sinos com música eletrônica e novos elementos, além de imagens que retratam a manifestação cultural, reinterpretadas com uma edição que ressalta o aspecto antropofágico da obra.

1. Descrição Geral

A cidade de São João del-Rei tem uma tradição sineira que faz parte dos seus 300 anos de história e muitas vezes, os sinos eram tocados por negros escravizados, que tinham uma origem musical muito própria e acabavam colocando um pouco de suas influências nas batidas. Ao ouvir os sinos tocando, é possível perceber semelhanças com ritmos como o maracatu, o baião, etc.

É partindo deste contexto que apresentamos “Sinógeno”, um EP (ou mini-álbum) visual feito a partir de samples da tradição dos sinos falantes de São João del-Rei, reconhecida pelo IPHAN como patrimônio nacional. É a primeira produção a samplear os ritmos africanos tocados pelos sinos da cidade, ou seja: um fato histórico, que leva a tradição musical iniciada há séculos atrás para um novo lugar, inserindo-a na linguagem da música eletrônica.

Além dos samples digitais e beats, criados por Rabay, o projeto conta com uma espécie de sampler orgânico, que é o instrumento “Sineiro”, criado e tocado por Maria Anália, musicista e luthier, que criou a peça, inspirada em uma marimba, a partir da pesquisa sobre os timbres dos sinos de São João e compôs linhas inspiradas nos toques originais da tradição.

Com imagens de Thiago Morandi, conhecido pelo seu trabalho de registro da cultura sanjoanense, o projeto conta ainda com um vídeo que aposta em uma edição que usa efeitos e cores distorcidas para reforçar o conceito de modernizar o passado, profanar o sagrado e manter a cultura viva através da antropofagia. Além disso, predominam tons vermelhos, que talvez sirvam para nos lembrar de aspectos contraditórios dessa história, que alguns gostariam de deixar esquecidos.

Técnica/Formato: Vídeo musical.

Indicação de performance pré-gravada ou ao vivo: Pré-gravada, disponível no link <https://youtu.be/xhSfKiEO3O0>

Tempo de duração: 10 minutos.

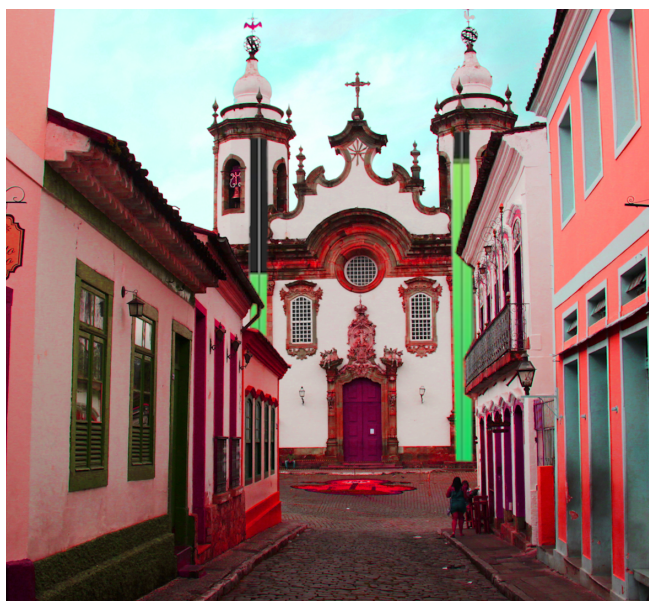


Figura 1. Frame de Sinógeno

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Gastrossônica: Desenvolvimento do suporte ubimus para atividades musicais gastronômicas

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Resumo. *Apresentamos as ferramentas desenvolvidas e discutimos os resultados do primeiro estudo focado em gastrossônica. A gastrossônica é um campo de pesquisa emergente dentro das vertentes ubimus. Ela abrange a utilização de alimentos e de estímulos gustativos, olfativos e táteis vinculados ao universo gastronômico para ampliar as possibilidades criativas no fazer musical. A proposta complementa os trabalhos já existentes no campo da interação humano-comida (human-food interaction) explorando os aspectos lúdicos e criativos com ênfase no fomento ao bem-estar. Participaram no estudo 12 sujeitos distribuídos em duplas. Os resultados colocam em destaque a possibilidade de utilizar recursos gastronômicos como estratégia de compartilhamento de informações em atividades musicais grupais.*

Abstract. *We present the tools developed and discuss the results of the first study in gastrosonics. Gastrosonics is an emergent field of research within the ubimus movement. It deals with the use of food and gustatory, smell and tactile stimuli furnished by the gastronomic universe to enhance the affordances of musical creation. Our work complements the extant proposals in human-food interaction, targeting playful and creative activities to enhance well-being. Twelve subjects participated in this study. The results indicate the possibility of using gastronomic resources to share information in group-oriented musical activities.*

1. Introdução

Neste artigo propõe-se um novo campo de pesquisa dentro do contexto das iniciativas da música ubíqua. O foco é a música feita em espaços domésticos utilizando recursos vinculados à gastronomia. Apresentamos resultados de experiências direcionadas ao espaço doméstico, com foco nas atividades musicais assíncronas utilizando como incentivo para as decisões criativas a modalidade gustativa. A proposta alinha-se por um lado às iniciativas que exploram a multimodalidade em música ubíqua (Keller et al. 2010; Keller et al. 2014) e por outro lado à pesquisa em design de interação humano-comida (*Human-Food Interaction*) (Comber et al. 2014).

A música e a comida têm um longo histórico de associações. No entanto, a pesquisa

sobre o impacto do uso do som nas experiências de comer e beber é recente. Estudos empíricos mostram que existe uma tendência a associar sabores doces com sons de tessitura aguda, com música de tempo lento, com articulações *legato*, com dinâmica suave e (dentro da linguagem tonal) com harmonias consoantes (Bronner, Frieler, Bruhn, Hirt, e Piper 2012; Mesz, Trevisan e Sigman 2011). Complementarmente, os sabores ácidos tendem a ser associados com sons de alturas agudas, com tempos rápidos e com intervalos dissonantes. Os sabores amargos são associados a frequências graves e a sons sem alturas definidas (Crisinel e Spence 2012; Wang, Woods e Spence 2015), enquanto que o sabor salgado é geralmente associado às articulações *staccato* (Mesz et al. 2011; Knöferle e Spence 2012). Um aspecto interessante é que essas associações também foram documentadas fora das culturas ocidentais (Knöferle, Woods, Käßler e Spence 2015), sugerindo que elas podem ser efetivas além das especificidades culturais ou dos gêneros musicais.

Diferentes tipos de sons têm sido usados para modificar a experiência gastronômica com comidas e bebidas diversas. Como resultado, tanto os chefs de cozinha quanto os músicos tentam explorar as potencialidades expressivas de combinar música e comida para maximizar o impacto dos sabores ou para diminuir ou evitar fatores de rejeição a alimentos (Houge e Friedrichs 2018; Spence e Piqueras-Fiszman 2014; Youssef 2015). Esse enfoque tem muito potencial de aplicação na expansão das propostas artísticas multimodais que vêm sendo fomentadas pelas práticas *ubimus* (Aliel et al. 2015; Aliel e Messina 2019; Keller et al. 2011).

A ampliação multimodal das experiências alimentícias é alvo de atenção renovada. A prática do “tempero sonoro” é viabilizada através do desenvolvimento de dispositivos sensoriais (Spence 2019; Velasco, Reinoso Carvalho, Petit e Nijholt 2016; Velasco, Obrist, Petit e Spence 2018). Consideremos, por exemplo, o dispositivo construído por engenheiros japoneses, “o acompanhante de mastigação”¹ Essa ferramenta detecta os movimentos da mandíbula e toca sons pré-gravados em sincronia com os movimentos da boca (Spence e Piqueras-Fiszman 2014). A sincronicidade da mastigação com os sons modula a percepção da textura do alimento tendo assim o potencial de ampliar o prazer ou ainda a surpresa da experiência alimentícia. No Centro Muntref de Arte e Ciência, Mesz et al. (2017) criaram um aparelho similar para uso com bebidas, o “copo de vinho aumentado”. Uma taça de cristal foi equipada com sensores que detectam os gestos do usuário durante o ato de beber, identificando o momento em que o líquido faz contato com os lábios. O dispositivo percebe as mudanças de posição no espaço através de eletrodos e também de sensores capacitivos, assim como de um acelerômetro. Os dados são enviados via *wireless* a um computador para seu posterior processamento e manipulação. Esses dados podem ser usados para ativar estímulos diversos, ampliando o potencial transmodal do uso de bebidas para propósitos científicos e artísticos. Como as modificações do objeto são mínimas visando manter a aparência de uma taça de cristal normal, não é necessário treinamento específico para a utilização do dispositivo (Mesz, Herzog, Amusátegui, Samaruga e Tedesco 2017).

A evidência do impacto do som no gosto sugere o uso da alimentação e das atividades gastronômicas como incentivos para a criação musical. Esse potencial pode ser fortalecido pela utilização das tecnologias web. As atuais propostas *ubimus* ampliam as possibilidades

¹ Nome no original: *Chewing Jockey*. disponível em: https://www.researchgate.net/publication/220982230_Chewing_jockey_augmented_food_texture_by_using_sound_based_on_the_cross-modal_effect.

vislumbradas pela pesquisa pioneira de Wei et al (2011)² sobre teleportagem ou teleportação de alimentos, abrindo mais uma frente de pesquisa dentro do campo emergente da música ubíqua doméstica (Keller, Costalonga e Messina 2020; Keller, Messina e Oliveira 2020).

2. Gastroeventos e gastroícones

Como apontado por Colzato, Lorenza, Haan e Hommel (2015), o consumo de alimentos durante tarefas de caráter criativo pode limitar ou aumentar os recursos cognitivos disponíveis para a atividade criativa. Dando continuidade ao trabalho desses autores, propomos o conceito de gastroevento e sua representação, o gastroícone, estendendo o uso dos recursos epimusicais³ para o campo do sabor. O gastroevento envolve o consumo de alimentos (líquidos ou sólidos) ou a percepção de aromas ou texturas com o objetivo de desencadear uma série de associações que levam a uma escolha estética. O gastroícone é um elemento visual que representa um gastroevento.

