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Ariane Stolfi, Leandro Costalonga, Marcello Messina, Damián Keller, Luzilei
Ariel

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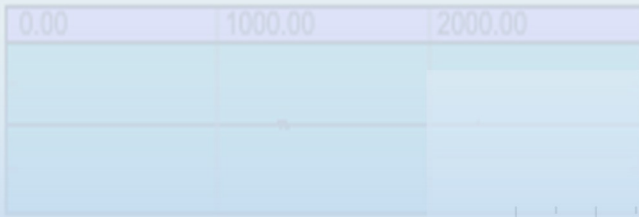


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68 r = Pdef('arp', Pbind('instrument', 'karp',  
69 'freq', Pseq(Scale.minor.ratios * [0.5,1,2,0.75,1.5] * 220, inf),  
70 'digitalPin', Pseq([4,5,6,7], inf),  
71 'amp', 0.5,  
72 'dur', 0.2,  
73 'decaytime', 1,  
74 'delaytime', 6  
75 )) .play(quant: 1);  
76 );|
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Proceedings

of the 10th Workshop on Ubiquitous Music (UbiMus)



[Voice + electronics + MIDI piano]

SoundSphere 1.3 - BETA

November 9 - 13, 2020
(online)



Xubimus

Ubiquitous Music Workshop
2020



- Ariane Stolfi
- Leandro Costalonga
- Marcello Messina
- Damián Keller
- Luzilei Aliel

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Proceedings of the 10th
Workshop on
Ubiquitous Music (UbiMus 2020)

Anais do X Workshop de
Música Ubíqua (UbiMus 2020)

November 9-13, 2020

Edited by

Ariane Stolfi

Leandro Costalonga

Marcello Messina

Damián Keller

Luzilei Aliel

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g-ubimus
Porto Seguro
2020

Organization

General chairs

Ariane de Souza Stolfi, Universidade Federal do Sul da Bahia (UFSB)

Leandro L. Costalonga, Universidade Federal do Espírito Santo (UFES)

Papers

Marcello Messina, Universidade Federal da Paraíba (UFPB)

Damián Keller, Universidade Federal do Acre (NAP/UFAC)

Maria Helena de Lima, Universidade Federal do Rio Grande do Sul (UFRGS)

Artistic sessions

Luzilei Aliel, Universidade de São Paulo (USP)

Daniel Puig, Universidade Federal do Sul da Bahia (UFSB)

Public liaison

Evandro Miletto, Instituto Federal de Ciência e Tecnologia do Rio Grande do Sul (IFRS)

Leonardo Souza, Universidade Federal do Sul da Bahia (UFSB)

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EDITORIAL

Ubiquitous Music Making in COVID-19 Times

Damián Keller¹², Leandro Costalonga³, Marcello Messina¹²⁴

¹ Amazon Center for Music Research (NAP)
Rio Branco – AC – Brazil

² Universidade Federal do Acre (UFAC)
Rio Branco – AC – Brazil

³ Universidade Federal do Espírito Santo (UFES)
São Mateus – ES – Brazil

⁴ Universidade Federal da Paraíba (UFPB)
João Pessoa – PB – Brazil

dkeller@ccrma.stanford.edu, llcostalonga@inf.ufrgs.br, marcello@ccta.ufpb.br

1 Introduction

Picture a world with no mobility. Planes are landed. Urban transportation stopped. Large gatherings are non-existent and everybody is at home. That's 2020, today. Most countries have reduced social interactions to a minimum. Food markets, drugstores and gas stations remain open. But shopping malls, cinemas, coffee shops and pubs have closed their doors for the foreseeable future. The Covid-19 pandemic is among us, ready to strike the most vulnerable and sometimes also the healthy, rich and posh.

Covid-19 impacts every social strata. This is a key difference between this disease and the plagues that have been taking lives in the peripheral countries for decades. Pulmonary and respiratory diseases are among the leading causes of death worldwide. But according to the WHO¹ (2018), the so-called Group I conditions (communicable diseases, maternal conditions arising during pregnancy and childbirth, and nutritional deficiencies) are particularly devastating among the low-income populations.

Until today, music making has predominantly been done through face-to-face, synchronous interactions. While it is true that some forms of music making – for instance, studio post-production or karaoké – rely on resources that are prepared offline, the implicit target of musical activity is to make sound together, if possible in person and at the same time. The current pandemic has turned the traditional forms of music making into high-risk and in some cases potentially deadly activities. So is music making becoming an activity for a select elite, secluded from the mundane buzz and divorced from community exchanges, again? The answer from the ubimus community is a strong no!

¹ WHO (2018). The top 10 causes of death. Geneva, Switzerland: The World Health Organization. <https://www.who.int/news-room/fact-sheets/detail/the-top-10-causes-of-death>

Ubimus research has targeted both more accessible forms of music making and a search for new modalities of artistic practice. These endeavors entail a deep understanding of the underlying creative phenomena – both the ones approached by disciplines such as musicology or music cognition and the emerging forms of creativity tied to the intense deployment of technology and involving the adaptive and opportunistic utilization of resources found in everyday settings (i.e., *little-c music* - Keller and Lima 2016). As in other fast growing fields, there is a tendency to incorporate technological resources without the support of a firm experimental evidence or a consistent theoretical scaffolding. Take for instance the recent emergence of the Internet of Musical Things. This proposal was formulated in parallel by Turchet and Barthet (2017) and Keller and Lazzarini (2017). After several exchanges in the ubimus community, the various acronyms were dropped (IoMT, IoMUT, etc.) and the label IoMusT was adopted.²

There are two issues worth mentioning here. The ties of the Internet of Things (IoT) with ubimus are explicit. Nevertheless, it is not yet clear whether the creative ubimus activities enabled by the IoT infrastructure can be labelled simply IoMusT. Turchet et al. (2018) attempt an inclusive definition of the term. But the examples provided unveil a bias toward a subset of long-standing forms of music making, strongly tied to the hegemonic acoustic-instrumental paradigm. Granted, ubimus is given a place as a form of music making that enables the exploration of the resources of the IoMusT. But part of the recent ubimus contributions to creative musical practices are not supported by the proposed IoMusT functionalities. Why is this so?

Ubimus has pushed the meaning of music making beyond the passive adoption of the technological infrastructure, initially designed around the use of musical instruments. Some IoMusT proposals enforce an early definition of ubimus, laid out by Pimenta et al. (2009). These proposals involve the deployment of tools rather than the development of the creative potential enabled by multiple forms of interaction among cognitive, social and material resources. Hence, they imply a narrow interpretation of ubimus research (alternatively, see Keller and Lazzarini 2017 for an up-to-date definition of ubimus).

Another limitation of the current IoMusT approaches is the priority given to the synchronous usage of remote resources. It is argued that the deployment of the tactile internet [Maier et al. 2016] will enable synchronous musical activities within a radius of 300 kilometers. Despite the tendency to increase the amount of information available on the spot, overcoming some of the technical caveats faced by the telematic approaches to music making such as network jitter and delay, there are human-performance limitations that even speed-of-light data transmission rates may not solve. One aspect is knowledge sharing. Network-based activities involving stakeholders with uneven levels of musical training demand careful attention to the strategies employed for supporting knowledge transfer. Moreover, recent ubimus experiences had their authors and participants speculating as to the desirability of synchronous interaction at all costs [Messina et al. 2019; Aliel and Fornari 2015]. The acoustic-instrumental approach relies on synchronous visual cues (such as those issued by a conductor during the orchestral performance) and on auditory cues (such as the click-track guide employed to synchronize

² After three years of research, there is a panoply of variations of this idea that highlight various forms of resource usage and several modalities of connectivity. One example is the concept of ubiquitous sonification. It furnishes a bridge between one thread of ubimus initiatives and the extant practices of sonification and musification [Sarmiento et al. 2020].

meter-based music). These cues become useless when the temporal decisions are decentralized, as it occurs in various forms of comprovisation (see the examples by Messina and Feichas 2020; Aliel and Keller 2020 in these proceedings). Both generative strategies [Kramman 2020] and free improvisation [Clemente et al. 2020; Stolfi 2020] present difficult scenarios to synchronous aesthetic decision-making. Generative strategies, if not supported by consistent epimusical resources,³ may become unwieldy for novices. Free improvisation relies on a large pool of tacit knowledge usually shared through arduous, long-term investments in collective musical practice. The synchronous usage of IoMusT resources does not necessarily address these caveats.

Despite its current limitations, the use of the IoMusT provides a promising thread of research for ubimus initiatives. An especially intriguing avenue involves the incorporation of robots as active partners in ubiquitous music ecosystems. Musical robots have been successfully employed to increase the performance accuracy of humans in drumming tasks [Grindlay 2008]. But similarly to the issues encountered in human-to-human interactions in music making, robotic resources need to be partially aware of their (robotic and non-robotic) partners' actions and intentions.⁴ According to Kapur (2005), “[the robot] must be able to sense what the human is doing. In a musical context, the machine can perceive human communication in three general categories. The first is directly through a microphone, amplifying the audio signal of the human’s musical instrument. This serves as the machine’s ears. The second is through sensors on the human’s musical instrument. This is an extra sense that does not generally arise in human-to-human musical interaction. The third is through sensors placed on the [human] body, deducing gestural movements during performance using camera arrays or other systems for sensing. These are analogous to the machine’s eyes.” Beyond the use of the anthropomorphic metaphor, ubimus robotics entails an understanding of previous, current and future actions of the stakeholders. The problem of synchronization, currently explored by the NesCOM researchers, provides a complex challenge encompassing the technical issues of the support infrastructure and the study of the cognitive implications of remote interactions with the mechanical devices.⁵ In some ways, this is similar to space exploration. The action-perception link that characterizes the musical actions exerted on passive objects is broken. To be aware of the robotic actions, the human partners use the partial information furnished by the robots. The temporal constraints may also be relaxed through iterative asynchronous exchanges, opening opportunities for creative strategies involving successive refinement. Therefore, a paradigm of musical interaction targeting passive “instruments”, “orchestras” or enforcing centralized decision making may ignore key aspects of this ubimus ecosystem.

2 Artistic practices and creative processes in ubimus

The overcoming of musical interaction based on synchronous, face-to-face exchanges, prevalently (and often exclusively) trapped within the settings of concert halls and similar

³ Extramusical resources that have a direct impact on the processes of sonic production.

⁴ The discussion of robotic awareness can be related to the current philosophical explorations of what constitutes human consciousness. While this is an intriguing topic for theoretical speculations, it may still lie beyond the reach of experimental ubimus research.

⁵ Weinberg et alii (2020) propose “listen like a human, play like a machine, be social, watch and learn, and wear it” as behavioral targets of musical robots. It is interesting to note the incorporation of embodiment as a key design feature. This view was pioneered by Brooks (1991), among others, and has gained weight during the last decade. This aligns the design of creative robots with the ecologically grounded approaches to creativity, yet adding another thread to the creative applications of ubimus initiatives.

spaces, has been one of the ongoing preoccupations of ubimus practice. Ubimus research has targeted multiple processes of collaborative musical creation involving the usage of remote resources. We maintain that the interaction between distant and yet interconnected agents has been among the priorities of ubimus research since the start of the field [cf. Keller et al. 2010; Miletto et al. 2011]. This fits surprisingly well within the new social protocols of physical distancing⁶ motivated by the current pandemic.

Artistic responses to this ubimus priority, at times, tend to focus on the crafting of creative products that showcase remote interaction as part of a musical piece [Aliel and Fornari 2015] or on the implementation of creative processes conducted in a regime of remote interactions, not necessarily evident in the final products [Aliel, Keller and Alvim 2019]. In another recent thread, the focus on graphical live coding (live patching) entails a blurred distinction between processes and products, giving way, however, to a set of disproportionate reliance on synchronous interaction. In this experience, the numerical operations inherent to coding were followed by qualitative research approaches to unearth the embedded ecological, territorial and geopolitical metaphors [Messina et al. 2019]. Rooted in phenomenology and deconstructivism, the potentialities and shortcomings of the physical presence and its simulation(s) provide a basis for collaborative improvisations, eventually resulting in a literal “hijacking” of the original piece [Messina and Aliel 2019]. Consequently, the authors and participants started wondering whether synchronicity was actually that important for remote creative activities.