Os gastroícones não determinam os resultados estéticos. Portanto, esperamos que diversas instâncias de um mesmo gastroícone levem a resultados sonoros diversos, envolvendo perspectivas estéticas complementares. Por outro lado, o gastroevento é definido como uma ação que acontece dentro de um período de tempo claramente especificado - com indicação de início e fim - e situado dentro de um contexto musical específico. No entanto, a adoção de ritmos periódicos, a sincronização ou a repetição de acordo com diretrizes temporais hierárquicas não são requisitos⁴. Essa atitude aberta e neutra perante as informações musicais é motivada por múltiplos fatores: 1. Os participantes leigos geralmente não têm dificuldade para executar instruções envolvendo informações qualitativas relacionadas à manipulação do tempo, mas podem encontrar empecilhos se a demanda envolve sequências sincronizadas (Hennig 2014); 2. Várias propostas ubimus fornecem estratégias flexíveis para a organização temporal evitando a adoção de paradigmas métricos, centralizados ou hierárquicos. Esse tipo de exigência tende a limitar o suporte tecnológico a um leque pequeno de gêneros musicais (cf. discussão crítica em Messina e Aliel 2019; Stolfi et al. 2019); 3. A escuta de diferentes tipos de sons pode impactar o sabor em formas específicas. Porém, apesar de não descartar esses aspectos da pesquisa intermodal, nosso foco é a influência do gosto na criação sonora. Isso justifica uma atitude cuidadosa na escolha de estratégias de manipulação dos parâmetros do gosto, atendendo a limitações decorrentes dos processos de organização sonora. Por esse motivo escolhemos restringir a experiência a um conjunto pequeno de bebidas e aplicamos critérios restritivos para as classes sonoras fornecidas na atividade, incluindo amostras e procedimentos sonoros explicitamente associados às dimensões gustativas. Também instruímos os sujeitos para que eles procurem relacionar sua degustação com suas escolhas estéticas.

² Nesta pesquisa foi desenvolvido um sistema para permitir a interação remota de uma família no momento do jantar. O sistema permite compartilhar vídeo, áudio e interações remotas através da renderização de alimentos com mensagens personalizadas. Desta feita, serve-se um prato remotamente e capturam-se os gestos através de um dispositivo *Kinect*

³ Keller, Messina e Oliveira (2020) sugerem a aplicação da nomenclatura *epi* para os recursos que têm impacto direto nos resultados sonoros.

⁴ Evitamos cuidadosamente incorporar conceitos como o objeto sonoro Schaefferiano, a nota musical baseada na perspectiva acústico-instrumental, ou a noção de instrumento voltada exclusivamente para o âmbito sonoro.

3. Recursos epimusicais: Bebidas

Foram escolhidas bebidas, ao invés de outros alimentos, pela simplicidade proporcionada pelas pequenas porções de 200 ml, a simplicidade da ingestão, a possibilidade de reproduzir o mesmo sabor para cada um dos voluntários e poder representar cada um dos sabores perceptíveis ao nosso paladar.

As bebidas usadas durante as sessões foram água, café, suco de maçã, suco de laranja e suco de limão. Os insumos são preparados pelos participantes no seu lar. Para obter uma temperatura uniforme, as cinco bebidas ficam refrigeradas durante pelo menos 3 horas antes do início de cada sessão e são servidas em copos de vidro transparente.

As escolhas visam induzir quatro das cinco dimensões básicas do gosto: Café sem açúcar - *amargo* (uma colher de café instantâneo Nescafé em 200 ml. de água); Suco de limão - *ácido* (20 ml. de suco de limão em 180 ml. de água, na preparação foi utilizada polpa congelada); Suco de maçã - *doce* (caixinha de 200 ml.); suco de laranja - *ácido e doce* (caixinha de 200 ml.); e água mineral sem sódio - basicamente *insípida*. A dimensão umami é considerada um elemento importante no estudo do sabor, no entanto, decidimos adiar sua inclusão pelas dificuldades operacionais encontradas na preparação do suco de tomate. No Rio Branco, esse suco não é comercializado em embalagens de 200 ml.

4. Amostras sonoras

Os materiais sonoros foram fornecidos aos participantes em formato .wav, sem compressão, codificados com 3 dígitos. Foram enviados 106 arquivos com durações de 5, 10, 15 e 30 segundos. Para a criação dos áudios utilizamos síntese granular e processamento via filtragem num *patch* desenvolvido por Damián Anache⁵, que funciona no ambiente de áudio Pure Data (PD) (Puckette 1997). A arquitetura do *patch*, possibilita especificar parâmetros como tamanho do grão sonoro, intervalo entre os grãos, incremento, densidade, amplitude da intensidade sonora global e reverberação. Essas características são controladas por *sliders* individuais e autônomos em tempo real e com a possibilidade de renderizar a amostra sonora em formato de áudio .wav. Os sons estão baseados em correspondências intermodais entre gostos básicos e parâmetros sonoros. Sons rápidos, dissonantes e agudos são geralmente relacionados ao gosto ácido. Sons lentos, graves e ásperos são vinculados ao gosto amargo. Sons fortes, consoantes, legato são normalmente associados ao gosto doce.

Incluímos dois tipos de materiais: a) “Sons com gosto”, gerados a partir de parâmetros associados aos gostos básicos (60%). Numa enquête prévia, dezoito arquivos tinham sido validados como correspondendo aos gostos básicos de amargo, doce e ácido (mais de 70% dos participantes (N=19) associaram cada som ao gosto correto). Os outros arquivos foram renderizados através de síntese granular, introduzindo variações leves a partir dos parâmetros já validados. b) “Sons neutros”, que foram produzidos para não serem associados com algum gosto específico (40%), incluindo sons sintetizados e gravações de eventos cotidianos.

5. Perfil dos participantes.

⁵ Disponível em <https://puredata.info/Members/pdiliscia/grainer>. Data de acesso: 29/06/2021.

O experimento gastroesferossonico Rio Branco se deu em duplas que trocavam arquivos sfs do SoundSphere de forma assíncrona. Esses arquivos contêm dados da criação desenvolvida pelos participantes como: amostras escolhidas, amostras utilizadas, diferentes itens de mixagem, filtros, etc. A escolha dos voluntários não teve um critério especial, estes foram selecionados conforme sua disponibilidade em participar do estudo, não houveram critérios especiais para pareamento por idade ou de sexo.

6. Ferramentas de aferição

As ferramentas de aferição abrangem dois formulários disponibilizados online, o CSI-NAP e o ISE-NAP (Keller et al. 2011). O **ISE-NAP** extrai dados relacionados ao perfil dos sujeitos. A ferramenta contém perguntas sobre o perfil do sujeito, como o nível de escolaridade, a idade, e a presença de problemas oftalmológicos ou auditivos. Tem uma seção dedicada a aspectos do uso de tecnologia, como o uso de dispositivos portáteis e navegadores web. Para os sujeitos com treinamento musical formal, o ISE-NAP disponibiliza uma seção de coleta de dados sobre o tipo e a duração das atividades musicais realizadas.

O **CSI-NAP** foca a experiência criativa e os subprodutos da atividade, permitindo a avaliação dos itens numa escala Likert de cinco níveis. Por exemplo, através da pergunta “a experiência foi boa?”, pode-se aferir a relevância atribuída à atividade incluindo fatores como o suporte tecnológico, os materiais disponibilizados ou o contexto no qual foi feita a atividade.

A produção criativa dos participantes no experimento também é avaliada. São utilizadas duas dimensões: a relevância e a originalidade. Nesses quesitos buscamos saber se os participantes acham que sua criação foi “inovadora”, se os resultados foram os esperados e se a atividade foi produtiva. Enquanto à pergunta “foi fácil colaborar?”, ela abrange a disponibilidade para as trocas e a avaliação do apoio fornecido pelas ferramentas. Também são aferidos o nível de atenção ou o esforço cognitivo despendido na atividade, e o engajamento individual ou grupal.

7. Gastroícones em SoundSphere

Como estratégia inicial, na versão 1.5 do protótipo SoundSphere implementamos suporte para atividades gastrossônicas. As funcionalidades da Metáfora da Esfera Sonora (Bessa, Keller, Farias, Ferreira, Silva e Pereira 2015; Bessa, Keller, Freitas e Costa 2020) foram expandidas viabilizando o suporte para a ação de beber durante a realização de mixagens de áudio. A versão 1.5.1 permite inserir as amostras selecionadas no painel de mixagem (o setor com linhas horizontais na figura 1). Essa versão dispõe dos mesmos recursos das versões anteriores: o leitor sfs e o TOE (Freitas et al. 2019; Freitas et al. 2020).

Como contribuição para o desenvolvimento da Metáfora da Esfera Sonora, a versão 1.5.1 apresenta os gastroícones.⁶ Esses elementos dão suporte para atividades que relacionam música e sabor. Os gastroícones incluem recipientes cheios ou vazios que podem ser inseridos em eventos sonoros ativos ou inativos, dependendo do tipo de processo de associação dos

⁶ O design visual foi realizado pelo pesquisador da Untref, Sebastián Tedesco. O modelo de interação e a implementação em software foi feita pela equipe do NAP (cf. Bessa et al. 2020).

elementos musicais com a ação de ingerir bebidas. O ícone pode ser utilizado como registro da associação entre o evento sonoro e o sabor, como indicação de ações feitas ou a fazer ou como forma de exclusão de opções (utilizando os recipientes vazios).

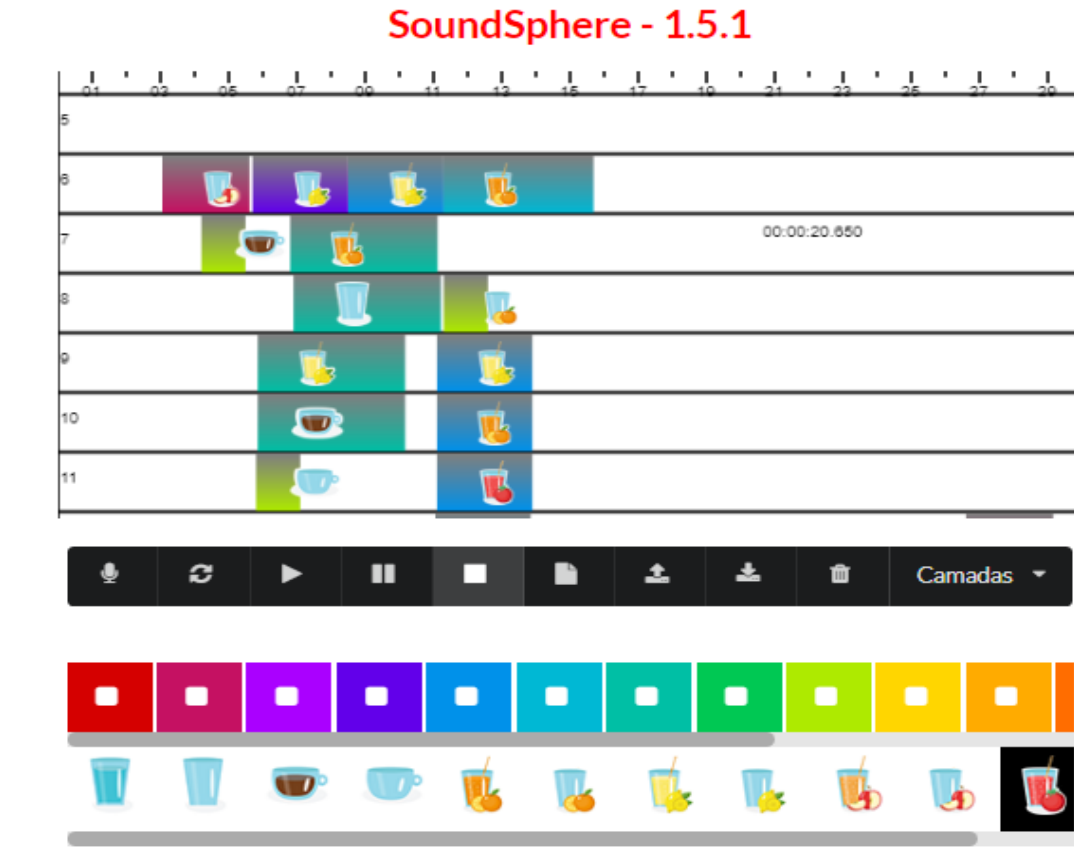


Figura 1. Interface SoundSphere na versão 1.5.1, contendo os gastroícones.