This raised attention to issues related to presence and synchronicity within improvisation frameworks is shared by several artistic contributions included in these proceedings [cf. Pessanha et al.; Aliel and Oliveira; Messina and Mejía], and by most of the papers documenting creative processes [cf. Kramann; Aliel and Keller; Clemente et al.; Messina and Feichas]. In particular, bodily presence with its metaphysical and somatechnical⁷ implications is at the basis of the *InFracta* project, presented by the Corpo Generativo Group (Pessanha et al.), and characterised by the progressive transformation of gestures into sounds and, subsequently, of sounds into images.

Aliel and Oliveira propose a new version of the *Lyapunov Time* improvisation [Aliel et al. 2019] characterised by the deployment of the audience’s mobile phones as triggers of the live electronics — consequently, non-musicians eventually become active participants of the performance. By extending the musical activities to a preliminary workshop and a rehearsal, the composer-performer-audience interactions transcend the limited timespan of the official performance. The usage of smartphones to support free-improvisation practices is also explored by Clemente et al. in what they describe as a TAFI (Technology Assisted Free Improvisation) approach. The authors apply various improvisational strategies in educational contexts to encourage the development of musicianship. This approach is aligned with the proposals presented by Brown et al. (2014) but instead of targeting the technological resources for sonic production, they employ the acoustic instruments to achieve ubimus-oriented objectives.

⁶ Here, in line with one of the most important distinctions in social psychology terminology, we purposely replace what has largely been referred to as “social distancing” with the more appropriate notion of “physical distancing” [cf. Hipp and Perrin 2009; Matthews and Matlock 2011]. We believe that keeping this distinction in mind may prove useful for ubimus practices, too.

⁷ “Somatechnics” refers to the intersection between the body as a purely material object and the very same body as a discursive entity, related to the encounter with biocultural and technological accessories [cf. Pugliese and Stryker 2009].

Another contribution that examines the creative interaction between musicians and laypeople is Aliel and Keller's experience within the artistic project *The Maxwell Demon*. Critically engaging with the concepts of entropy, paradox and simulation, the authors develop a mobile app for audio synthesis and processing. This tool is used for a studio performance session with a mixed sample of participants, including musicians and non-musicians. Among other things, the results highlight the negligible impact of previous musical knowledge for this type of creative activities, contributing to an increased engagement of lay participants outside of the concert hall.

Going by the intriguing title "Of Renouncing to do Something Grandiose", Guido Kramann's contribution is centred on a thought-provoking reflection on possible ways of structuring ubiquitous music practices, with an emphasis on improvisation, to foster a deeper understanding of the lay participants' creative processes. Abundantly drawing upon board games structures, Kramann introduces *pulse2357*, an Android app based on the sonification of chess-like alternated moves performed by the two opponents.

Other communities have brought interesting contributions that have been readily embraced by ubimus practitioners. Improvisation is a case in point. There is a well-established tradition of free-improvisatory practices in Brazil. But until recently, attempts to establish bridges between professionally oriented improvisation and the participation of lay musicians were rare. In an effort to overcome the artificial separation between musically trained subjects and casual collaborators, ubimus practitioners have laid out bridges to integrate improvisatory practices with active audience involvement. The artworks featured in the UbiMus 2020 highlight the diversity of the aesthetic perspectives enabled through and encouraged by ubimus research.

3 Technological advances for ubimus activities

Being musical is, without a doubt, a special trait of being human. The ability to coordinate and synchronize movements with an unlimited combination of sounds (featuring variations in texture, dynamics, pitch, duration) in perfect timing is a characteristically human achievement. Given an appropriate context, this complex activity can be performed as a group, on the fly, without prior knowledge of what is coming next. The predisposition to perform such demanding tasks has been studied and partially explained from perspectives ranging from the cultural to the biological. Music performance is subject to further constraints: we are limited by our body and by the characteristics of the material resources employed in sound making.

Musical instrument designs can borrow from the advances in electronics and computing to overcome part of the performance limitations of the acoustic instruments. Since Hugh Le Caine's pioneering experiments in the late 1930s, there have been multiple initiatives to address the need for varied and flexible sound-making tools. These initiatives gained a renewed impulse with the recent ubimus developments. The "music anywhere" principle embedded in ubimus involves releasing the performer from the constraints imposed by the physical contact with a material resource and by the requirements of colocated physical presence.

During this time of social isolation due to the Covid-19 pandemic, it has been observed that musicians are struggling to adapt web conference communication systems to perform group-based musical activities without observing important aspects of interaction support, such as the fact that the human rhythmic abilities did not arise to synchronize people with metronomes but rather to align the actions of groups of humans, leading to social synchronization and

entrainment. If the support systems are unable to trick our senses into believing that we are in the presence of other musicians (through synchronization mechanisms refined throughout the history of human evolution), then they are doomed to fail. Based on this idea, Camporez et. al propose synchronization strategies and algorithms for musical robots so they can mimic the way humans synchronize with each other during a music performance. The emerging field of the Internet of Musical Things (IoMusT) has been dealing with these challenges for some time, as reported by Vieira, Schiavoni, and Barthelet in their bibliographic research included in these proceedings. Sarmento, Holmqvist and Barthelet present a view of ubiquitous sonification for a musical smart city that also demands support for organizing computational processes through synchronization.

Modern video conferencing tools allow hundreds of participants but not without its limitations, which become even more pronounced when dealing with time-dependent activity such as music performance. It is not yet possible to single out a group, but researchers have dealt with the limitations by establishing and enforcing social rules for that particular use. For instance, in a choir rehearsal, the "host" (usually the conductor) controls the microphones of all attendees opening and muting their channels as required, hence adopting a studio-engineer role. Everyone listens and sees the leader. This strategy can be highly efficient since chitchat is more controlled, everyone has a clear view of the leader and can even appreciate its vocal quality and technique throughout the rehearsal. Some of these tools have been upgraded to improve the experience, with features such as: a) support for audio sharing; b) software-based audio routing; c) support for multiple audio interfaces targeting heterogenous input; c) advanced media control for voice over music; d) private rooms with independent audio settings; e) background noise filtering and other forms of processing; and f) media sharing. The use of this software certainly requires a dose of creativity, but this does not mean that the tool itself was designed to support musical creativity. Vieira and Schiavoni (in these proceedings) discuss how the Pipe-and-Filters architecture, a common feature in software development, can boost creativity either by applying this technique in development or by using these structures as a way to organize the technical tasks.

It seems that the pandemic has leveled the way we make music by restricting the technologies suitable for this purpose. How is this different from the issues faced by people with disabilities when the tools are not designed with accessibility in mind? Camporez et. al. (this volume) use feature-extraction techniques to develop an Assistive Musical Interface that could aid mobility-impaired people to compose and perform synchronously with other musicians.

The challenges we are now facing due to the Covid-19 pandemic have been addressed by ubimus research for over a decade. Despite the multiple contributions on the technological front, there is still much to learn from the new working conditions imposed by physical distancing. Music making done by anyone, anywhere remains a key objective of the technological advances of ubimus research. But the meaning of anywhere has now been tinged by the weight of a community-responsible attitude that places further demands social interaction.

4 Ubimus in the field, applications in education and human development

An intriguing characteristic of the ubimus community is the intent to pursue ideas around musical issues that do not necessarily involve professionals (though as exemplified above, sometimes professionals are also included in proposals tailored for lay participants). Two areas of application have emerged as key targets of these initiatives: educational activities and human development and well-being. The former field has been championed by Helena Lima, Andrew

Brown and Nuno Otero, among other researchers [Brown et al. 2014; Lima et al. 2012; Lima et al. 2017; Otero et al. in press]. Two methodological approaches show promising results: dialogics and computational thinking.

Ubimus dialogics is based on the educational principles laid out by Paulo Freire [Freire 1997; Shor and Freire 1987], highlighting the role of the horizontal exchanges among group members, the respect for cultural diversity and the adoption of a positive attitude toward local knowledge. During the 1980s, dialogics strongly influenced the participatory design movement in Scandinavia [Ehn 1988]. Participatory design strategies have also been incorporated in ubimus design, emphasizing the grass-roots qualities of the ubimus methods [Pereira et al. 2018]. As previously stated, ubimus research faces multiple challenges related to the social implications of remote music making. While colocated music making has traditionally been used to encourage social bonding, it is not yet clear whether asynchronous musical activities may also have a positive impact on social cohesion. The application of dialogics could provide a path to investigate this issue.

Computational thinking (CT) has had a strong impact on twentieth-century music making. This perspective is implicit in the early initiatives of algorithmic composition and computer-based generative approaches to music making [Hiller and Isaacson 1959; Xenakis 1971]. In spite of its early usage by professional composers, CT has not been widely adopted as a strategy to ground alternative music-educational activities. Given this gap, ubimus furnishes an opportunity to apply the lessons learned in CT-based professional creativity to the realms of little-c music making and informal education. An attractive feature of the CT perspective is its potential for support of non-technical knowledge transfer. Some forms of computational thinking may be enabled through embedded-embodied approaches to human-computer interaction. For instance, the deployment of creative surrogates may be tailored for computationally enhanced collaborative strategies [Keller et al. 2015]. These proxies may involve sonic, visual, audiovisual and haptic modalities, plus some hybrids that feature elements of each modality. Future CT strategies may also be expanded by the incorporation of taste and olfactory stimuli for music making [Mesz et al. 2012].⁸

Given the current restrictions in outdoor circulation and the impossibility of participating in large social gatherings, ubimus approaches present a renewed potential of application in music therapy and human development. Assistive technologies can be used to promote the inclusion of people with visual, auditory or psychomotor special needs in creative activities. This infrastructure may also be applied for the enhancement of musical experiences by the general population. Assistive-living scenarios could feature non-invasive, individually attuned, forms of support to enhance well-being and to foster health-promoting indoor activities. A case in point is walking. Music-listening is a widely adopted activity to encourage physical exercise. Could this practice be applied to creative music making? How could creative music making be enabled without restricting body movements?

Santos et al. focus on the demands of doing music in the context of elementary education, with a special emphasis on the development of ubimus infrastructure applicable both to educational and domestic contexts. They describe the implementation and usage of musical mats,

⁸ Given the possibility of developing food replicators (a Star-Trek invention that has become reality through 3D printing), it is now possible to explore a complete package of nutrients, smells and textures, combined with audio resources to achieve aesthetically enhanced gastronomic experiences.

an artifact encompassing a desktop computer, a Makey Makey⁹ microcontroller and a mat-based triggering mechanism. The implemented system makes use of the shareware utility Soundplant¹⁰ as a tool for sonic production. Santos et al. carried out an informal study involving eighty seventh-grade students, doing activities within classroom settings. Despite the preliminary characteristics of the study, Santos and coauthors report a promising potential of deployment highlighted by the low cost of the equipment and by the playful modalities of interaction provided by the trigger mats.

Camporez et al. target the usage of assistive musical interfaces based on eye tracking. They propose the application of information-retrieval techniques to deal with segmentation and similarity ratings of musical resources. The retrieval techniques are employed to find sound samples according to specific criteria. They argue that the facilitated access to large digital databases may enable new forms of music making [Stolfi, Milo and Barthet 2019].

Low-cost wearable devices offer opportunities to deploy music therapies outside of clinical settings. Domestic environments are particularly attractive because they provide a familiar and customizable context of use, which could be adapted for the specific needs and preferences of the targeted subjects. To unleash this potential, several technical hurdles need to be overcome regarding both the support for sound making and the human-computer interaction demands. Expertise in this area has been developed by Timoney et al. (2015) during the BeatHealth Project. According to the authors, wearable devices need to be lightweight and energy-efficient, but at the same time they cannot exceed the average cost of the current personal electronic devices. The ubimus strategy of hardware repurposing seems to be particularly well-suited to this end [Flores et al. 2010].

Complementarily, the infrastructure of the Internet of Musical Things (IoMusT) may furnish network-based resources for music making which could be accessed through the wearable components. The usefulness of the IoMusT and of other ubimus resources may be expanded through the development of machine-learning algorithms. By analyzing the history of interactions and by predicting future behaviors, therapeutic strategies could be tailored for individual needs. This form of ubimus support, involving the prediction of future events, has not yet received detailed attention from the research community. This thread might unveil new affordances and constraints for creative music making.

Summing up, multiple ubimus human-development approaches are actively being pursued by various research groups in the ubimus community. It is likely that this area will move toward a convergence in methods and concepts in the years to come. Two promising ubimus conceptual frameworks have been proposed by Helena Lima and Nuno Otero, dialogics and computational thinking. Their technological counterparts are still scattered and lacking consistent architectures. Current proposals include eye-tracking interfaces, trigger mats and wearable devices for physical activities. Portable prototypes have also targeted bimanual, touchless interaction [Keller et al. 2019] and multitouch-based techniques [McGlynn et al. 2012]. Hopefully, the strategies developed for creativity-oriented design could also be adapted for human-development ubimus deployments.

⁹ <http://www.makeymakey.com>.

¹⁰ <http://soundplant.org>.

5 Targeting a second wave of ubimus initiatives

In a recent publication, Keller, Messina and Oliveira (2020) suggest that ubimus is currently moving beyond the proposals laid out during its first decade of existence (more accurately, within a period marked by the beginning of the g-ubimus network activities and the first ubimus international publication by a major press, from 2007 to 2014). Hints that ubimus research is breaking new ground can be gathered from the variety of themes, from the need to broaden the conceptual perspectives and from the renewed relevance of the ubimus approaches facing the health-risks of the traditional artistic formats. The Covid-19 pandemic has literally changed the playing field (pun intended). How can ubimus research contribute to the renewed musical needs of a society in partial confinement?

First of all, enhanced support for social interaction seems to be among the pressing needs of a post-coronavirus world. Granted, the destructive impact of the neoliberal economic policies -- with a release of all legal restrictions on the financial accumulation and speculation -- has reduced the access to healthy food and reasonable shelter of large contingents of people. The Syrian and Venezuelan migrant crises -- both induced by an ongoing campaign to conquer oil reserves -- have placed millions of people in a highly vulnerable and potentially catastrophic situation. The consequences of the lack of shelter and food cannot be overstated. But the current restrictions on social interaction, especially when considering children, may also have long-lasting effects.

Collaborative music making by means of ubimus ecosystems could furnish a way to avoid some of the negative aspects of online social exchanges while encouraging meaningful ways of engagement [Brown et al. 2014]. Recent ubimus projects unveil interesting issues arising from the non-verbal exchanges prompted by synchronous and asynchronous resource sharing, without the support of face-to-face interaction [Messina et al. 2019; Stolfi, Milo and Barthelet 2019]. Are facial expressions necessary for musical knowledge transfer? Acoustic-instrumental practices built around fixed scores, centralized decision making and linear organization of time would appear to indicate so. There are at least two aspects to consider: temporality and semantics. A key contribution of ubimus to musical theory is its ability to deal with time without resorting to genre-specific mechanisms [Keller and Lazzarini 2017b]. Tempo, beat or pulse, bar or measure and rhythmic figures are all forms of temporal organization intrinsically tied to meter-based music making. Ubimus ecosystems let the stakeholders deal with their sonic resources through the organization of temporalities rather than through the imposition of meter. For instance, time tagging uses local acoustic cues for decision making; Graphic-procedimental tagging employs selected visual features of found resources as visual triggers for musical actions;¹¹ The Playsound.Space system uses sonograms to complement the semantics-based selection processes and the sound sphere metaphor provides a combination of color-coding, tones of grey and airport-style abbreviations of semantic labels to furnish information on the sonic mix deployed on its virtual sphere. Musical partners rely on these cues to reach consensual decisions. While it is true that some collaborative ubimus activities have relied on explicit verbal exchanges to support collective decision-making, synchronous

¹¹ Graphic-procedimental tagging, aside from being a metaphor for creative action, can also be classified as a form of sonification. This is one of the intersections between ubimus and auditory display that are being explored in the special issue dedicated to the overlap between the two areas that will be published by the Computer Music Journal.

face-to-face interactions do not seem to be a requirement for musically effective usage of ubimus ecosystems.¹²

A non-trivial aspect of creative practice is how to conceptualize the future. In utilitarian applications, anticipation basically involves using a sequence of the extant events to predict future behaviors or outcomes. Within the context of creative practice, there is a further demand to foster relevant and original results.¹³ If anticipation precludes originality, it may be suited for rote activities but it will likely be detrimental for creative endeavors. This may constitute a barrier to pursue this path. The assessment of the contribution of future events (or the lack of contribution) to the creative outcomes can only be done after achieving the musical results [Pati et al. 2018]. It would seem that assessing the impact of the future on the creative performance is an impossible task. Nevertheless, if we consider the impact of the predicted outcomes on the creative potential, we may then get access to partial but useful information. The potential for creativity depends on the quantity and quality of the resources available for the projected creative actions. If the context of a creative activity is known, anticipation could involve assessing the quality and quantity of the resources applicable to the creative processes while taking into account their future potential contributions. This methodological path is being threaded by the ubimus community. It is still too early to determine whether it will yield answers for the multiple unknowns of future actions in creative practice. But at least it provides a way to deal with issues that so far have not been considered by other perspectives on musical interaction.

The ubimus workshops have provided a fertile terrain to seed new ideas. Some of the proposals discussed by the ubimus community were later adopted by other fields of research, including economics [Abolhasani et al. 2017; Oakes et al. 2011], interaction aesthetics [Xuan 2017] and tangible computing [Palaigeorgiou and Pouloulis 2018]. It is interesting to note that key ubimus proposals, such as the standardization of mobile and web protocols for music making, are slowly making their way as design targets of mainstream computer-music research. Consider, for instance, this statement by Gurevich (2012): “[...] standardization does have its benefits: spectators on some level know how [interaction with musical devices] works. Furthermore, the ubiquitous touchscreen mobile phone and tablet offer a richer gestural repertoire and palette of sensing technologies. Years of experience using and seeing others use these gestural devices have inculcated a suite of interactional techniques and paradigms into many of us. Although there is no substitute for embodied musical knowledge, many recent mobile apps have already demonstrated that mobile devices can offer both a low entry fee for novices and complex means for interaction.” Gurevich proposal of using everyday personal devices in musical interaction design echoes the strategies employed and discussed in the early ubimus workshops [Flores et al. 2010; Keller et al. 2011; Pimenta et al. 2009].

How does the “embodied musical knowledge” mentioned in the statement above stand in relation to the strategies for musical interaction enabled by the ubimus ecosystems? Here a fine distinction needs to be established. Ecologically grounded creative practices applied the notion of embodiment to creative music making before this concept became popular among

¹² Despite the preliminary evidence on this trend, the implications of the lack of face-to-face interaction have hardly been documented. A whole area of ubimus research targeting the dynamics of social interactions and their relationships to the ubimus ecosystems is currently ripe for development.

¹³ According to Weisberg’s (1993) definition of creativity, creative processes and products need to be both original and relevant. Innovative proposals that are not considered applicable to the task or resources that are not utilized by the stakeholders do not meet the criteria to be labeled creative. Complementarily, resources or procedures that do not present any novelty are not usually classified as creative.

musicologists and anthropologists [Keller 2000; Keller 2001; Keller and Capasso 2006].¹⁴ This notion was not divorced from the concept of embedded or situated action, indicating an epistemological approach consistent with the recently labeled E4¹⁵ perspective [Malinin 2016]. While a detailed discussion of the implications of embodiment is beyond the scope of this editorial, limiting embodiment to one aspect of acoustic-instrumental music making implies a narrow vision on musical knowledge acquisition. The usage of interfaces and resources that emulate the behavior of European orchestral instruments is a prime example of genre-specific knowledge. Rather than calling this knowledge “musical” it should be labeled “orchestral” or even better, “piano-”, “clarinet-” or “guitar-based” knowledge. This view of music making only targets the resources linked to the instrumental performance of acoustic and digitally emulated acoustic instruments. This type of knowledge has limited applicability since it does not encompass the rich experiences provided by a growing variety of multimodal artistic formats, by the application of analogue computing and it does not engage with the recent contributions of the makers movement to music making. In particular, ubimus research has shown that everyday musical creativity lies beyond the reach of this genre-specific perspective.

The expanded notions of music making encouraged by the ubimus conceptual frameworks seem to acquire a special relevance during these times of scarcity. Reduced physical mobility, lack of face-to-face, physical interaction, avoidance of crowds are all detrimental factors for the acoustic-instrumental ways of music making. Will musical robots, musical algorithms or refined methods of data analysis replace music making as it was done during the twentieth century? Not necessarily. Will the new areas of ubimus application, highlighting the usage of domestic settings, the asynchronous strategies of group support and the incorporation of multiple modalities of exchange help to foster well-being, musical diversity and meaningful interaction? This is one of the goals of the current ubimus initiatives. For better or worse, music making as we know it will have to make room for artistic practices compatible with a planet in decomposition.

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¹⁴ See Keller and Lazzarini (2017) for a coverage of ecologically grounded creative practices as they relate to ubimus. See also Carson (2020) for an informal discussion of early eocompositional initiatives.

¹⁵ Embodied, embedded, enactive, ecological cognition.

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KEYNOTE SPEECH

The ubiquity of guitar effects to sound processing

Joseph Timoney¹

¹ Dept. of Computer Science at NUI - Maynooth University. Mariavilla, Maynooth, Co. Kildare, Ireland

{JTimoney@cs.nuim.ie}

Abstract. *Ever since the electric guitar was invented the musicians that played it wanted to change or enhance its sound, maybe the tone was just too clean and innocuous. Les Paul experimented with tape effects to create his wonderful multi-tracking and delays, and the early Rock n' Roll pioneers, such as Johnny Burnette and Link Wray, hacked their amplification equipment to grind more sound from it. The first guitar pedals came with the DeArmond Tremolo in 1946, as used by Bo Diddley, then followed by the Gibson Fuzztone in 1962, as unleashed by Keith Richards on 'Satisfaction'. The original advert for the fuzztone sold it like it was a synthesizer, a tone genie for the electric guitar. It was claimed by Gibson that it could do organ-like tones, mellow woodwinds, whispering reeds, booming brass, and bell-clear horns. Even then the idea of the effects chain was understood as they suggested adding it with reverb and tremolo. Fifty year and more later, guitar effects are more popular than ever. They are available in hardware, in software, and as software running on digital hardware.... They are made with valves, germanium transistors, silicon transistors, discrete components, Integrated circuits, DSPs, FPGAs... They certainly could be labelled as ubiquitous and they have reflected all the advances in technology over the decades. The influence has stretched beyond the guitar into other instruments: the wah-wah pedal on the Rhodes pianos, the distortion pedals used with the TB-303, the phasers used on Jean Michel's Jarre's string synthesizer... Modern music would not be where it is without them. However, although they are associated with music that is sometimes wild and rebellious, or dreaming and ambient, there is an awful lot they can teach us about signal processing if we look inside to grasp how they do what they do. Waveshaping, filters, modulation, nonlinearities are all terms that could have come from a communications textbook but also belong to the realm of guitar effects. They can teach us so much about the application and consequences of signal theory. Curiously, the academic perspective only gradually emerged, firstly with papers in the Audio Engineering society, and then later with the international community of Digital Audio Effects. However, the field has not been compromised by either the academics or the corporations and there is a healthy tribe of boutique pedal makers, and software coders currently developing their own ideas into effects and finding devotees across the internet. Therefore, a ubiquitous community with a beating heart exists. This talk will take a short journey through this world, to remind us of so much that has been achieved, how it impacted the music we love, and how the broad cohort of musicians and technologists trade challenges to their inventiveness to make great music and even greater sounds.*