8. Procedimentos

As atividades experimentais foram realizadas em Rio Branco, Acre. Participaram 6 duplas, em sessões realizadas ao longo do dia, usando fones de ouvido e num espaço com baixo nível de ruído. Foi solicitado o uso de um dispositivo estacionário equipado com mouse, teclado QWERTY e com suporte para o navegador Google Chrome.

Foram fornecidas instruções aos participantes do que teriam que fazer durante o experimento. Foi explicada a preparação e refrigeração das bebidas, os objetivos do experimento, o vínculo institucional e as condições necessárias para a execução. O experimentador foi até a casa dos voluntários para resolver dúvidas e fornecer os insumos aos participantes (as bebidas seriam inicialmente adquiridas pelos voluntários, porém devido a limitações econômicas, o grupo NAP as forneceu). As bebidas são água, café, suco de maçã, suco de laranja e suco de limão. Os sucos vêm em unidades de caixas de 200 ml. O café é solúvel (sem açúcar) e o suco de limão é feito a partir de uma polpa congelada. O ambiente do experimento foi a casa dos participantes, onde foram executadas 5 sessões ao longo do dia, uma para cada bebida. Os participantes deviam ingerir as bebidas enquanto faziam as

mixagens. O ISE-NAP foi preenchido por cada voluntário no início do experimento, já o CSI-NAP foi preenchido após a realização de cada sessão. Os participantes também receberam um protocolo por e-mail, solicitando dados pessoais e incluindo perguntas sobre problemas de audição, de gosto ou de olfato.

A ordem das sessões foi definida pelos experimentadores, cada sessão adotou uma bebida específica.⁷ A ordem das bebidas foi aleatória, mas foi a mesma para os dois participantes de cada dupla. Os sujeitos foram instruídos a produzir mixagens sonoras congruentes com o sabor da bebida, enquanto ingeriam a bebida lentamente⁸. Ao selecionar uma amostra sonora, o gastroícone correspondente devia ser inserido no evento (figura 1). Na primeira sessão, um participante fazia uma mixagem enquanto consumia uma das bebidas da lista, depois enviava o arquivo produzido pelo SoundSphere para o outro participante. O segundo sujeito trabalhava no mesmo arquivo (seja adicionando, apagando ou modificando eventos) enquanto consumia a mesma bebida que o seu parceiro, e enviava o arquivo de volta para que o primeiro sujeito desse continuidade à mixagem enquanto utilizava a segunda bebida. O processo continuava até que os dois participantes concluíssem a sequência de bebidas.

Ao terminar cada sessão, os participantes preencheram um questionário acerca do gosto da bebida. O questionário adota uma escala Likert de 5 pontos que vai de “discordo totalmente” (-2) a “concordo totalmente” (+2), com 0 correspondendo a “não sei” ou neutro. As categorias avaliadas são: amargo, doce, ácido, salgado, umami, prazeroso, intenso, estimulante, complexo e familiar.

9. Resultados das sessões preliminares

Para analisar as respostas do formulário CSI-NAP, relacionadas com 3 aspectos positivos e 3 aspectos negativos da experiência, agrupamos as informações fornecidas pelos sujeitos em sete categorias. Assim, foi possível quantificar tendências dentro de um grupo de respostas abertas como mostrado na tabela 1. O primeiro a destacar é a dificuldade no uso do software por parte dos sujeitos. Comentários como “acho a plataforma um pouco complexa” e “dar bug na hora de utilizar” [sic] foram comuns entre os aspectos negativos (em maior número que os comentários positivos). Porém, na categoria referente ao trabalho grupal, todos os comentários foram positivos mostrando que ainda com as dificuldades encontradas, a interatividade não foi afetada. Na categoria relacionada ao processo criativo, a maior parte dos comentários foram positivos destacando os aspectos como: “consegui explorar amostras sonoras diferentes”. Em termos gerais, a experiência sensorial foi positiva: “sai da zona de conforto sonoro tradicional” e “experiências sensoriais interessantes”. Nos comentários negativos podemos destacar “o sabor da bebida.” e “o local estava barulhento”. Nas categorias de prazer, diversão e experiência cognitiva, não houve diferenças significativas entre os comentários positivos e negativos. Os sujeitos acharam o experimento “legal”, “interessante” e “divertido” e em alguns casos, “lento” e “monótono”; e descreveram os aspectos cognitivos e sensoriais como: “relevantes” e “[a] ideia é boa” com “muitos sons para ouvir”.

⁷ As bebidas não incluem o sabor umami, porém escolhemos manter esse item para análise em experiências futuras e para determinar o nível de confusões entre as cinco dimensões do sabor.

⁸ O protocolo indica que se um participante perde a vez, essa parte do procedimento deve ser pulada, sem afetar o resto do procedimento.

Tabela 1. Comentários obtidos nas sessões preliminares.⁹

Categorias	Número de comentários nos aspectos positivos	Número de comentários nos aspectos negativos
Design da ferramenta	12	37
Processo criativo	14	3
Trabalho grupal	12	0
Experiência sensorial	24	11
Não sabe / não responde	14	17
Prazer e diversão	32	25
Aspectos cognitivos	13	11

10. Estudo Gastrossônico 1

Participaram 12 sujeitos adultos (6 mulheres e 6 homens) com idade média de 35,2 anos e um desvio padrão de 10,90 anos.¹⁰ Três com escolaridade em ensino médio, cinco com ensino superior completo e quatro cursando o ensino superior. Somente três sujeitos declararam ter recebido treinamento formal em música (entre 3 e 7 anos) sendo um deles músico ativo profissionalmente. Todos têm ampla experiência no uso de tecnologia e quatro relataram experiência específica em tecnologia de áudio.

10.1. Resultados do uso de amostras

Todos os sujeitos realizaram a atividade no ambiente doméstico, abrangendo espaços diversos: sala, quarto e cozinha. Um dos sujeitos fez a atividade em pé, possivelmente por falta de disponibilidade de espaço. Todos os dispositivos utilizados foram computadores portáteis, com mouse óptico. O formulário CSI-NAP foi respondido imediatamente após a conclusão de cada atividade.

Tabelas 2 a 5. Avaliação da experiência criativa, 43 interações (laranja = 10, limão = 10, maçã = 10, café = 7, água = 7).

Experiência criativa	
relevância	originalidade
1,05 ± 0,84	1,14 ± 0,89

Resultado criativo	Materiais sonoros	Local da atividade
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⁹ Como foram aplicados estudos ao longo de todo o processo de design da ferramenta SoundSphere, diversos comentários dão destaque para as limitações da ferramenta. Parte dessas limitações foram corrigidas na versão atual.

¹⁰ Em estudos futuros também será aplicado um termo de consentimento.

relevância	originalidade	quantidade	
0,81 ± 1,05	0,84 ± 1,02	0,67 ± 1,02	1,23 ± 0,61

Facilidade de uso		
seleção	modificação	mixagem
0,74 ± 1,11	0,49 ± 1,16	0,56 ± 0,98

Diversão		Colaboração
seleção	modificação	
0,88 ± 0,88	0,86 ± 0,91	1,26 ± 0,90

Em termos gerais, as avaliações dos resultados criativos e das atividades apresentam divergências entre os sujeitos. Os fatores relevância, originalidade e colaboração nas atividades tiveram escores positivos. O ambiente doméstico também foi considerado positivo. A maioria dos sujeitos achou a proposta divertida. Mas os itens específicos sobre o suporte e sobre os resultados não mostraram tendências uniformes. A variabilidade pode ser atribuída a fatores diversos. Discutiremos algumas limitações na seção final do artigo.

10.2. Resultados da relação entre bebidas e amostras

Foram avaliadas cinco dimensões vinculadas ao sabor das bebidas com o intuito de determinar por um lado se os sujeitos conseguiam diferenciar os sabores e por outro lado se existiam divergências na experiência gustativa dentro do grupo. Os resultados mostram alinhamento entre os sujeitos, com diferenças claras entre os sabores. Tem destaque a aferição da água, com todos os resultados alinhados entre os participantes com uma única exceção: o fator estimulante.

Tabela 6. Avaliações dos sabores das 5 bebidas (média e desvio padrão para todos os sujeitos).

	Agradável	Estimulante	Familiar	Complexa	Forte
Laranja	-0,5 ± 1,08	0,8 ± 0,92	0,8 ± 1,23	0,6 ± 1,17	0,8 ± 1,03
Maçã	0,33 ± 1,58	0,22 ± 1,56	0,11 ± 1,62	0 ± 1,41	0,33 ± 1,58
Limão	-1,1 ± 1,20	-0,3 ± 1,42	1,4 ± 1,35	-0,3 ± 1,42	1,3 ± 1,25
Café	0,14 ± 1,21	1,43 ± 1,13	2 ± 0	-0,57 ± 1,13	0,71 ± 1,60
Água	1,86 ± 0,38	0,29 ± 1,70	2 ± 0	-2 ± 0	-2 ± 0

O outro aspecto da experiência gustativa para o qual coletamos dados subjetivos foi a percepção do sabor, especificado em cinco dimensões: doce, salgado, amargo, umami e ácido.

As bebidas utilizadas somente incluíam três dessas dimensões. Porém, a avaliação completa é importante para obter dicas sobre possíveis confusões entre dimensões. É interessante observar que exceto com o suco de laranja, a aferição negativa do sabor salgado foi unânime. A avaliação da água foi uniforme e consistente entre todos os sujeitos. Com exceção do suco de laranja, a avaliação da dimensão umami teve uma incidência negativa maior. E a dimensão doce foi uniformemente negativa na água, no café e no suco de limão. Em conjunto, esses resultados mostram uma aferição consistente entre os sujeitos, com maior variabilidade na percepção do gosto do suco de laranja.