KEYNOTE SPEECH

Pesquisa e aplicações em música ubíqua no campo Educacional

Maria Helena de Lima¹

¹ Departamento de Expressão e Movimento, Universidade Federal do Rio Grande do Sul. Porto Alegre, RS, CEP: 91509-900

{helena.lima@ufrgs.br}

Resumo. *Um dos focos de pesquisa presentes nestes 10 anos de workshop ubimus, constitui as aplicações e contribuições em ubimus no campo educacional, em especial junto à Educação Básica, etapa que compreende as modalidades de ensino que englobam a Educação Infantil, o Ensino Fundamental de nove anos e o Ensino Médio. As contribuições em ubimus no campo educacional abrangem tanto a aplicação e o registro de experiências em ensino e pesquisa na modalidade de investigação-ação participativa em contextos educacionais formais e informais, dentro e fora da sala de aula, como também pesquisas de cunho teórico a partir do levantamento do estado da arte relacionado ao tema. Todas as ações possuem como perspectiva o professor como pesquisador de sua práxis educacional. No que diz respeito à pesquisas na modalidade investigação-ação, desde 2010 várias ações em ubimus têm sido desenvolvidas em contextos formais e informais de Educação Básica, e mais especificamente desde 2012, o CAp - Colégio de Aplicação da UFRGS - Universidade Federal do Rio Grande do Sul - tem sido sistematicamente protagonista de experiências e pesquisas em ubimus em Educação Básica. As ações de ensino e pesquisa desenvolvidas no CAp têm como foco aspectos relacionados ao processo investigativo e à aplicação do enfoque cognitivo-ecológico em atividades relacionadas à pesquisa e ensino, através da prática da ecocomposição, tendo como propostas: a realização de atividades de criação, composição, colaboração e compartilhamento, através da utilização da infraestrutura tecnológica existente em ambientes e contextos não planejados para a atividade artística musical; a compreensão dos processos de apropriação por parte de músicos e leigos de ferramentas cotidianas disponíveis nos seus ambientes para realizar atividades de criação musical a partir de seus nichos / contextos, abrangendo o impacto dos recursos locais nas atividades criativas e a ação dos indivíduos na geração de novos recursos produzindo adaptações no seu entorno; a aplicação e registro de processos investigativos e reflexivos em Iniciação Científica júnior com alunos do Ensino Médio, a partir das perspectivas interdisciplinar e transdisciplinar. Os processos investigativos em ubimus na Educação Básica, possuem como base a concepção educacional dialógica e participativa envolvendo alunos da Educação Básica, em especial do Ensino Médio através da modalidade de bolsas de Iniciação Científica Júnior - IC jr -, além de bolsistas Iniciação Científica de graduação, bem como parcerias e colaborações estabelecidas com membros do G-ubimus - Grupo de Pesquisa em Música Ubíqua g-ubimus/CNPQ. No que diz respeito a contribuições ao campo teórico da pesquisa em ubimus em Educação Básica, destacamos dois conceitos desenvolvidos ao longo do processo: os conceitos de diásporas mentais e mentes diaspóricas (2013), que se interconectam e aproximam ao conceito de criatividade musical cotidiana e ao enfoque cognitivo-ecológico em ubimus. Os conceitos de diásporas mentais e mentes diaspóricas procuram sintetizar a dinâmica complexa do emergente movimento não-linear e*

retroativo observado através do uso ostensivo da internet e de ferramentas de iteração: mentes individuais interagindo diasporicamente, coletivamente, modificando/influenciando e ao mesmo tempo retroagindo e sendo também modificadas / influenciadas em uma interação contínua. Estes conceitos relacionam-se aos emergentes movimentos, comportamentos e processos criativos interativos, interpessoais, protagonistas, não hierárquicos, ou com hierarquia flutuante, individuais e coletivos associados à crescente necessidade de expressão e compartilhamento. Eles sintetizam o movimento complexo, que nos potencializa sermos ao mesmo tempo em vários espaços e tempos, que nos desimpede de limitações físicas, locais, sociais, que reafirmam nossa identidade complexa, física e não-física, cerebral, mental, espiritual, contraditória e consensual, coletiva e individual. Esses comportamentos estão vinculados a uma necessidade profunda humana de expressão, não somente de ideias mas também sentimentos emoções, e de uma profunda necessidade de estar junto. Ou seja, à expressão da complexidade da manifestação do homo no mundo em suas facetas, segundo Morin: sapiens, faber, demens, ludens, mythologicus. Facetas que impregnaram nossas próprias relações com o mundo que construímos, e com a tecnologia que retroage sobre o mundo e sobre nós, e a forma como criamos. Facetas que estamos mais do que nunca vivenciando nestes tempos limitantes de pandemia, através dos movimentos de nossas próprias diásporas mentais, interagindo, criando, nos recriando nessas interações mentais. Em nossas complexas interações associadas à tecnologia, destacamos também o comportamento associado ao jogo, na forma característica de como exploramos as possibilidades proporcionadas pelas ferramentas tecnológicas que possuímos em nossa ambiente. Esse jogar, segundo Heidegger, se apresenta como uma característica essencial de nossa existência, na exploração e na relação que estabelecemos com o mundo: do ser como essencialmente ser-um-com-o-outro, do jogo como parte da existência dessa relação. Refletir sobre esses emergentes movimentos, comportamentos e suas interações e repercussões, e tomarmos consciências deles como potenciais espaços do fazer criativo consciente, constitui uma das tarefas da educação em todos os níveis, e acreditamos, da pesquisa em ubimus. Constitui fazer ciência com consciência. Acreditamos que a diversificação dos espaços potenciais para o fazer criativo, gera novas demandas do suporte tecnológico e sublinha o caráter interdisciplinar e transdisciplinar da pesquisa em ubimus. O foco na criatividade musical cotidiana coloca em evidência a necessidade de desenvolver perspectivas aplicáveis não só às práticas musicais existentes (como as manifestações da música instrumental, por exemplo), mas também às práticas musicais futuras, tendo como perspectivas: (1) A interação social como eixo dos processos criativos; (2) a utilização dos ambientes cotidianos como âmbito ideal para a prática artística; (3) o incentivo à atividade exploratória através do uso de recursos locais e do suporte tecnológico. Incluo aqui o que consideramos essencial dentro da perspectiva educacional: (4) o incentivo aos processos reflexivos e a possibilidade de trocas dessas reflexões entre os pares envolvidos em todos os níveis do processo criativo. Todos os aspectos aqui levantados enfatizam a necessidade de reflexão e de ações conjuntas em relação ao desenvolvimento de tecnologias colaborativas que proporcionem formas de interação social que estejam em acordo com as perspectivas em ubimus, e que considerem tanto o desafios de nossa realidade de profunda de desigualdade social e de alcance de recursos, no contexto brasileiro, considerando a abrangência dos espaços de Educação Básica, onde ao mesmo tempo coexistem situações tão dicotômicas, como a explosão da circulação de informação impulsionada pelas redes sociais virtuais, bem como a própria limitação e mesmo ausência de acesso à infraestrutura de suporte e à Internet. Os aspectos aqui levantados dentro do âmbito da pesquisa em ubimus na Educação Básica, extrapolam os limites desta e colocam em ênfase próprio o perfil multidisciplinar do grupo de pesquisa em ubimus, além de ressaltar o perfil interdisciplinar e transdisciplinar de sua

pesquisa e a abrangência de sua atuação. Esses aspectos também apontam potenciais questionamentos e processos reflexivos sobre nossos determinismos e possibilidades, da paradoxal complexidade interativa de nossa constituição física, cerebral, mental, espiritual, de nossos avanços e recuos, da necessidade de uma profunda reflexão sobre a ciência, sobre a tecnologia que produzimos e que nos produz. Processos reflexivos necessários mais do que nunca hoje, em todas as instâncias e níveis educacionais, ressaltando também que, nestes tempos de pandemia, esta reflexão não constitui mais apenas uma opção.

OF RENOUNCING TO DO SOMETHING GRANDIOSE

Guido Kramann¹

¹Brandenburg University of Applied Sciences

kramann@th-brandenburg.de

***Abstract.** A central idea of ubiquitous music is that music does not arise from the ideas of an isolated genius, but rather from the interaction of several participants [Keller et al. 2014]. But this requires a certain amount of restraint on the part of the designers of the respective setting and at the same time seems to require a full disclosure of the underlying theoretical and aesthetic concepts to the participants, if the participants are really to be taken seriously and given the means to actually be able to become creative themselves in an understandable way within the given context. In this paper, the consequences of such a demand are first discussed theoretically. Finally, for the concept developed by the author, "Every human being can compose on the basis of natural numbers", an attempt is made in this specific case to determine in what form such a concept could be passed on in order to meet the above criteria.*

1. Introduction

Almost everyone knows the piece 4'33 by John Cage. Almost always, when people discuss this piece, at some point the conversation reaches a point where a person says something like: "Anybody can do that." And the other person then replies something like: "Yes, maybe. But it's famous because John Cage did it, and it doesn't make sense for you to compose 2'33 now." But isn't that exactly the message of this composition?: With an invitation to listen carefully, composing already begins and anyone can be the person who invites to listen carefully and any other person can accept this invitation. The piece corresponds to an actual trend in sound art creation in which the composer is no longer the creator of a musical structure, but determines the setting in which the composition then happens [de la Motte-Haber 2018]. But typically, in such settings, art is not, so to speak, left free, but the artistic genius merely acts on a meta-level and continues to claim the sovereignty of interpretation and copy rights to the work published in this way.

What is wanted here is perhaps most likely to be found in the traditions of folk art and folk music. There the knowledge of an art form is not anchored in a single individual, but within a larger community. However, the aspect of preservation often dominates so strongly in these traditions that these traditions threaten to freeze. If one sets oneself the goal of making realtime composition generally available to laypersons, on one hand external availability through interconnectable, widespread mobile devices of a similar type and through data available on the Internet may be helpful. On the other hand, the knowledge about the possibilities of composing music must be made generally accessible in a transparent way. Why is this important? Isn't it enough that corresponding programs sonify, for example, arbitrary gestures in a way that is not further explained? What is the difference between using a software to perform a musical performance, or to be used

as a real-time composition program, in an informed way, in an experimental way with feedback, or without a deeper understanding of the users and without feedback?

That depends, of course, on the demands made here. Everybody can find something great because it gives you a great feeling without understanding what's behind it. Maybe a deeper understanding would even destroy the feeling. This may be the case with the reception of music and art in most cases. But what about the creation of music, what about improvisation?

Without understanding the laws according to which an interactive musical improvisational performance works, one cannot act intentionally in relation to this performance, and without intentional action by the individual, there can be no mutual interaction between the people involved, and thus, no collaborative creative process can be established. Of course, the creator of the setting could reject this intentionality of the participants. However, in that case, no bond would be created by the joint interaction within the improvisational performance, but only in the sense of a feeling of community based on joint participation and involvement, and this in turn would do much less to fulfill the basic idea of a socially effective art form. Not to mention the fact that the available technical resources would then not have been used to their full potential.

This much may be said as motivation for why it might make sense to disseminate improvisational tools that provide an explicit understanding of composing, before going on to discuss what the nature of such tools must be in order to satisfy this. However, in line with the introductory comments on 4'33, the following seems clear: In the end, the point is to convey so much motivation and understanding that an impulse to try out and develop the things conveyed can keep itself alive.

To anticipate: minimalist concepts are easy to communicate and understand and also motivate by quickly getting into practical work. As an indication for the validity of this claim, it may be said that in the pedagogical-didactic field, concepts of minimal music, but also Orff's pentatonic, are often used to introduce pupils to musical improvisation and composition – yes, let's say to compose their own 4'33 or 10'33 or 2'22 – without any great theoretical burden [Götte 2002], [Straus 2014], [Saliba 2010].

2. The publication of gamelike settings as a method to convey an easy mastery of compositional practices

One skill that many people share is mastery of board games. A look at board games such as chess or GO, suggests that a game is particularly popular over a long period of time if its complexity and degree of interest result mainly from complex and interesting game situations, but the rules of the game are kept relatively simple in comparison. Games of this kind can provide valuable clues, or a kind of blueprint, to create easy-to-learn composition games, which, however, allow a high degree of intentional contribution by the players and, with a low entry threshold, open up the perspective of an ever higher level of mastery despite unchanged simple rules.

It is possible to lend musical meaning to extra-musical actions in a way that in the end the musical meaning is inherent in the playful actions. However, this is usually not achieved simply by reference to a given game, but requires certain adjustments both on the playing side and on the musical side. Exactly these adaptations are the remaining parts

that should be learned by the laymen who are involved with the game. But it is enough to learn the rules of the game first and to experience the musical context bit by bit from the practical game. The sound-processes are inherent in the game and the rule-setting can be regarded as successful, if the connection between the actions of the players and the resulting sound-process can be anticipated and imagined by the players in an appropriate and lively way.

It should be emphasized that the correlations between the game turns and sounds are arbitrary determinations by the makers of the game. It is also generally the case that the connection between a sign and what it designates is essentially arbitrary and can lead to a more or less rich perception. Or, to use the words of Edmund Husserl, who in the context of the development of his phenomenology in his "Logical Investigations II" deals in detail with the connections between signs and the character of our resulting imagination of the signified:

"In the transition from a significant intention to the corresponding imagination, we do not just experience a mere increase, as in the transition from a faded picture or a mere sketch to a fully vivid painting. Rather, the significative intention in itself lacks any fullness, only the intuitive imagination brings it closer to it and, through identification, into it." (Husserl 2009), p. 607, translation. Original is german.)

As Husserl makes clear in the same treatise, on the way from a symbolic representation to the object intended by it, there is a sequence of stages of fulfillment that must be passed through:

"We make the number $(5^3)^4$ clear to ourselves by falling back to the definitory idea: 'Number which arises when one forms the product of $5^3 \cdot 5^3 \cdot 5^3 \cdot 5^3$ '. If we want to make this latter idea clear again, we have to go back to the sense of 5^3 , i.e. to the formation $5 \cdot 5 \cdot 5$. Going even further back, 5 can be explained by the definition chain $5 = 4 + 1, 4 = 3 + 1, 3 = 2 + 1, 2 = 1 + 1$.'" (Husserl 2009), p. 601-602, translation. Original is german.)

One would expect such a conditional connection of successive fulfillments, also in the case of a correspondingly complex connection between game symbol and correlated musical performance. But one can also imagine stages of fulfillment that are not mutually dependent, such as the mere mention of a person's name, a remembrance of the person, and finally his physical appearance. This provides a useful indication of how a close relationship between the symbolic game situation and the concrete sound events represented by it can be guaranteed: The sequence of fulfillment levels associated here should be kept as flat as possible. For example, it would be very, very flat if simply the noise when placing the game pieces was amplified very loudly. But there would be no direct relation between the meaning of the moves as such and the sound that occurs. In the following, a practical attempt is described to bring both together as good as possible, namely a directness of the sound production due to the moves and a meaning of the sounds, which is closely related to the meaning in the game, together.

3. Pulse235 – Design of a board game with an inherent correlation to music

The primordial way of forming tone scales goes back to the ancient Greek culture and is based on frequencies or – what comes out to be the same – time periods corresponding to ratios of integers that differ from each other in a few small prime factors, see for example [Düring 1987]. The tempered tone system preferred today in Western culture also refers to these primordial scale definitions. It represents a good compromise between cleanness and modulation possibilities [Lerdahl 2005].

The basic idea for the board game is to go back to integer sound frequencies, whereby these frequencies can be formed by the product of the first four prime factors, i.e. 2,3,5 and 7. A sound is represented on the board as a diagonal triple chain of coloured game pieces. The colours code the four prime factors with 2=blue, 3=red, 5=green and 7=yellow. The aim of the game is to create as many different triple chains as possible by moving pieces on a 9 by 9 field, starting from an initial distribution of a given number and colour of tiles. In order to increase the selection of the frequencies that can be formed without making the game more complicated, a fourth prime factor corresponding to the actual number of the permutation is selected.

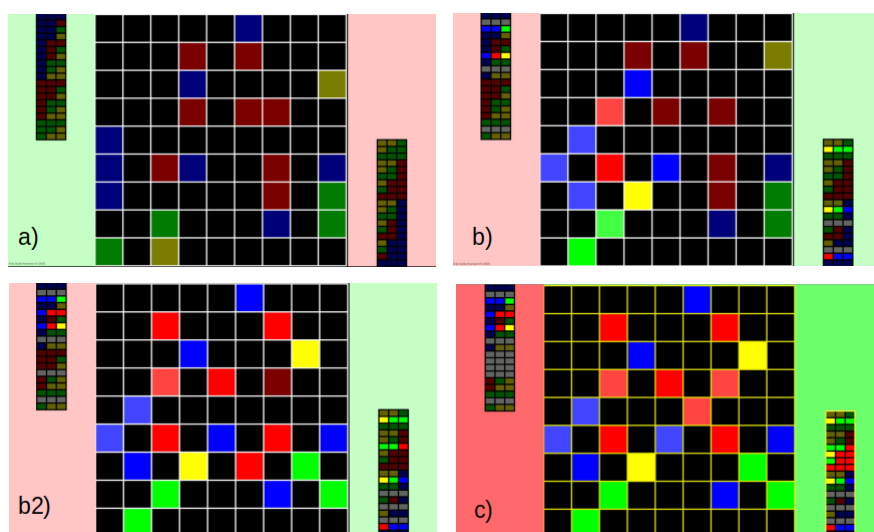


Figure 1. Game phases for Pulse2357: a) beginning, b) and b2) middle phase, c) final configuration.

Two players take turns touching an empty square. If there is exactly one tile closest to this position in either horizontal or vertical direction, that tile will move to that empty position. Those diagonal triple chains completed by a move that have not previously appeared are awarded as winnings to the player who has just made a move (Figure [1] b), b2). If at least fifty percent of the possible different triple chains have already appeared, the player who made the most of them may continue to make moves alone until a state is reached where all tiles in at least one triple chain are involved (Figure [1] c). This means that overlaps are also allowed. When this final state is reached, after touching a board again, a starting situation for a new game is established. These starting positions are random. But they have the property that not a single tile has a neighbour in the diagonal. In summary, this means that all pieces always remain on the board. It begins with no chain

of three (Figure 1a) and ends in such a way that each tile is part of a chain of three. The game, as it is described now, could be played without any musical performance. In the following, we will determine in more detail to what extent the chosen rules of the game are particularly suitable for forming the basis of a musical dramaturgy and how the sound generation was implemented to ensure that the connection between the sound events and the course of the game is as transparent as possible.

So how is music generated from such a game process? In each phase of the game there are a certain number of different integer frequencies that are interpreted as sound events in time. In order to allow an easy assignment between pitch and time, the series of whole numbers is considered a temporal sequence. A tone is played exactly when the currently valid natural number has the corresponding frequency as a divisor. This requires a detailed explanation:

4. The natural numbers as a time sequence taken as the basis for the sonification of the moves in pulse2357

In the following, we will show that the sequence of natural numbers – with or without zero does not make much difference here – understood as a time sequence, as far as the relationship between horizontal rhythm and vertical harmony is concerned, has a great affinity to classical musical structures. For this purpose, attention is drawn from the successive natural numbers to the divisors belonging to each individual number.

Any arbitrary integer positive divisor d occurs regularly in the sequence of natural numbers at a constant distance, which is also d .

Two arbitrary but different divisors d_1 and d_2 occur simultaneously relative to their size, the less dissimilar they are to each other. The degree of dissimilarity can be taken as the number of prime factors that they do not have in common, or more differentiated, it can also be demanded that the dissimilarity is greater the larger the prime factors in which the numbers do not match. Leonard Euler proposes a formula for this. From those powers k_i of the prime factors p_i , in which two compared numbers (frequencies) differ among themselves, the degree of dissonance designated after Euler with "gradus suavitatis" (GS) results according to the following formula $GS = 1 + \sum_{i=1}^n (p_i - 1) \cdot k_i$ [Busch 1970]. (The much discussed problems in the application of the gradus to classical harmony theory will be ignored in this context.)

Now the sequence of numbers, which have a certain divisor d in common, itself forms a progression, thus fulfilling the Peano axioms, see e.g. [Russel 1993], pp. 1-10. All in all, all these progressions are interwoven in such a way that such pairs whose divisors d_1 and d_2 have a high GS seldom occur in the same number, whereas this occurs more often in those with a low GS.

If one understood these dividers directly as frequencies of tones, then such tones appear more often in combination, which harmonize well, and such rarely appear in combination, which harmonize less well, all within the context of the concept introduced here. For the sake of simplicity, this should be called "vertical" resp. "harmonic" property.

However, if we look further, it is also the case that frequencies of similar pitch tend to occur in short succession rather than those with large frequency differences. This shall be called the horizontal or melodic characteristic.

Both together, i.e. the harmonic and the melodic properties of \mathbb{N} obviously show a great similarity to the structuring of music according to classical understanding. Also, for example, in classical choral music it is required (very roughly formulated) that successive notes should not show too large leaps, while at the same time sounding harmonics should sound together.

It is quite clear that what is said here for the natural numbers is of course not identical with classical harmony or counterpoint, but it shows – and this cannot be denied – amazing similarities with it. Neither shall we go into the problem further here that there are serious differences in the physiological consonance and dissonance perception compared to what is calculated with GS. Thus we hear a frequency ratio of two prime numbers such as 3001 to 1999 (GS=4999) to 3 to 2 (GS=4).

But as already mentioned, in order to make the fundamental similarities between a classical musical movement and the natural numbers, understood as a time sequence, visible at all, this should be sufficient.

Listing 1. Simple sonification of the natural numbers

```

import processing.sound.*;
SinOsc sino; // sine Oscillator
int t=0;      // counter for natural numbers

public void setup()
{
    size(640, 360);
    textSize(100);
    background(255);
    sino = new SinOsc(this);
    sino.freq(1);
    sino.amp(0.1);
    sino.play();
    frameRate(8); // draw() is called eight times per second
}

public void draw() // cyclically executed function
{
    background(255);
    fill(0);
    text(t,100,height/2);
    int tt = t;
    int f = 2*2*2*3*3*3*5*7; // base number (see text)
    int num2=0,num3=0,num5=0,num7=0;

    // Divide the base number by the prime factors 2,3,5,7
    // occurring in the current natural number:
    while(tt >0 && tt%2==0) {f/=2; num2++; tt/=2;}
    while(tt >0 && tt%3==0) {f/=3; num3++; tt/=3;}
    while(tt >0 && tt%5==0) {f/=5; num5++; tt/=5;}
}

```

```

while (tt > 0 && tt % 7 == 0) { f /= 7; num7++; tt /= 7; }
if (num2 <= 3 && num3 <= 3 && num5 <= 1 && num7 <= 1 && f >= 110
&& f <= 1760)
    sino.freq(f); // audible sound
t++; // natural number incrementing
}

```

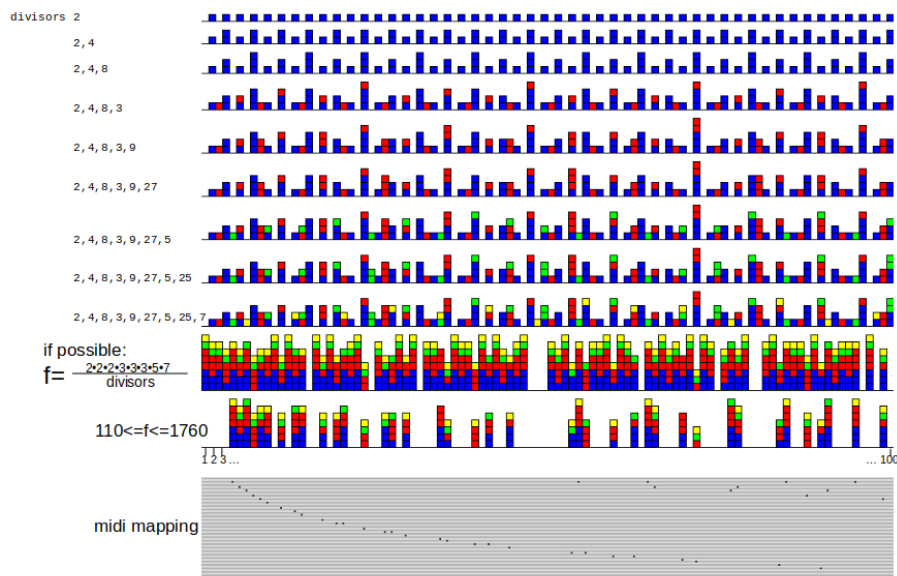


Figure 2. Visualization of what the program does in Listing 1, except the midi-mapping. Line by line, more and more dividers between 1 and 100 are added in color-coded form: 2=blue, 3=red, 5=green, 7=yellow.