11. Implicações do estudo gastrossônico 1

Como primeiro estudo em gastrossônica, propomos uma atividade musical colaborativa assíncrona na qual participaram treze sujeitos distribuídos em duplas.¹¹ Todos os sujeitos receberam cinco bebidas: água, café, suco de maçã, suco de laranja e suco de limão. Foi utilizado um insumo por sessão até concluir as cinco sessões. A atividade proposta envolvia criar uma mixagem no ambiente SoundSphere escolhendo as amostras sonoras que tivessem a maior identidade com o sabor da bebida sendo consumida. O universo total era de 106 amostras, mas os sujeitos podiam reutilizar ou excluir os materiais já existentes em cada uma das iterações.

A coleta de dados incluiu múltiplas sessões preliminares, nas quais os sujeitos utilizaram a ferramenta SoundSphere para fazer mixagens enquanto consumiam uma das cinco bebidas. A análise desses comentários apontou seis aspectos da experiência e um grupo de respostas nas quais os sujeitos não conseguiram interpretar o pedido ou não tiveram uma opinião explícita sobre o item. Os seis grupos incluíram comentários sobre o design da ferramenta e descrições vinculadas ao prazer e à diversão da experiência (o número maior). Em segundo plano houve observações sobre aspectos sensoriais e cognitivos da experiência. Por último, as duas categorias que receberam menor atenção foram o trabalho grupal e os processos criativos. No entanto, os aspectos criativos, as características grupais e o perfil sensorial da experiência foram os que tiveram um viés maiormente positivo. Já o design da ferramenta recebeu muitos comentários, mas a maioria foram críticas.

A aferição da experiência focou em dois aspectos. Por um lado foram avaliados fatores diversos do suporte material e tecnológico, incluindo a aferição dos resultados criativos pelos próprios participantes. Complementarmente, foram aferidas as dimensões vinculadas ao sabor das bebidas visando estabelecer quais características da experiência gastronômica poderiam ser aplicadas no procedimento analítico. Os resultados são diversos e permitem estabelecer um quadro com aspectos de destaque e outros que precisam de estudo específico, possivelmente aplicando técnicas de aferição complementares.

Tiveram destaque o suporte à colaboração e o fomento à criatividade durante a experiência. Também houve escores positivos da maioria dos sujeitos no quesito referente ao local da atividade. No entanto, a aferição da quantidade de materiais sonoros disponíveis e os três aspectos do suporte (seleção, modificação ou mixagem) não tiveram escores alinhados entre todos os participantes. Complementando a análise dos comentários feitos pelos sujeitos experientes, é possível que o suporte seja suficiente para as expectativas dos usuários leigos, mas que seja necessário incorporar estratégias alternativas para os participantes com

¹¹ Houve diversas desistências.

treinamento musical.

Os resultados obtidos na aferição da experiência gastronômica com as bebidas foram positivos. As respostas da maioria dos sujeitos ficaram alinhadas em quatro das bebidas utilizadas (água, café, limão e maçã) e apresentaram uma maior variabilidade no caso do suco de laranja. Esses resultados reforçam a proposta da utilização de bebidas como estratégia de transferência de conhecimento em atividades musicais grupais. Também indicam dificuldades específicas quando o insumo utilizado abrange dimensões diversas do gosto, como é o caso do suco de laranja que inclui os fatores ácido e doce. Esperamos que estudos futuros em gastrossônica permitam aprofundar o domínio dos métodos e ampliar as possibilidades de aplicação deste campo emergente de pesquisa.

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Vantagens e desafios do emprego da metodologia STEAM no ensino de música na educação básica brasileira

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Abstract. *Music education in Brazil faces several challenges, from the lack of trained teachers in the area to the lack of suitable places for practice and the scarcity of musical instruments. Besides, there are structural and socioeconomic problems that interfere with the country's educational system. To help remedy these problems, this paper presents reflections on the use of the STEAM methodology in music education, also assisting in the instruction of the sciences and other fields of the arts. The teaching contexts of before and during the pandemic are taken into account.*

Resumo. *O ensino de música no Brasil enfrenta diversos desafios, desde a falta de professores formados na área, até a ausência de locais adequados para a prática e a escassez de instrumentos musicais. Somado a isso, existem os problemas estruturais e socioeconômicos que interferem no sistema educacional do país. Para ajudar sanar, em partes, estes problemas, este artigo apresenta reflexões em torno do emprego da metodologia STEAM na educação musical, prestando auxílio também na instrução das mais diversas ciências e de outros campos das artes. São levados em considerações os contextos de ensino de antes e durante a pandemia.*

1. Introdução

O ensino de música no Brasil vem de longa data. Começando com as escolas mantidas por jesuítas até o século XVIII, passando pelo movimento em favor do Canto Orfeônico, promovido por Getúlio Vargas na década de 1930 até o golpe militar de 1964, que conduziu a educação para o mercado de consumo sob hegemonia estadunidense e mudou drasticamente a maneira como esse tema era abordado. Foi somente em 1996 que a lei referente as diretrizes e bases da educação nacional assegurou a música nos parâmetros curriculares [Marianayagam 2013]. Em 2008, a lei N° 11.769 sancionada pelo presidente Luiz Inácio Lula da Silva estabeleceu a obrigatoriedade da disciplina nas escolas de educação básica [Santos et al. 2015].

Para pensar a educação musical no Brasil é preciso, primeiro, pensar nos objetivos desta educação. [da Silva 2012] indica que ela deve ser focada em: fortalecer a ideia de que a música faz parte da cultura e contribui para o desenvolvimento da sensibilidade frente ao fenômeno sonoro; propiciar ampla discussão sobre o papel da música

na sociedade; desenvolver sistematicamente conceitos e habilidades musicais; estimular a pesquisa musical nas mais diversas localidades escolares, promovendo aproximações culturais, demonstrando perspectivas de mercado e estimulando a formação de novos profissionais, e prestigiar atividades musicais diversas.

Das habilidades a serem sistematicamente desenvolvidas, encontram-se os conceitos básicos da música (melodia, harmonia e ritmo), rudimentos da teoria (escalas, acordes e tons) e leitura da notação musical. Quanto as habilidades gerais, estão a melhoria na concentração, ativação da memória e raciocínio lógico, aprendizado de novas culturas, dentre outras que auxiliam no processo cognitivo.

O mesmo autor defende ainda que a formação pedagógico-musical dos professores que vão atuar nessa área devem abarcar reflexões sobre as funções da música e os objetivos dela na educação, possibilidades para o trabalho de música em sala de aula e conhecimento em diversos conteúdos e procedimentos metodológicos para o fazer musical.

Ainda que obrigatória, nem sempre esta disciplina está presente na grade curricular do ensino básico e os motivos são os mais variados possíveis, indo desde a falta de professores capacitados, ambientes tratados acusticamente para a prática musical, escassez de instrumentos e outros. Todos eles são agravados pelos problemas estruturais da educação no país e também por condições socioeconômicas, além daqueles que surgiram em virtude da pandemia do Novo Coronavírus nos anos 2020-2021. Somado a isso, existe o fato do ensino de música ainda ser pautado nos cânones musicais europeus [Queiroz 2020]. Estes pontos serão melhores debatidos na seção 2.

Um campo que pode auxiliar para sanar parte destes problemas é o da Música Ubíqua (ubimus) [Keller et al. 2014], principalmente por priorizar a criatividade e a exploração crítica e reflexiva das possibilidades presentes em um ambiente musical. Para além disso, corrobora ao permitir que ferramentas e objetos do cotidiano de cada aluno seja utilizado com propósitos musicais e artísticos [de Lima et al. 2018]. Uma metodologia que também apresenta estas características é a *Science, Technology, Engineering, Arts, and Mathematics* (Ciência, Tecnologia, Engenharia, Arte e Matemática) - STEAM, um paradigma que reúne todas estas áreas do saber para a construção de um novo conhecimento. Ainda pode ser evidenciada nestas duas áreas que a interação social é o cerne dos processos criativos [de Lima et al. 2018]. Dito isso, o foco deste trabalho está em apresentar as principais vantagens e desafios do emprego desta técnica no ensino de música na educação básica brasileira, debatendo ainda maneiras para sua implementação e correlações com a ubimus. Suas propriedades e aplicações serão melhores debatidas na seção 3.

Ao pensar na possibilidade de utilizar esta metodologia para o ensino de música surge a necessidade de pensar nas tecnologias que poderiam ser utilizadas para este fim. Ferramentas de auxílio para criação musical que também expandem seus domínios para o STEAM, como Sonic Pi, Pure Data, Chuck, SuperCollider e FAUST são apresentadas na Seção 4, bem como suas aplicações práticas.

Uma discussão acerca do uso desse conceito, baseada na experiência empírica dos autores, será feita na seção 5, enquanto conclusões resumidas sobre este trabalho serão apresentadas na Seção 6.

2. Contexto da educação no Brasil

A presente Seção foca no contexto educacional brasileiro, levando em consideração a realidade pré e durante a pandemia de COVID-19. São expostos os principais problemas na prática educacional, além daqueles socioeconômicos que interferem na construção do conhecimento.

Cenário pré-pandemia

O sistema educacional brasileiro lida com questões na ordem estrutural, pedagógica, financeira e socio-cultural. [Campioni 2018] classifica esses problemas em externos e internos, sendo que os externos dizem respeito a desigualdade de oportunidades e aprendizagem no ambiente escolar, a começar pelo desempenho inferior das metas estabelecidas.

Segundo dados mais recentes do Programa Internacional de Avaliação de Alunos (PISA, na sigla em inglês) realizado em 79 países, apenas 2% dos alunos brasileiros com até 15 anos apresentaram proficiência em ao menos um dos três campos analisados (leitura, matemática e ciência), enquanto 43% apresentaram nota mínima nos três temas [OECD 2018].

Pode-se observar também a evasão escolar, causada pela baixa renda familiar; pouca ou nenhuma escolarização dos responsáveis; domicílio localizado em áreas rurais ou longínquas e discriminação por cor ou gênero. Atrelado a isso, existem os fatores socioeconômicos, observados na desigualdade de oportunidades e de acesso ao ambiente escolar.

Outros dois fatores externos que interferem na educação são a violência em sala de aula [OECD 2018] e o baixo nível do índice que sintetiza a renda, escolarização e ocupação do estudante (Nível Socioeconômico - NSE) [Campioni 2018]. No que diz respeito a violência contra professores, o país lidera um ranking elaborado pela Organização para a Cooperação e Desenvolvimento Econômico (OCDE), com os mesmos 79 países avaliados no PISA. Quanto ao NSE, que refere-se a alunos em situações vulneráveis, a proficiência em Língua Portuguesa foi de 7,5% para aqueles classificados com índice baixo, contra 71,6% dos que apresentam índice elevado. Em Matemática, os valores foram de 2,5% para o primeiro grupo e 58,2% para o segundo.

Os desafios internos aparecem em menor número, mas são igualmente importantes para entender o sistema educacional brasileiro. Eles são definidos como: falta de qualidade nas escolas, observadas pela falta de professores ou carência de profissionais formados na área em que lecionam; falta de bibliotecas, quadras e laboratórios; atrasos em repasses, que ocorre tanto em nível federal quanto estadual, e burocracia com procedimentos de registro de aula, algo que ocupa bastante tempo da equipe escolar e torna a educação pouco adaptável as necessidades dos alunos [Campioni 2018].