In addition, a very short program is presented here (code [I](#)), which sonifies the natural numbers in a very simple way. It was implemented in Processing / Java, see <https://www.processing.org>. To keep it short, no effort was made to achieve a particularly interesting sound. A more elaborate realization of the same thing can be watched as a youtube video: <https://youtu.be/e81wd1b3FEE>. Not the entire actual natural number is taken, but only its parts of 2s, 3s, 5s and 7s. And also these parts are not used directly, but they are taken as divisors of another constant number, which I call the base number (here $2 \cdot 2 \cdot 2 \cdot 3 \cdot 3 \cdot 3 \cdot 5 \cdot 7 = 7560$). Finally, the result of this division is interpreted as frequency and translated musically. Only if this division is possible without remainder and the result lies in the frequency range of the used musical instrument, also a tone sounds (Figure [2](#)). The procedure thus filters out those tones that are in simple ratios to each other and are playable. It should be seen as a kind of humanization process that is applied to the original natural numbers. The musical form is essentially created by not playing parts that lie outside this frame.

The fundamental correlation was thus demonstrated. **And the challenge in the sense of ubiquitous music could now be: do something on the basis of the natural numbers by conceiving this sequence as a temporal sequence and using the divisors of each number as the basis for your own composition. This would be the supra-individual part of the contribution, so to speak, resp. the part that refers to something comprehensible for everyone, to which all people in general have equal access.**

5. Real world implementation (overview)

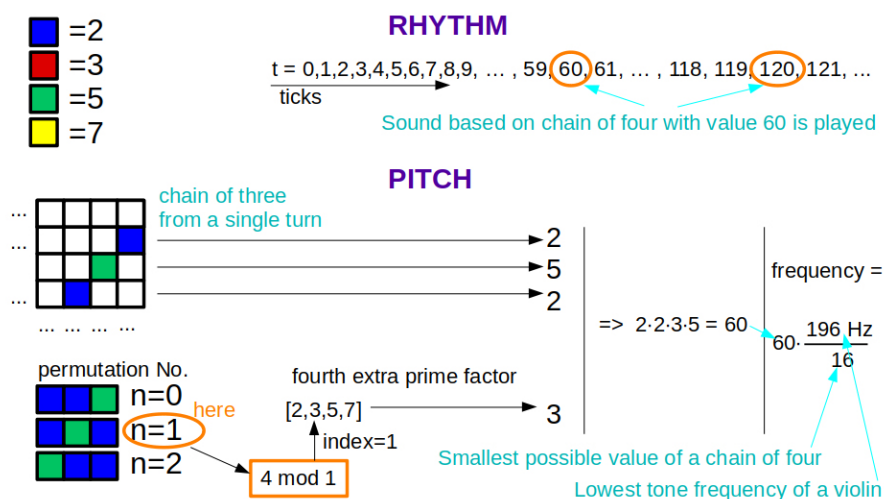


Figure 3. Extract pitches and rhythms from the chains of three.

The game was implemented as an Android app to test it and to have a reference and is available here for free: <https://play.google.com/store/apps/details?id=processing.test.pulse2357>

In order to derive tones and their rhythms from the initially abstract integer values resulting from the chains of three, the following steps were taken in this implementation:

A counter was implemented, which counts up the natural numbers with a constant time step, uninfluenced by the course of the game. One tick of this counter corresponds to the shortest duration possible in the real-time composition. The current value of this counter shall be called t here.

After each move, all triple chains on the playing field are automatically detected.

In order to increase the amount of tones that occur and to make full use of the available information contained in a chain of three, a fourth element is selected based on the color permutation of each chain of three, so that in the end there are all the chains those of four (Figure 3).

In order to make every chain of three in the game audible, the initially abstract values, which are obtained by multiplying the prime factors of the elements of the chains of four resulting from the chains of three, are multiplied by a factor that ensures that the smallest possible value of a chain of four corresponds to the lowest playable frequency (Figure 3 right side).

Finally, frequencies that are too high are octaved down until they are within the playable range. The range used is that of a violin. In order to lighten the sound set somewhat, the current values from the chains of four were ordered by size and the largest was always preferred if the current value of t had both as divisors. Since the largest value is also the rarer divisor of \mathbb{N} , this results in the fact that all notes corresponding to the quads are always played. This reduces the sound to a single voice. In order to bring back more voices into play, simply not only the tone with the highest value in the chain of four was played, but the n largest. To achieve again a certain variety of sounds, the

sounds kalimba, marimba, pandrum and violin were used in various playing techniques and were assigned to rank n in combination with other game parameters, which will not be discussed further in this presentation.

6. Discussion

What have we gained by implementing a real-time composition program in the form of a board game like pulse2357? Basically you can also think of it as a programming language for musical processes, like Max or Pure data. The possibility of adapting and using languages like this for collaborative, distributed live composing and thus as an approach for the realization of ubiquitous music has already been tested and discussed [Messina, M., Svidzinski, J., de Menezes Bezerra, D., da Costa, D. F. 2019]. Especially during the presentation of this work at the CMMR 2019 conference, it became clear that a major difficulty in the implementation of cooperative distributed composing is not only the technical feasibility, but also the different views of the partners involved on how to deal with an appropriate tool. Indeed, the presentation expressed a certain disappointment that some of the partners, located in different countries and even continents, did not trust in the cooperative interaction and gradually added structures appropriate to the current events, but tended to copy ready-made structures into the current sketch, thus dominating the process on the one hand, but preventing something completely new from emerging out of the cooperation with the others. Apparently, the concrete success of ubiquitous music depends to a considerable extent on whether the sense and functionality of a provided software tool is also understood by its users. It seems obvious to see such experiences as a kind of legitimation for the efforts made in the present work, which essentially consist of looking at what preconditions which are needed to mentally grasp a musical theory and application structure behind a software tool.

Due to the fact that the ticks of the musical performance are not coupled to the turns of the game at pulse2357, this game would also be suitable for a distributed application. However, considered as a programming language, the game represents one which allows the user only a very limited range of action. This seems to be the price for the fact that it can be learned so quickly and the user is aware of what he can do at all times. On closer inspection, it has been possible in many places to make musical rules and rules of the game identical. However, very little has been done to make this connection visible to the user. This can be explained very well by the used tiles: The tiles represent the prime factors 2,3,5,7 and the reference is made by a colour coding with 2=blue, red=3, green=5 and yellow=7. This is very simple, but the colours do not show this relation to the numbers. It is expected that the players learn and internalize this relationship. Neither is the relation to the sound resulting from the combination of three pieces and its rhythmic occurrence directly evident from the constellation on the playing field. Here, too, the user must learn that he must multiply the numbers corresponding to the colour codes with each other in order to get an idea of the rhythm and sound that might result.

Although it was said that through the audible feedback and the automatic control of the game moves for their correctness, the player gradually develops an inner model for the interrelationships between the game situation and the resulting music. But without the study of a playing instruction, these relationships are very difficult to discover just by experiencing the playing situations. The connection between game and music and the game itself is kept simple, but nothing is done to make these simple connections

comprehensible other than by pure experience.

How did it come to this? The following explanatory model appears to be appropriate: The use of symbols (in this case the tiles on the playing field) reduces the task to be mastered to providing practical options for action. The meaning behind these options for action is hidden from the user as unnecessary ballast, so to speak. Thus, easy handling and transparency of a matter seem to be in direct contradiction to each other.

In the short term, pulse2357 or similar approaches can be used to get people to compose (cooperatively) very quickly. In the long run, the practice conveyed in this way by no means guarantees an understanding of the principles behind it, as described in chapter 4, even though everything has been done to keep these principles simple.

7. About the idea of using transparent symbols (Future prospects)

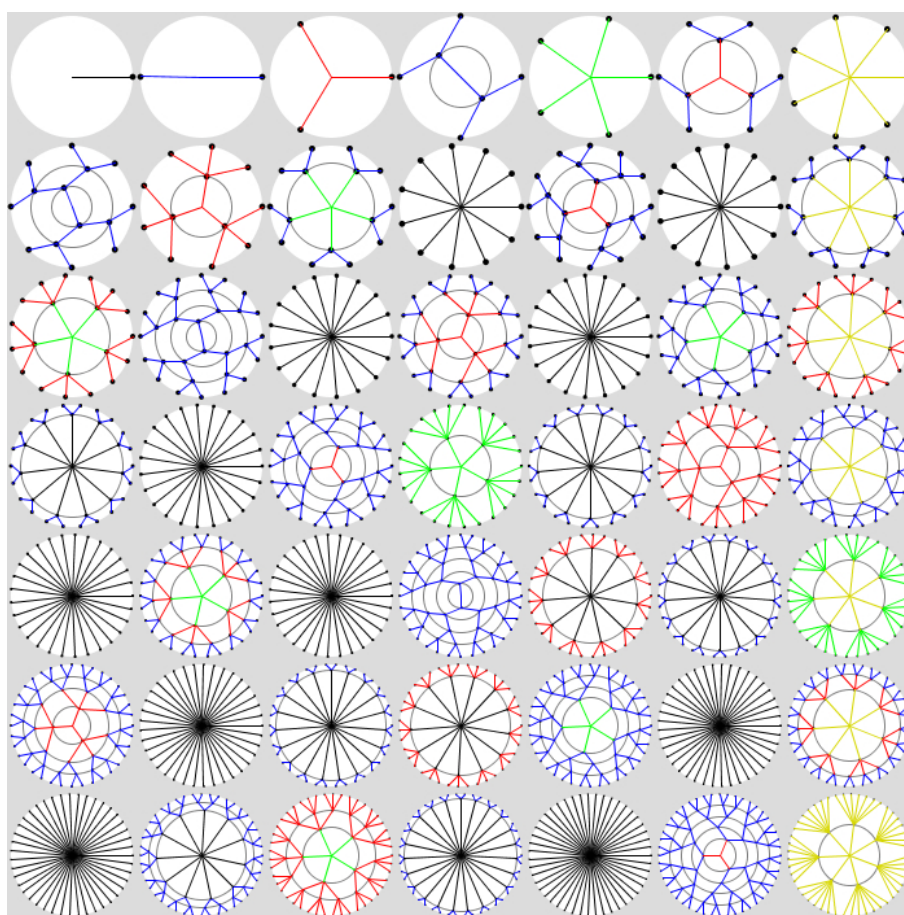


Figure 4. Symbolic representation of the natural numbers from 1 to 49 considering their prime factor decompositions.

To get ahead at this point, just think about making the approaches to composition introduced here available to children. No doubt a first grader would be able to understand and play pulse2357 quickly. But only with a very weak knowledge of basic arithmetic and without an idea of what the divisors of an integer number are, there would be no chance of making the method of composition fruitful for himself. But wasn't arithmetic initially assumed to be an already learned inner model and described as a wonderful basis for the

basic understanding of the compositional method introduced here? When presenting the above figure to people of different ages and educational levels, it became clear that the vast majority of them could not find out what this figure represents without further explanation (Figure 4). Explanation: The number of points evenly distributed on the edge of each of the displayed circles corresponds to the natural number that is represented. These run in their natural order from 1 to 49. In the circles, a separate layer is inserted for each prime factor of the current number. These are arranged from inside to outside in order of size. A multiplication between prime factors is represented by a branching. Accordingly, prime numbers are represented by symbols that have no further division into layers on the inside. So 6 is $3 \cdot 2$ and thus there is a three-star in the center of the corresponding symbol, whose three ends branch outwards binarily.

As mentioned above, even educated adults, unless they were mathematicians, were not able to say within a reasonable time (a few minutes) what the figure above represents. Thereby it represents a conceptual design to introduce a kind of transparent symbols into future musical board games, thus such symbols that show what is represented by them, here the inner structure of natural numbers, in order to be able to quickly recognize similarities in this respect. Of course, after a short explanation, most people recognized that this illustration was meaningful. But why does it also fail to meet the demand made on it to let that which is symbolically represented through it shine through immediately? One reason could be that normally nobody is really aware of the fact that there is a difference between a number and the set represented by it. Accordingly, one will not be able to identify an alternative number representation as such when confronted with it. Another explanation would be that the representation in the figure does not actually explain what prime factors are with respect to the set represented by the number symbol, but that an understanding of these new number symbols, as one has to admit, rather goes beyond the representation of numbers as a decimal system that we are familiar with.

One idea to meet these problems could be the drop in sets to symbolically represent numbers and their divisors. And dynamic computer-based representations could help to handle the otherwise expansive representations. However, the symbolic character and the associated advantages of simple practical handling may also be lost here. To substantiate this idea, the divisibility of a number is visualized in the following figure by the various possibilities of arranging the set representing it in a rectangle (Figure 5).

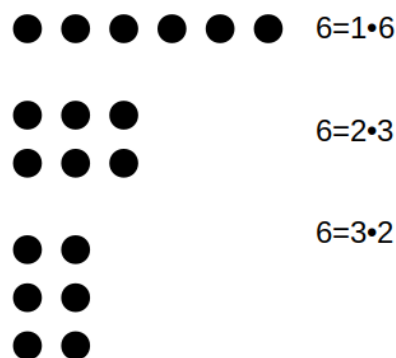


Figure 5. Visualization of the divisors of a number through the different possibilities to arrange the set representing it in a rectangle.

This still would have given no idea whatsoever of how also sounds could be better understood using symbolic representations and thus, would give a kind of explanation for their inner inter relationship.

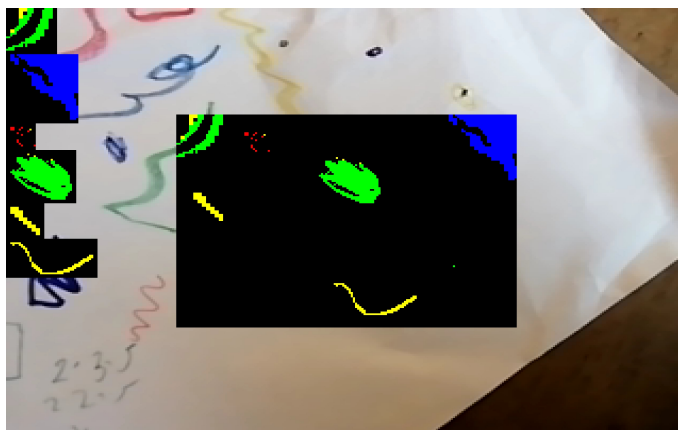


Figure 6. Composing for children.

Trial and error is the basic approach of children. Children tend not to deal with a thing in theory. They prefer to just try something. This makes them a very challenging target group. If a concept is to be suitable to enable everyone to compose, it should be adaptable so that children can do something with it. The idea of representing the divisibility of sets by showing all the rectangles in which this set can be arranged led to the idea of obtaining such rectangles from image sections that are continuously recorded by a camera. Using the appropriate Android app, children can then create a visual score of colorful shapes on a piece of paper. Continuous objects are recognized by the software and are displayed in the rectangle surrounding them on the left (Figure 6). The pixels of these rectangles must be thought of numbered line by line. Where a pixel is coloured, the corresponding number n is active. The colour encodes the instrument with which the corresponding tone is played. The principle of when a tone sounds corresponding to n follows the concept described above: A variable t is continuously incremented. t corresponds to the time sequence of the natural numbers. Whenever n is a divisor of the current value of t and n is also a divisor of a constant base number b , which is composed only of multiple prime factors 2,3,5 and 7, then a tone is played whose frequency f is calculated as $f=b/n$. During the actual implementation of the app, the size of the base number was adapted to the size of the rectangular objects. The app can be seen in action here: <https://youtu.be/Zrd5mLkp4sE>. The app is expected to be tested by first and second graders at a primary school during a STEM project week in April 2020.

An extended PC-based version, in which the sound generation is done by physical modeling, was used to accompany a movie with sounds that was created during the flight of a drone (Figure 7): <https://youtu.be/nbw-LRxXVCY>

8. Conclusion

As a basic approach to open composing to as many people as possible, a simple variant of a musical theory was sought that could be presented well by means of mathematics, and formulations for simple playing were sought that would allow manipulations in the field

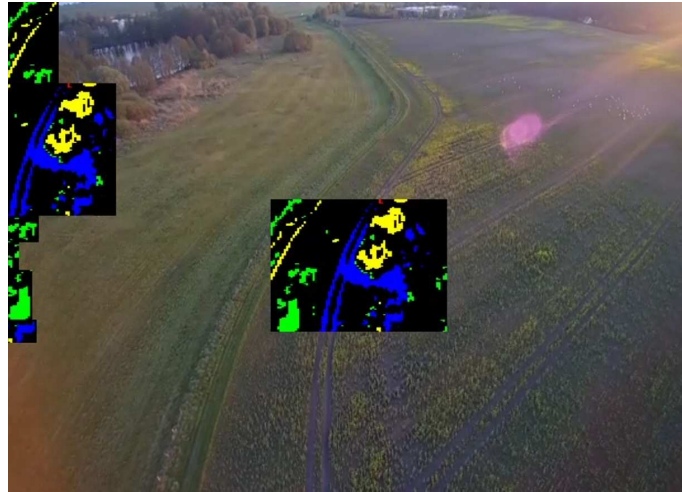


Figure 7. Algorithmic sonification of a film recorded by a drone during flight. The film was kindly provided by Klaus Stanjek, see <https://www.cinetarium.de/>.

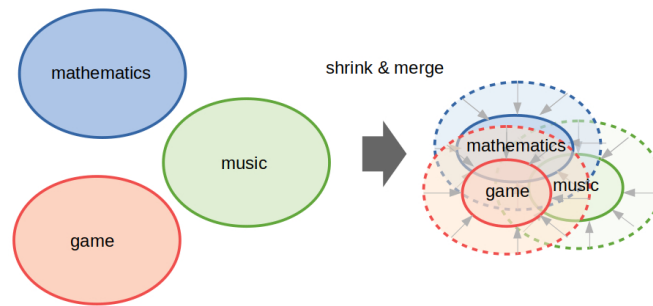


Figure 8. Selection of suitable subsections of mathematics, music and gaming for a fusion.

of this simplified musical theory, thus making it possible to compose. To put it somewhat simply, suitable areas in the fields of mathematics, music and possible games were sought which correspond well to each other and in the best case merge with each other (Figure 8). The reason for this was that it is then possible to carry out actions in an understandable way within a field that one already has a good command of – here mathematics – which then have an equally understandable effect in the musical field. The purpose of transferring the whole thing to a game was to give the user a goal to pursue and thus to ensure a secure continuation of a corresponding performance. Likewise, the rules of the game show the user his possible options for action, without the user having to know the musical laws behind them. In any case, this has led to the development of practical software tools. However, it has also been shown that the relative simplicity of the overall arrangement does not guarantee that the overall context will be understood by the user. The latter, however, has been identified as a basic prerequisite for ensuring that the composition methods behind the real-time composition tool can be made fruitful by the users themselves in the pursuit of their own creative goals. In the following attempt to open up the use of the compositional method presented here to children as well, it became rather clear that a profound transparency cannot be created here at all, because the target group

is basically neither openly nor mentally able to grasp the concepts behind it theoretically. Instead, the corresponding Android app, similar to the implementation as a game with its rules, limits itself to an action-oriented comprehensibility. And if one thinks about this in more depth, one has to realize that everything we deal with is always connected with arbitrarily complicated and complex interrelationships under the often seemingly simple surface, which we at best only guess at, but never fully understand. How is that meant? – For example, someone might have fully understood the theory of Pulse2357 and then still know nothing about how playing technique and timbre for the instruments are derived from the playing configuration. Furthermore, someone who is familiar with this area does not need to know how the physical modeling instruments used work. And finally, someone who understands all of this may know very little about hearing physiology, hearing psychology and why something like a positive aesthetic feeling is created in connection with the method presented here. This complex can be further deepened and expanded as desired. And so, after this long search, which this work also represents, the only realization that simplicity is always an illusion may stand.

On the positive side, however, one could also try to defend the approaches presented here in the following way: Music has something to do with the fact that a relationship between temporal events is established and transcended by the listener to the extent that, after recognizing certain harmonic-rhythmic principles, the listener builds up expectations for musical events that will occur in the future. The attraction of a successful composition is then usually not simply to confirm the expectations, but to interpret the expected in a new and different way by means of the new things that really sound, in a way that is unexpected to the listener. In Buddhism there is the concept of dependent emergence, to which everything in the world is subjected. While in Buddhism it is said that nothing lasts and thus, always becomes a source of suffering (see e.g. [\[Batchelor 2015\]](#)), the reverse could be said for music: composing creates dependencies on sound elements that previously existed independently of each other, whose relationship to each other awakens passion in us. In the approach presented here, this relationship between the elements is ensured by the use of natural numbers and their natural relationship to each other.

In this fact lies the transparency and simplicity of all the approaches discussed here. And actually, with every algorithmically based compositional method, one must ask oneself the fundamental question of where the experienced relationship of the structures generated by it comes from. Has it somehow been brought in by rules that go back to the intuition of the programmer, is this reference brought in by the user of the program (and can he fail in it?), or does the inner order of the resulting compositions, as here, come from a source that can be explicitly stated and objectively described and further investigated? As a consequence of this fact, all the variants of algorithmically / generatively supported composition programs presented here, no matter what you do with them, always produce something like music in the sense described here. However, the prerequisite is always that the composition system as a whole is always permeable to the described mathematical / musical principle, which is based on the natural numbers as a temporal sequence. When designing these programs, a certain reluctance was always required not to supplement the whole thing with aesthetic rules of any kind that the developer intuitively felt to be correct. According to the title of this work one is required to renounce doing something (too) grandious (special / intransparent / complicated). Above the recognized always existing

and never quite intellectually penetrating depth layers, there is always a superficial layer in the examples here, which in a varying way forms simple relationships that can be easily explained and in which an explanation is already included why relationships arise on a rhythmically harmonic level through the regular use of the respective program and thus, opening the door to become ubiquitous.