Quanto aos desafios referentes ao emprego da tecnologia em sala de aula, quatro principais problemas são destacados por [Pinto 2019]: i) falta de engajamento dos alunos; ii) adaptação dos professores; iii) atualização constante; e iv) escolha das ferramentas adequadas.

O primeiro problema está diretamente relacionado com a forma passiva com que os alunos recebem conhecimento. Ao se utilizar meios tecnológicos, este problema é agravado diante da facilidade de se copiar os arquivos digitais. O segundo desafio passa

novamente pela falta de professores capacitados e formados na área, somado ao pouco conhecimento tecnológico. A terceira questão está relacionada as constantes mudanças nos *softwares* e artefatos computacionais, que podem ter mudanças tão significativas que irá se chocar com a falta de capacitação dos professores, citada no tópico anterior. O quarto e último problema passa pela escolha da tecnologia a ser utilizada, onde ela deve ser robusta o bastante para contemplar todos os requisitos educacionais, ao passo que também deve ser economicamente viável, ter uso intuitivo e consumir poucos recursos de *hardware*.

Cenário durante a pandemia

No dia 30 de janeiro de 2020, a Organização Mundial da Saúde (OMS) declarou que a COVID-19, causada pelo SARS-COV-2, popularmente conhecido como Coronavírus, constituía uma pandemia. Em decorrência disso, no dia 18 de março de 2020, o Ministério da Educação (MEC) emitiu a portaria nº 343, que em caráter excepcional, permite a substituição das disciplinas presenciais por aulas que utilizam tecnologias de informação e comunicação.

Embora necessário para conter o COVID-19, o fechamento das escolas teve (e ainda tem) impactos severos na educação básica, ainda mais se forem levadas em consideração as desigualdades brasileiras. Segundo o relatório Educação em Pausa¹, divulgado pela UNICEF, 4 milhões de estudantes brasileiros (14,4%) estavam sem acesso a nenhuma atividade escolar.

Nas favelas, a situação é ainda pior. De acordo com pesquisa do DataFavela², 55% dos estudantes de favelas estão sem estudar durante a pandemia, principalmente pela falta de dispositivos adequados, má conexão com a internet e professores distantes.

Além de todos estes problemas, a educação musical ainda enfrenta resquícios da colonização em seus currículos, conteúdos, objetivos e abordagens metodológicas, sendo baseada em estratégias para o ensino da música erudita ocidental [Queiroz 2020].

3. STEAM

As mudanças ocorridas no mundo por conta globalização, do avanço tecnológico, e agora, da pandemia, interferiram também na forma como o conhecimento é difundido, rompendo com modelos tradicionais de ensino. A Organização das Nações Unidas para Educação, Ciência e Cultura (UNESCO, na sigla em inglês) editou no relatório “Educação: Um tesouro a descobrir” os quatro pilares para a educação no século XXI: aprender a ser, aprender a fazer, aprender a viver juntos e aprender a conhecer [Fortes 2011, Delors 2018].

Entretanto, o que se observa hoje na realidade brasileira é um sistema de ensino engessado, com a forma de transmitir conhecimento atrelada a um curso, também chamado de disciplina. [Fortes 2011] define disciplina como uma seleção de conhecimentos que são ordenados para serem apresentados aos alunos com apoio de procedimentos

¹Disponível em: <https://www.unicef.org/brazil/comunicados-de-imprensa/covid-19-mais-de-97-porcento-dos-estudantes-ainda-estao-fora-das-salas-de-aula-na-america-latina-e-no-caribe>

²Disponível em: <https://observatorio3setor.org.br/noticias/55-dos-alunos-que-moram-em-favelas-estao-sem-estudar-na-pandemia/>

didáticos e metodológicos. Ainda segundo a autora, esse caráter do ensino dificulta a aprendizagem do aluno, já que não estimula o desenvolvimento da inteligência nem a capacidade de resolver problemas e estabelecer conexões entre os fatos.

Desta maneira, o ensino fica restrito somente a transmitir determinados conhecimentos em diversas áreas. Um desdobramento desse conceito resulta no ensino multidisciplinar, onde diversos conteúdos são ensinados em paralelo, ainda que de forma individual, sem que haja correlação entre eles.

Ultrapassando esse contexto, surge a difusa metodologia de interdisciplinaridade. Heckhausen, como citado em [Fazenda 2017], apresenta-o como “a ciência da ciência”, isenta das particularidades das disciplinas, o que proporciona uma análise maior de características em dada situação. [Japiassu 1976, Lavaqui 2007], por sua vez, dividem esse campo entre interdisciplinaridade linear e estrutural. O primeiro modelo é caracterizado pela troca de informações entre diferentes disciplinas, mas sem uma cooperação mais efetiva. O segundo modelo é definido por uma maior relação entre diferentes campos de estudo, mas sem uma imposição de um sobre outro.

De uma forma geral, a interdisciplinaridade busca estabelecer relações de complementariedade entre os conhecimentos, mudando o processo pedagógico e a forma como um novo conceito é aprendido, além de permitir ao aluno uma experimentação da vida real. É importante frisar que a interdisciplinaridade não quer a extinção da disciplina como método isolado, mas propor que os alunos aprendam a observar as diferentes nuances de um único objeto [Bonatto et al. 2012, Fortes 2011].

Com a facilitação do acesso à informação, os professores não são mais os únicos detentores do conhecimento, cabendo a eles uma nova função, que é atuar como intermediário entre a informação e o aluno para facilitar a aprendizagem. Essa nova realidade também exige dos educadores uma formação interdisciplinar e é neste ponto que entra o conceito de STEAM.

O STEAM, como citado, é um método de ensino ancorado na interdisciplinaridade e considerado uma evolução da abordagem STEM, que não incluía o campo das Artes em sua proposta. Sua abordagem é baseada em cinco estratégias de ensino: i) *Hands-On*, que incorpora o aprendizado prático, permitindo aos alunos explorarem e investigarem um problema e depois proporem uma solução; ii) inclusão de problemas do mundo real; iii) integração e aplicação do aprendizado; iv) incentivos ao questionamento e a reflexão; e v) controle dos alunos sobre seu aprendizado [Cordova and Vargas 2016, Land 2013].

As vantagens do uso dessa metodologia podem ser observadas através das 10 competências gerais da Base Nacional Comum Curricular (BNCC), a saber: conhecimento; pensamento científico, crítico e criativo; repertório cultural; comunicação; cultura digital; trabalho e projeto de vida; argumentação; autoconhecimento e autocuidado; empatia e cooperação, e responsabilidade e cidadania [da Silva 2018]. Assim, presta-se ajuda no que diz respeito a análise e resolução de problemas, compreensão dos princípios da computação e outros. Aplicando esta abordagem, o problema do mundo real a ser solucionado é o ensino de música.

4. Ferramentas de auxílio a Música a partir do conceito de STEAM

Em tempos pré-pandemia e com os desafios listados para a prática musical em ambiente escolar, algumas ferramentas poderiam ser utilizadas para suprir a falta de estrutura e instrumentos, de modo que o som não fosse prejudicado e que o gasto financeiro para obtê-las não comprometesse o já aferrolhado orçamento das escolas. Em tempos de pandemia, dada a falta de capacidade de conexão e de *hardwares* potentes, além das questões financeiras de boa parte dos alunos, é necessário que as ferramentas tenham baixo custo computacional e monetário. Em ambos os casos, o mesmo instrumental pode ser aplicado, também auxiliando no emprego do STEAM. Alguns deles são apresentados a seguir.

- **Sonic Pi**³: É um ambiente de *live coding*, onde a escrita do código acontece com o programa em execução. Pela sua sintaxe simples e organizada é muito adequado para iniciantes na música e na programação, já que permite interações descomplicadas por parte dos usuários, garantindo que eles se concentrem somente nos conceitos-chave do processo. Ainda pode ser caracterizado como uma atividade lúdica [Sinclair 2011]. Por conta de suas características interdisciplinares, é uma ferramenta que enfatiza a importância da criatividade no processo de aprendizagem, auxiliando também em uma diversa gama de assuntos, como: desenvolvimento de habilidades artísticas, manuseio e uso de tecnologia de ponta, raciocínio lógico, melhora das abstrações matemáticas e lições sobre improvisação musical, composição, manufatura de instrumentos eletrônicos e programação em tempo real [Santos 2016].
- **Pure Data**⁴: Ambiente de programação gráfica, usado para composição interativa e como estação de síntese de áudio em tempo real. Outra característica importante é que ela permite colaboração simultânea entre músicos conectados em uma mesma rede, seja ela local ou não. O Pd (outra forma de se referir a esta linguagem) também foi transformado em uma biblioteca, permitindo seu uso como *engine* de som em diversas outras aplicações.
- **Chuck**: Outra linguagem focada no *live coding* e performance em tempo real. Auxilia na composição algorítmica para síntese sonora, gravação e exibição de efeitos visuais. Seu objetivo é ser proativo e interativo com o usuário. Como um todo, permite ao programador escrever código de maneira mais rápida e simples [Wang 2008]. Seu uso é comum no desenvolvimento de aplicações musicais e é utilizada na Orquestra de Laptop de Princeton (PLOrk).
- **SupperCollider**: O SupperCollider é uma linguagem orientada a objetos, com foco na composição algorítmica e síntese de áudio ao menor esforço. Sua principal função é transformar conceitos musicais em funções ou métodos, criando música a partir da manipulação desses elementos através de blocos. Entre suas principais qualidades estão o dinamismo e a brevidade, que permite ao usuário criar estruturas que geram eventos de maneira agrupada. Os *patches* podem ser construídos dinamicamente e parametrizados por números de ponto flutuante e por gráficos de gerador de unidade [Wilson et al. 2011].
- **FAUST**: Functional Audio Stream, popularmente conhecido como FAUST, é uma linguagem de alto nível focada no processamento de sinais digitais, com suporte

³<https://sonic-pi.net/>

⁴<https://puredata.info/>

para aplicações de áudio em tempo real e *plugins* musicais para diferentes plataformas, incluindo sistemas móveis. Por conta do seu caráter profissional e preciso, trabalha com funções discretas e funções de segunda ordem, sendo mais utilizado por usuários avançados na música e na programação [Michon and Smith 2011]. Dentre as suas vantagens, estão: fácil criação e leitura de comandos, suporte para interfaces gráficas e geração de código em linguagem C++ a partir da cadeia de blocos.

5. Discussão

Segundo o ensaísta Alvin Toffler, o mundo passa agora por sua terceira onda de transformação, que ocorre na chamada “Era da Informação”, marcada pela automatização de tarefas e mudanças nos meios de comunicação [Toffler 1998]. Em vista disso, o modo de ensino tradicional começou a ser superado, em parte pelas mudanças que ocorreram no mundo, em parte por não despertarem o interesse necessário no estudante.

Um campo emergente e com potencial de corroborar para esse novo modelo de sociedade que se vislumbra é o próprio STEAM. Além de apresentar todas vantagens já enumeradas, a proximidade com a arte proporciona a inserção de uma nova estratégia curricular, que pode levar a incorporação de perspectivas e construções decoloniais, rompendo com a lógica de ensino que sempre dominou no Brasil, em especial no que diz respeito ao ensino de música. Tal técnica auxilia ainda na alfabetização digital e até mesmo na diminuição da desigualdade social entre países e classes.

Ao se pensar no uso do STEAM para ensino de música e de suas áreas adjacentes, este elemento assume automaticamente destaque no campo das **Artes**. No entanto, é fácil perceber a importância das demais disciplinas no cumprimento desta tarefa. A **Ciência**, por exemplo, pode ser útil nas discussões que surgem sobre as propriedades do som, bem como em possíveis elucidações sobre a audição e toda a biologia por trás de nosso sistema cognitivo. Por meio da **Tecnologia** é possível abordar a programação de computadores e os principais fundamentos do áudio digital, além da introdução ao pensamento computacional, como a resolução de problemas a partir de métodos como “dividir para conquistar”. Os fundamentos da **Engenharia** podem ser úteis para explicações sobre acústica, funcionamento de instrumentos eletroacústicos e dos meios de gravação e reprodução sonora. Por fim, a **Matemática** está fortemente presente na música, por meio de conceitos como funções periódicas, trigonométricas, razão áurea, entre outros.

No que diz respeito as ferramentas citadas na seção 4, destacam-se as questões artísticas, tecnológicas e matemáticas, justamente por serem linguagens de programação que lidam com abstrações matemáticas em diferentes níveis para alcançar resultados sonoros e gráficos. Pelo fato de algumas delas comporem sistemas embarcados, como o Pure Data, questões relacionadas à engenharia e arquitetura de *hardwares* podem ser exploradas, uma vez que haverá integração entre a parte lógica e a parte física. O uso prático destas ferramentas também pode ser útil para ilustrar os conceitos envolvidos nelas, principalmente aqueles referentes à ciência da computação, acústica e elétrica.

Observações realizadas pelos autores a partir de suas experiências empíricas ao lecionar cursos e disciplinas que ensinam música com intermédio da tecnologia mostraram pleno acordo da STEAM com as propostas dialógicas [Freire 2020] e com os conceitos fundamentais da ubimus, onde todos eles propõem o aprendizado a partir do

diálogo, da troca de experiências, da investigação e da curiosidade pelo ambiente no qual o processo educacional é realizado. Isso tudo se mostra um contraponto a educação bancária, focada na leitura mecânica e sem apropriação profunda do significado do texto [de Lima et al. 2018].

Entretanto, alguns problemas aparecem na adesão do STEAM. Para melhor observá-los, é preciso retomar alguns pontos apresentados na seção 1, a começar por professores sem a formação necessária. Mesmo que obrigatória, a disciplina de música não é exclusiva, o que faz com que em muitos casos ela seja ministrada como uma linguagem das artes. O emprego do STEAM traria também a necessidade do conhecimento tecnológico. A falta de espaço adequado é outro problema que afeta as duas áreas, vista a inexistência de salas tratadas acusticamente e que comportem alunos e instrumentos. O mesmo pode ser observado em laboratórios de informática pouco equipados.

Existe também a questão das tarefas executadas nessas duas áreas convergirem para atividades decoradas e repetitivas. Geralmente isso ocorre por erros na didática e/ou pelo foco somente em alunos que se destacam, cabendo aos demais repetirem as mesmas ações sempre. O desafio aqui, portanto, é impedir que atividades criativas se tornem mecanizadas.

Possíveis soluções

As possíveis soluções para os problemas citados passam pelo envolvimento de todos os setores da sociedade na educação, assim como melhorias na gestão do ensino e tornar a comunidade mais participativa no mesmo. [Cruz 2018] indica que a melhoria depende de mais atenção à primeira infância, garantindo a pessoas dessa faixa-etária mais acesso a cultura e as artes, além da criação de sistemas públicos de financiamento a educação e expansão do ensino para o nível profissional.

Ainda que a ubimus seja centrada nas ações criativas de seus atores e a metodologia STEAM vá de encontro a este pensamento, é impossível não citar a importância de um maior direcionamento dos recursos financeiros para o sistema educacional, especialmente para as populações e escolas em desvantagem social. Isso refletiria na formação de profissionais mais capacitados e engajados, além de melhores materiais e espaços para o ensino de música. Para que esta ação seja possível, a revogação imediata do teto de gastos é essencial, bem como livrar-se das ideologias, como a pauta do Escola sem Partido e das pouco eficientes escolas militares.

As soluções, segundo [UNESCO 2008], passam por uma alfabetização tecnológica, de modo a integrar o uso das ferramentas básicas de informática e comunicação; aprofundamento do conhecimento, que objetiva aumentar a habilidade dos alunos enquanto cidadãos, tornando-os capazes de agregar valor à sociedade e aplicar conhecimentos escolares na solução de problemas complexos; e finalmente, criação de conhecimento, que embora considerado o mais difícil, é essencial para aumentar a participação cívica e a criatividade cultural.

Tratando especificamente do ensino da música, [Marques and Brazil 2016] indicam que os impasses se devem a perspectiva que esse campo seja um passa-tempo, ensinado somente em momentos de lazer ou como complementação de outras atividades. Em tempos atuais, os questionamentos dizem respeito a praticidade e tecnicismo do ensino, que é voltado para o mercado. Para suprir essas questões, a música deve proporcionar

valores para além daqueles que possam ser adquiridos por dinheiro e oferecer uma visão ampla para percepção e participação no mundo.

Quanto aos problemas referentes ao uso da tecnologia no ensino, apresentados na seção 2, o primeiro deles pode encontrar soluções ao colocar os alunos como peças centrais no aprendizado, de forma que interajam mais com a aula e não fiquem reproduzindo tarefas repetidas. Quanto ao segundo problema, as soluções podem ser encontradas em temas previamente debatidos neste trabalho, como maior investimento na formação de profissionais e foco na educação básica. Para além disso, a criação de cursos que tenham uma maior aproximação entre música e tecnologia também pode ajudar no processo. Isso tudo pode corroborar para solucionar o terceiro problema, que diz respeito a atualização constante das tecnologias. Uma vez que os professores são mais preparados, eles serão capazes de se adequar a estas ferramentas de forma rápida. Para o quarto problema citado, a solução pode passar pela escolha de ferramentas livres e de código-aberto, que além de grátis, comumente funcionam em diversos sistemas operacionais [Gonçalves and Schiavoni 2020, Schiavoni and Gonçalves 2015]. Aliado a isso, há a constante evolução de funcionalidades e apoio da comunidade desenvolvedora.

6. Conclusão

O ensino musical promove o equilíbrio, proporciona um estado de bem-estar, facilita a concentração e o desenvolvimento do raciocínio. As vantagens da tecnologia refletem em melhor interpretação e organização das informações e no estímulo ao autodidatismo, enquanto a inclusão digital democratiza o conhecimento e diminui a desigualdade.

A metodologia apresentada neste trabalho busca preencher a lacuna ainda existente no ensino musical do Brasil, contribuindo também para uma abordagem interdisciplinar que se expande para outras áreas. Para isso, é necessária uma adequação da grade curricular do ensino básico, de forma que seja capaz de suportar o STEAM. Este processo para por uma análise das novas práticas e perspectivas escolares de uma geração que já nasceu submersa em aparatos tecnológicos. As necessidades e realidades dos alunos também devem ser levadas em consideração na mudança dessa grade, de forma que contemple todas as classes sociais.

Além das vantagens já citadas, soma-se ainda a possibilidade de uma maior compreensão da temática abordada por parte dos alunos, tornando-os mais críticos. Aliado a isso, o STEAM permite aos mesmos uma revisão sobre seus preconceitos, a partir da variedade de perspectivas que são apresentadas a eles. Há também um maior preparo dos estudantes para a vida profissional e em sociedade, já que os problemas que eles vão se deparar são complexos e dificilmente uma única disciplina aborda todos os lados de uma questão. Os benefícios também são vistos para professores, que usufruem de uma pluralidade de ideias e terão uma maior interação com o corpo docente.

Mesmo que sejam claras suas vantagens, o processo de integração desse método nas escolas é um processo longo e que depende de vários fatores. Ações que podem ajudar partem da ação continuada, que diz respeito a preparação e motivação do corpo docente para adotar a técnica, reforçando de forma teórica e prática suas benesses; planejamento de forma conjunta, onde os professores precisam conversar entre si para que programas de ensino rumem para uma convergência, e finalmente, flexibilização, pois será necessário mudar também a forma como se transmite conhecimento, em alguns casos, exigindo o

abandono do quadro-negro e do giz.

Ainda que com alguns percalços, o caminho que se abre pela frente é impulsionado pelas novas tecnologias que vão surgindo, muitas delas voltadas justamente para classes mais baixas da sociedade. Outro fator que colabora é o novo perfil de profissionais da educação que está surgindo, representado por pessoas que cresceram justamente na era digital e estão familiarizados com os meios tecnológicos. Guardada as devidas proporções de investimento e adesão do STEAM, o método pode começar a ganhar cada vez mais espaço no sistema educacional e ajudar, dentre outros, no ensino de música.

Agradecimentos

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Incorporando a relação espaço-tempo na criação artística

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Abstract. *This study presents the development of a new interface for the GlueTube application in order to make it more accessible to the general public. It was identified that this tool, which aims to make it possible to paste material online for musical creation, had a little intuitive GUI. It was proposed to solve the problem using spatial anchoring to organize temporal events, since it would be a viable alternative to this problem.*

Resumo. *Este estudo apresenta o desenvolvimento de uma nova interface para a aplicação GlueTube de modo a torná-la mais acessível para o público em geral. Foi identificado que esta ferramenta, que tem por objetivo possibilitar a colagem de material online para criação musical, possuía uma GUI pouco intuitiva. Propôs-se para resolução do problema a utilização de ancoragem espacial para organizar eventos temporais, visto que seria uma alternativa viável para este problema.*

1. Introdução

A colagem musical é uma técnica que utiliza de trechos de gravações ou partituras já existentes, geralmente pelo uso de amostragens, para a criação de objetos e composições de som. Entre as ferramentas que permitem a criação de material musical por meio de colagem está a ferramenta GlueTube, apresentada na Seção 2, que utiliza a técnica de colagem de materiais online como material para a criação de novos trabalhos artísticos.

Tal ferramenta, apesar de ter um potencial muito grande como ambiente de criação artística, pode ser melhorada ao incorporar na apresentação gráfica de seu ambiente de criação, ferramentas e metáforas que trazem a relação entre espaço e tempo para a criação artística. Esta relação, apresentada na Seção 3, trouxe a possibilidade de recriar esta ferramenta e incorporar na mesma esta metáfora.

2. O GlueTube

O GlueTube é um ambiente de criação tanto musical quanto visual, fundamentado nas técnicas de colagem e no uso dos vídeos disponíveis no YouTube e de outros conteúdos online como notícias, imagens e sons [de Paulo et al. 2019]. Além deste ambiente de criação, a ferramenta possui também uma galeria para que as obras feitas neste ambiente possam ser tocadas e apreciadas. Assim, incorporando o player de vídeos do YouTube com códigos HTML e Javascript, a plataforma permite tanto a criação de peças artísticas quanto a apresentação das mesmas.

Na sua parte de criação, a ferramenta permite ao usuário a edição de uma meta partitura, com os dados dos recortes utilizados na colagem, organizando a apresentação

deste material no tempo. Assim, a apresentação de cada elemento visual ou sonoro é agendada na meta partitura para acontecer em um determinado instante de tempo após o início da peça. Esta meta partitura traz ainda outras informações para a organização do trabalho como a posição na tela para a apresentação, o tempo de apresentação, a repetição (loop) do trecho e outras informações necessárias para a criação baseada na colagem.

A exibição das peças criadas com o GlueTube é feita na mesma plataforma online onde as peças são criadas. Ao permitir a utilização de material online para a criação de novas peças, o GlueTube traz uma discussão importante acerca do direito autoral e também da pirataria de conteúdo da Internet. A solução proposta foi que a reprodução do conteúdo seja feita apenas a partir da própria ferramenta, a fim de realizar download do material criado ou upload de conteúdo para a ferramenta, utilizando apenas material online para a criação artística sem acarretar a cópia de conteúdo online.

Além de ficar disponível para a exibição pública, as peças criadas no GlueTube também ficam disponíveis para serem usadas por outro usuário na criação de um novo material artístico. Assim, a plataforma reforça o conceito de colagem e reaproveitamento de material permitindo também a colagem das meta partituras criadas neste ambiente.

Uma das aplicações desejáveis para o GlueTube é servir como uma ferramenta introdutória na educação musical e de introdução a arte mediada pela tecnologia. Espera-se com isso, alcançar um público interessado na produção de colagem digital.

Esta ferramenta já foi utilizada no contexto da criação artística, tendo sido usada na criação da performance artística intermídia chamada “Black Lives Matters” [Paulo et al. 2019]. Esta peça é inspirada no movimento criado nos Estados Unidos em 2003 em decorrência do assassinato do jovem Trayvon Martin, e se trata de uma performance que combina uma criação sonora e visual gerada através do GlueTube e o balé contemporâneo, performado por duas bailarinas negras que emprestam seus corpos para as projeções criadas com a ferramenta. Os sons e imagens utilizadas na composição exaltam a cultura negra a partir de músicas, depoimentos e trechos de falas, sendo que todo este material foi feito a partir de colagem de conteúdo online.

3. Adotando a relação espaço-tempo na interface gráfica do GlueTube

A versão inicial desta ferramenta possuía uma interface gráfica considerada inadequada para a criação destes trabalhos por tratar a inserção de conteúdo para a colagem por meio de um formulário online. Apesar de este formulário ser o suficiente para a inserção dos dados no metamodelo de partitura da ferramenta, sua organização foge dos padrões encontrados em ferramentas similares que trabalham a edição de música e vídeo por meio de colagem. A Figura 1a nos mostra tal GUI. Apesar de esta GUI permitir ao usuário o controle total da meta partitura de sua criação, a mesma se mostrou pouco amigável nos testes iniciais realizados em nosso grupo de pesquisa.

Ao testar o GlueTube com colegas do nosso grupo de pesquisa, notamos que a ferramenta se mostrou pouco intuitiva e que mesmo usuários experientes tinham dificuldades de entender seu funcionamento. Esta dificuldade se mostrou um problema para popularização da ferramenta pois, segundo [Vieira and Baranauskas 2003], se um usuário não consegue entender como usar um website em poucos minutos, ele conclui que não vale a pena perder seu tempo e então o abandona.

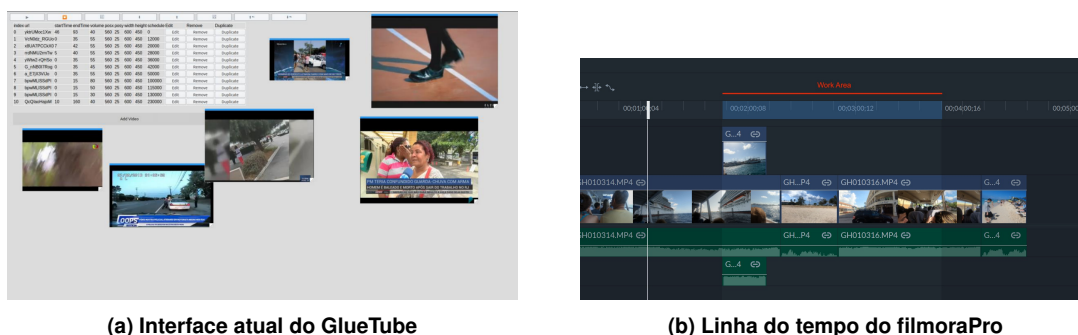


Figura 1. A interface original do GlueTube e a do filmoraPro

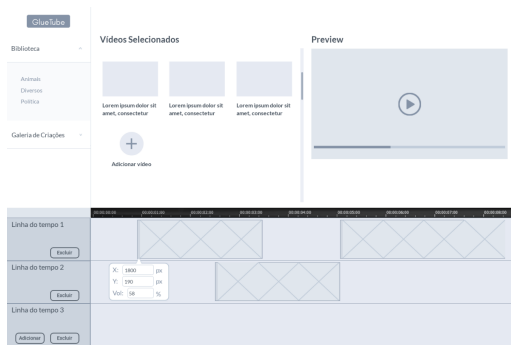
Optamos por modificar a GUI deste sistema com o intuito de melhorar a usabilidade por acreditar que este é um conceito chave para a interação humano computador. Vieira e Baranauskas a definem como a questão relacionada em o quão bem o usuário pode utilizar uma funcionalidade de um sistema [Vieira and Baranauskas 2003]. Notamos também que as necessidades, preferências e a capacidade do público alvo ao utilizar um sistema são essenciais para a adequação da ferramenta, e por isso foram realizadas pesquisas para identificar os métodos mais utilizados para manipulação de áudio e vídeo em um contexto similar ao desta ferramenta.

Para entender qual interface seria mais adequada para o ambiente de criação do GlueTube analisamos programas de criação de música e vídeo, o que nos mostrou, em uma análise inicial, que a organização por meio de uma linha do tempo, como a apresentada na Figura 1b, é muito comum entre os editores de vídeo. Tal abordagem traz a disposição dos vídeos em uma régua, criando uma relação entre o espaço (distância) entre os eventos e o tempo no agendamento dos mesmos. Além disso, a utilização de múltiplas linhas facilitam o entendimento de quando cada mídia será reproduzida e quais delas serão executadas em um determinado instante.

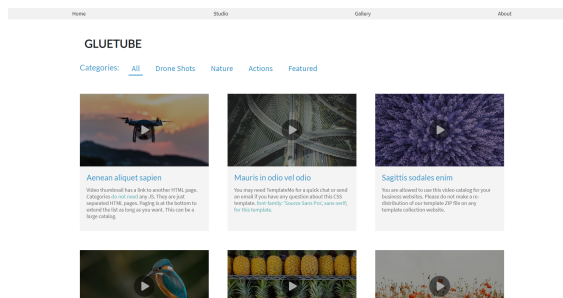
4. Resultados iniciais

O desenvolvimento de uma nova GUI de criação para o GlueTube, baseada na organização de eventos no tempo, permitiu uma relação entre a posição de um evento no espaço e sua ocorrência no tempo. O design proposto prioriza a experiência do usuário, visto que o objetivo é tornar o GlueTube acessível para pessoas interessadas neste tipo de criação artística. Foram consideradas neste design, a facilidade de navegação para que o usuário encontre o que precisa com no máximo três cliques, além da simplicidade do uso da GUI, sem comprometer a clareza das informações. Tal protótipo é apresentado na Figura 2a.

Outras modificações buscando melhorar a usabilidade irão alterar outras partes da ferramenta, como a galeria de arte, que possibilita o autor de expor seu trabalho nesta plataforma. A página da Galeria conta com um menu de divisão das peças em categorias, além de uma ferramenta de busca na qual é possível encontrar uma peça pelo nome da obra, do autor, palavras chaves, entre outras. Ademais, é possível realizar o download de uma partitura e, a partir dela, criar um novo trabalho.



(a) Wireframe da nova interface para o GlueTube



(b) Protótipo da galeria

Figura 2. Wireframe do atelier e protótipo da galeria

5. Conclusão

Este trabalho apresentou uma análise inicial da ferramenta GlueTube quanto a sua usabilidade e trouxe a proposta de uma nova GUI para esta ferramenta no intuito de permitir a utilização da mesma de forma mais simples, ampliando as possibilidades de criação e utilização da mesma e criando um paralelo entre este ambiente e ferramenta já existentes que possuem uma funcionalidade similar.

Apesar de acreditarmos que a GUI aqui proposta irá facilitar a utilização da ferramenta, sabemos que tal hipótese ainda carece de uma validação com usuários externos ao nosso grupo de pesquisa. Assim, é intenção dos autores realizar em breve testes com usuários para verificar a usabilidade do sistema e também coletar novas demandas e requisitos que possam melhorar ainda mais a usabilidade desta ferramenta. Também é parte de nossos trabalhos futuros experimentar esta ferramenta no contexto educacional para tentar avaliar a utilização da mesma neste contexto. Estas etapas eram previstas neste trabalho mas não puderam ser realizadas devido a situação da pandemia da COVID-19.

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Handbook of Ubiquitous Music 2021 — a short presentation.

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***Abstract.** In this short presentation, I will cover recent developments for the second book dedicated to the interdisciplinary research of Ubimus. Since the first Ubiquitous Music book publication¹ in 2014, creative research has broadened with ever-expanding practice-based methodologies. This has enabled the contextual review of diverse musical practices to advance discussions on ubimus theory and methods, ubimus technologies, ecologically grounded practices and ubimus, and ubimus educational perspectives and the digital humanities. The Handbook of Ubiquitous Music 2021 will compile and present these developments as they have evolved.*

¹ *Ubiquitous Music*. edited by Damián Keller, Victor Lazzarini, and Marcelo Soares Pimenta. Switzerland: Springer International Publishing, 2014.

Upcoming Special Issue and Open Call: Ecologically Grounded Creative Practices and Ubimus; Interaction and Environment

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Abstract. *Ubimus seeks to address the intersection between mobile networked technologies, embedded systems, modular hardware, internet of things (IoT), and emerging social, interactive and enactive perspectives on music-making. Thus, ubimus research has applied a variety of models, including ecological/embodied cognition, and accessible and participatory design. Its holistic view of music also finds parallels in Varèse's 'organized sound', Schafer's 'soundscape', Feld's 'acoustemology', Small's 'musicking' and Landy's 'sound-based music', whereby a variety of musics and practices converge. This proposed special issue will address ubimus from the perspective of ecosystems: sites for the meeting of technologies, people and creative experiences, and questions of materiality and sustainability.*

1. Introduction

This presentation will introduce and discuss the themes in an upcoming special issue on ubimus, which we are anticipating will be run in association with the journal *Organised Sound*. It is anticipated that the call for this special issue will open in late 2021, with publication in 2022 or 2023.

2. Special Issue Call: Ecologically Grounded Creative Practices and Ubimus; Interaction and Environment

Ubiquitous music (ubimus) seeks to address the intersection between current mobile, networked technologies, including embedded systems, vintage, modular (often analogue) audio hardware, internet of things (IoT) and emerging social, interactive and enactive perspectives on music making. Thus, ubimus research has applied a variety of theories and methods, including ecological, embodied, embedded and distributed models of cognition and creativity. In addition, ubimus practices involve participatory, accessible, inclusive and community-oriented approaches to design.

The diverse platforms, methods and theoretical perspectives of ubimus are unified by an agenda which seeks the integration of musical creativity with expanded and pliable conceptions of sonic activity, listening, embedded-embodied interaction and multimodality. Indeed, such 'sensory turns' find parallels in the recent sonic turn in the arts and humanities [Cobussen, Meelberg and Truax 2017], making ubimus and related

research suited to diverse discourses and constituents at various interfaces between the arts and technology. Through a broad dissemination of techniques and tools, and through a variety of fora, previously excluded groups are now actively participating in music creation. How is this affecting the scope and content of the new sonic practices which have emerged from this wider distribution of skills and technologies? Do we need new models to discuss the relationships between tools, creators and musics in the context of such distributed practices, away from the discourses of virtuosity and specialism, and legacy acoustic-instrumental models, which may persist within musicology?

The ubimus imperative towards a holistic view of musical experience and technological design finds roots in concepts such as Varèse's *organized sound* [Varèse and Weng-Chun, 1966], Schafer's [1977] *soundscape*, Feld's [1994] *acoustemology*, Small's [1998] *musicking* and Landy's [2007] *sound-based music*, all of which provide framing whereby a variety of sonic-oriented practices are seen to converge. Ubimus also finds common ground with emerging currents in human-computer interaction, including the embodied turn, third-wave approaches, multimodal and sonic interaction, immersive, augmented and locative media, and the emerging aesthetic and creativity-oriented perspectives on interaction design. The connections between ubimus and the current conceptions of socially-motivated and materially grounded interaction further points to the consideration of music as an ecosystem; a site for the meeting of people, technologies and situated resources for creative activities and experiences. The modularity of such approaches also references another aspect of music's materiality and associated questions of environmental sustainability; that of the challenge of reusing and reconfiguring older hardware to support new practices.

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Dossiê Ubimus na Revista Vórtex: Ubimus, Gastrossônica e Bem-estar

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Abstract. *The special dossier Ubimus, Gastrossônica e Bem-Estar covers advances in research in ubiquitous music with an emphasis on its impact in the field of gastronomy and health. One aspect of the intersection between music and health is the promotion of well-being, including the prevention of disease and the improvement of people's moods. In the current context of the pandemic, the potential of making group music needs greater investment in research. In the convergence between three aspects of research - interaction design, the study of food and the study of musical practices - we propose a new field of research, gastrosonics. This volume aims to highlight the innovative aspects of the ubimus proposals, focused on increasing well-being or linked to the field of gastronomy.*

Resumo. *O dossiê especial Ubimus, Gastrossônica e Bem-estar abrange os avanços da pesquisa em música ubíqua com ênfase no seu impacto no campo da gastronomia e da saúde. Um aspecto da interseção entre música e saúde é o fomento ao bem-estar abrangendo a prevenção de doenças e a melhoria do estado anímico das pessoas. No contexto atual da pandemia, o potencial do fazer musical grupal precisa de maior investimento em pesquisa. Na convergência entre três vertentes de investigação - o design de interação, o estudo da alimentação e o estudo das práticas musicais - propomos um novo campo de pesquisa, a gastrossônica. O presente volume visa dar destaque aos aspectos inovadores das propostas ubimus, focadas no aumento do bem-estar ou vinculadas ao campo da gastrossônica.*

1. O dossiê especial Ubimus, Gastrossônica e Bem-estar

O dossiê especial Ubimus, Gastrossônica e Bem-estar abrange os avanços da pesquisa em música ubíqua com ênfase no seu impacto no campo da gastronomia e da saúde. A interação através de recursos computacionais teve um aumento considerável a partir da disponibilização da rede mundial de computadores, da incorporação dos dispositivos

portáteis e da ampliação dos recursos tecnológicos nos contextos cotidianos. Essa infraestrutura fornece oportunidades de integração entre atividades que previamente estavam restritas a espaços específicos e que a partir de 2020 não podem ser mais realizadas na sua modalidade presencial. A música na sala de concertos é um exemplo frequentemente citado.

No contexto pandêmico atual, ações musicais mediadas pelas tecnologias de informação e comunicação e suas interfaces têm proporcionado o aumento da interação social, tanto no que se refere a apreciação estética como no processo ensino-aprendizagem da música e no contexto da saúde, com vistas a minimizar as consequências provocadas pelo distanciamento social, afetivo, que por sua vez infere negativamente no bem-estar e na saúde, principalmente na saúde mental dos indivíduos. Como se adequar ao novo contexto de cuidado e prevenção sem perder os aspectos positivos da interação social vinculados ao fazer musical? Apesar de ter seu início em um contexto no qual o distanciamento físico e os protocolos de prevenção de contágio não formavam parte da realidade cotidiana da maior parte da população do planeta, a pesquisa em música ubíqua pode ampliar as possibilidades de interação remota com efeitos cognitivos e sociais potencialmente positivos.

Dois aspectos centrais da atividade humana são a alimentação e a saúde. A interseção entre música e saúde constitui o campo da musicoterapia. Uma aplicação da pesquisa nessa área é o fomento ao bem-estar envolvendo não só a prevenção de doenças, mas também a melhoria do estado anímico das pessoas. O potencial da música é amplamente explorado nesse campo. Porém, o potencial do fazer musical grupal ainda precisa de maior investimento em pesquisa. O presente volume visa aprofundar essa discussão dando destaque aos aspectos inovadores das propostas ubimus.

O ser humano, procura, de maneira geral, satisfazer suas necessidades básicas, principalmente aquelas vinculadas aos aspectos físicos, sociais, psicológicos, emocionais, visando o bem-estar, que por sua vez está relacionado à qualidade de vida e à saúde. Bem-estar, trata-se de uma avaliação subjetiva da qualidade de vida e da felicidade (Trald & Demo, 2012) e qualidade de vida é um conceito complexo que incorpora uma dimensão ética e estética, que envolvem a integração de aspectos humanos, ambientais e econômicos sob enfoques qualitativos e quantitativos, objetivos e subjetivos, considerando a relação do indivíduo com o meio cultural dentro de um projeto de vida individual e comunitária (Alves, 2020). Três aspectos incorporam-se no construto da qualidade de vida: a) subjetividade; b) multidimensionalidade pois engloba, pelo menos, as dimensões física, psicológica e social; c) bipolaridade devido a presença de dimensões positivas e negativas (segundo a OMS) e a mutabilidade, vez que a avaliação da qualidade de vida pode mudar em razão do tempo, do local, da pessoa e do contexto cultural (Kellewo, 2010).

A relação entre música e alimentação também abrange uma produção importante em pesquisa. Um complemento interessante a essa área em expansão é o surgimento de

estudos em interação humano-comida (Human-Food Interaction) (Velasco et al., 2018; Mesz, 2021; Spence et al., 2019). Esse campo de pesquisa foca o desenvolvimento do suporte computacional para viabilizar experiências gastronômicas ampliadas através de recursos tecnológicos (Mesz et al., 2017; Wang et al., 2019). Temos portanto uma possível convergência entre três vertentes de investigação: o design de interação, o estudo da alimentação e o estudo das práticas musicais. A música ubíqua fornece um contexto ideal para abordar essa convergência. Não existe ainda um nome consensual para a pesquisa que trata da interação entre tecnologia, música e o universo gastronômico. Um nome possível para esse novo campo de pesquisa é a *gastrossônica*. O termo *gastrossônica* (gastrosonics) é raramente usado na literatura científica. Uma referência possível é a tese doutoral de Kilshaw (2006). Quais são as características específicas dessa área e quais aspectos ficam fora do seu rádio de ação são perguntas que precisam ser respondidas através de múltiplos estudos experimentais e do desenvolvimento de ferramentas conceituais. Mais um requisito imprescindível quando o assunto é música é o investimento forte na prática artística.

1.1. Tópicos sugeridos (não excludentes): Gastrossônica e música ubíqua

Sons musicais no contexto de experiências gastronômicas presenciais ou remotas.

Experiências lúdico-sonoras com comida ou bebida.

Performances ou instalações que combinem aspectos gastronômicos e musicais.

Uso de paisagens sonoras para ampliar as experiências gastronômicas.

Louça ou outros implementos com tecnologias sônicas XR (realidade virtual, ampliada ou aumentada)

Interações sonoras entre participantes de eventos gastronômicos.

Aplicações das estratégias musicais ubíquas às atividades gastronômicas.

Integração entre dispositivos da Internet das Coisas Musicais (IoMusT) e suas aplicações gastronômicas.

Aspectos conceituais, cognitivos e filosóficos da interseção entre música ubíqua e gastronomia.

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Journal of Ubiquitous Music: A multidisciplinary feature-targeted, research-oriented publication

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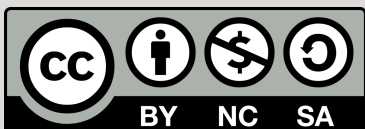
Abstract. *We present a proposal for a new publication, oriented exclusively to the advancement of knowledge on ubiquitous music practices and research. The objective of our talk is to share the initial ideas and to gather suggestions and opinions on this project from our community at large. The proposed publication will be hosted by the Arts Graduate Program of the Federal University of Espírito Santo. The selection process is linked to the Ubiquitous Music Workshops. A broadly targeted submission will be chosen as the featured article. This piece will be complemented with a series of invited or spontaneous commentaries. This blog-like format constitutes a volume. The target is a golden-access format, well-indexed and aligned with the requirements of Scielo or similar open-science repositories. We aim for a multilingual journal with a single language per volume and a summary of the highlights translated to English. Another proposal involves the incorporation of alternative presentation formats, reflecting not only the advances in the contents of ubimus research, but also impacting the methods for delivery and presentation.*

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