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The Potential Role of Internet of Musical Things in Therapeutic Applications

Joseph Timoney¹, Azeema Yaseen¹, Damien McEvoy¹

¹Department of Computer Science – Maynooth University

Maynooth – Co.Kildare – Ireland

{Joseph.timoney,damien.mcevoy}@mu.ie,azeema.yaseen.2020@mumail.ie

Abstract. *The application of the Internet of Things (IoT) specific to Music technologies is referred to as Internet of Musical Things (IoMusT). This field is in its infancy but potential applications include wide network interactive music performances, smart and wearable instruments, and multi-person virtual music systems. There is no framework as of yet, but a number of technical hurdles have yet to be overcome. These obstacles reflect the fact that many devices will be wearable which means they must be lightweight, energy efficient, and possibly low cost, but must also be powerful. Music therapy is yet untouched by these new technologies of IoMusT. However, it offers great potential for devices that could be applied in assistive living scenarios that provide a non-invasive, individually attuned, form of treatment that is always available. For example, wearable devices that are driven by low cost computing could offer interactive music therapies that are delivered outside of the clinical setting. These could be used to enhance a patient's wellbeing in between instruction and practice sessions with a therapist. The usefulness of ubiquitous music technologies will be further extended with the development of machine learning algorithms that are designed specifically to have a low computational footprint. These could be used to analyze and predict user behavior and thus tailor the therapy exactly on each occasion. This paper will develop a review of what has been achieved in this domain so far. It will then look ahead to see which trajectories are most likely for the future, particular within the guiding framework of ubiquitous music and computing. It will close with a discussion on the key technological enablers and risks that could hamper their progress.*

1. Introduction

Technology is everywhere and thus it is not surprising that it has had a profound impact on everyday musical experiences. Technology influences musical interaction probably in all its forms starting from music education (Zhang and Sui 2017) and creation (Anderson et al. 2020) to all possible ways it could reach the audience. The late nineteenth century saw the emergence of electronics for musical interaction, followed by the appearance of computers to do the very same at the end of the twentieth century. This has led to the ability of making very sophisticated music, either as an individual, or in group scenarios, using computers through wired/wireless networks. The research in musicology and its subfields such as systematic, computational (research between music and computer science) Mor et al. (2020) and applied musicology underlies a dynamic of technology-mediated music applications in human health and wellness. Ubiquitous music (Keller et al. 2014) explores novel and ubiquitous musical experiences for musicians and non-musicians which adds value to previous contributions. As music technology and industry expand, technologies like ubiquitous computing, internet of things (IoT), machine learning and artificial intelligence can transform the ways in which music is created or consumed. The field of ubimus stresses the creative and active role of all participants in musical activities.

This paper will discuss the role of ubiquitous computing and internet of things in music technology, what research has been published so far, and how this integrated environment can trigger future music-oriented therapeutic applications. The next section will give the background to the Internet of Musical Things (IoMusT) and its evolution from IoT. It will also discuss the broad contributions of technology into music therapy applications. The section after this will describe the goals of ubiquitous computing and music and how they may intersect with the future trajectory of IoMusT, mention will also be given to developments in artificial intelligence (AI). The following section will posit a framework through which IoMusT and ubiquitous music (ubimus) may be integrated and discuss potential applications. An example will be specified. The paper will then close by summarizing with conclusions and outline the most pressing challenges for future work.

2. Ubiquitous Music: Where Ubiquitous Computing meets Music

2.1 Ubiquitous Computing (Ubicomp)

The area of ubiquitous computing draws together many different fields in computer science. An illustration is given in Figure 1. The challenge for ubiquitous computing is to know how to merge these fields and create computing devices that behave in a ubiquitous manner for users (Schiavoni and Costalonga 2014).

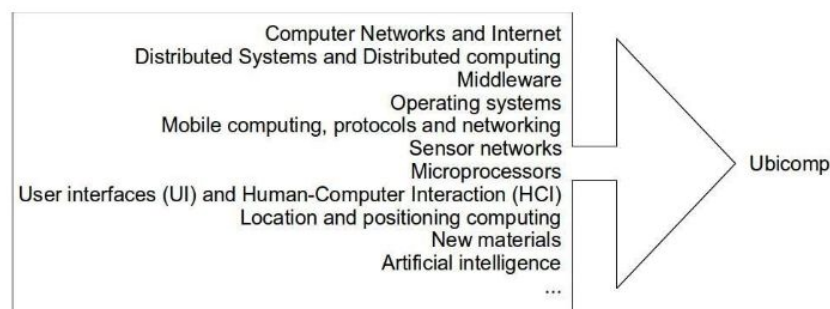


Figure 1. The research fields in Computer Science and Ubicomp (taken from Schiavoni and Costalonga (2014)).

2.2 Ubiquitous Computing and Music

Ubimus also merges various research fields in sound and music computing. Typical devices are cell phones, tablets, netbooks, micro-controllers, and portable computers. Anything as long as they are open, programmable, connectable, independent, autonomous, wireless, user friendly and expandable. From an ubimus application point of view, software should be open source and adhere to open standards.

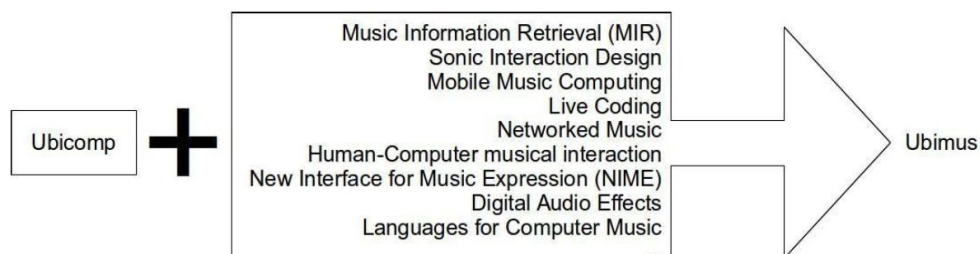


Figure 2. When Ubicomp meets music (taken from Schiavoni and Costalonga (2014))

2.3 Ubiquitous Music (Ubimus)

Ubiquitous music can be defined as a field of unbounded and creativity-supported musical environments, interactions and activities exploiting the concept and technology of ubiquitous computing. It enables artistic musical activities beyond co-located and conventionally tuned music venues. Music, in its nature, is not linear and so the definition of ubimus is multidimensional. It implicates different aspects of music, creativity and performing arts to articulate music as an ecological and creativity dominant field of research. These experiences are constructed by a combination of domains including cooperative composition, listening, and networked instrumental practice and performance either for musicians or non-musicians (Cogo-Moreira and Lamont 2018). This emergent field is grounded by the ubiquitous computing technology to establish the conceptual and theoretical models for technology supported musical interactions. These metaphoric representations are based on time and spatial facets of the musical context as given in Keller et al. (2011). Designing and building frameworks driven by this area of study require the integration of specific knowledge and methods, exploiting the fundamental synthesis of distinct techniques. In this regard, evolving computing research areas can offer new infrastructural opportunities for a wide range of individual or cooperative musical practices. In ubimus, the diversity of ecological backgrounds (social, artistic, and technological) endorse this field as an open developmental area eventually scalable to heterogeneous everyday contexts.

3. Internet of Musical Things (IoMusT)

3.1. Internet of Things

Internet of things brings together two terms ‘Internet’ and ‘Things’, where ‘internet’ carries the vision of a network and ‘things’ describe a layout for integrating and connecting the objects through different technologies (Atzori et al. 2010; Borgia 2014). As a system of identifiable objects, internet protocols, ubiquitous computing, communication technologies and sensing capabilities, it offers a shift from conventional internet approaches to connecting physical and digital objects. Things are embedded devices which not only sense the environment to collect data but also establish connections with each other and humans in the network (Gubbi et al. 2013). Some embedded smart objects, in IoT technology, draw on intelligent applications for several domains such as healthcare, smart cities, smart home and smart wearables (i.e. smart glasses, smart watch and smart speakers).

In an IoT network to make intelligent services more accessible, the user’s data is captured continuously (e.g. personal data including names, phone number or location) ; emotional data is also accumulated and analyzed for personally preferred services. In this regard, IoT technology could eventually deliver music tuned to a user’s emotional states (Seo and Huh 2019).

The sustainable IoT technologies have been envisioned to integrate health areas in a wider archetype for the development of human wellbeing (Salam 2020). This opens new perspectives on IoT frontiers to explore this technology to intersect with the advances in ubimus technologies. This will support evolving and interdisciplinary research trends in this field to make musical activities ubiquitous and more interactive.

3.2. Defining the Internet of Musical Things (IoMusT)

IoMusT has grown out of many discussions among researchers and references to it then appeared in publications including Hazzard et al. (2014), Keller et al. (2014), Keller and Lazzarini (2017), and Turchet et al. (2017). A significant review paper was published in 2018 by Turchet et al. (2018). It considers computing networks embedded within the functionality of physical objects (that is, the musical things) that are dedicated to the production and/or reception of musical content. These musical things are connected in a way that enables

multidirectional communication, both locally and remotely. IoMusT is both a subfield of ubimus and IoT. The underlying technological infrastructure enables ecosystems of interoperable devices connecting musicians and audiences, to support novel musician-musician, audience-musician, and audience-audience interactions. Ubiquitous music research has already contributed to the advancement of IoMusT-based creative proposals (Keller et al. 2019). The integration of multiple technological objects into ubimus ecosystems opens new opportunities for artistic applications of IoMusT and supports a creative usage of the internet.

3.3. Ubimus and IoMusT

Ubimus draws new ways of musical practices through technology assisted creativity support tools and relies on ubiquitous computing for this. Not only itself but can also provide grounds towards future music technology trends. This contribution is admired by a novel music technology, Internet of musical things (IoMusT) (Turchet et al. 2018). This technology can establish novel and robust systems to be adopted in creative arts therapies beyond co-located settings. Some of the current musical services (e.g. Networked Performances, Remote Rehearsals, new interfaces for musical expression), protocols for wireless communication and over-the-network audio processing (e.g. Bela board for low latency audio processing), and suitable smart instruments can be studied in Turchet (2019).

4. Music Therapy and Technology

4.1 Music Therapy: background

The power of music is widely accepted. It triggers people's emotions and its substantial impact on the human brain induces pleasurable responses (Zatorre et al. 2013). It drives music therapy, 'music as a therapeutic intervention in clinical settings', as a creative health profession to provide in-patient rehabilitation services. Music therapy can reduce anxiety and help patients to cope with stress in an in-patient setting as explained by Tan et al. Lin (2020). Its effectiveness has also been examined in mental health units for adolescents (Johnson et al. 2018). It improves their self-expression, boosting self-esteem and making them resilient to vulnerable situations.

At a larger scope, the above interventions can be extended to out-patient health care to promote remote and ubiquitous health services. According to the review in Schmid et al. (2010), home-based music therapies (HBMT) can be cost effective and accessible for everyone.

4.2 Technology Mediated Remote Music Therapies

Advanced health systems are incorporating telecommunication and information technologies to serve beyond the traditional settings. Technology supported creative and collaborative music activities have enough potential to be adopted as a technological intervention for music therapy. A relevant case study explained by Keller et al. (2014), reveals the importance of technology for music oriented artistic activities to build resilience (an ability to stay well and mentally healthy) among school students. The music jamming platforms, examples being jam2jam, CODES, and mixDroid, which allows cooperative audio production via Bluetooth connectivity to build improvisation skills, give motivation to build such technologies for holistic healthcare. This offers a multidimensional research paradigm to explore and establish integrated models of music and health technologies. The input from cross disciplinary fields such as: i) health technologies (e.g. telehealth and ubiquitous health); ii) information technologies (e.g. machine learning, artificial intelligence, ubiquitous computing and IoT), iii) music technologies (Digital Musical Instruments, MIDI, and machine improvisation,

music information retrieval (MIR) and embodied music cognition (EMC)) can offer a great contribution to establish new technology models for music therapies.

5. The Model for IoMusT based therapeutic Environments

5.1. Definitions

a) Embodied Music Cognition (EMC)

Embodied Music Cognition is the study of corporeal musical interactions (physical movements) that are linked to the perception of a music player and their gestures with the intention of finding a more thorough understanding of the associated emotions as they perform. Thus, the bodily involvement determines the way in which the music is perceived, felt, or experienced, according to Leman et al. (2018).

This information will be sent to the associated ubiquitous technologies (Desktops, PDAs or Mobiles) that possess additional add-ons to control or engage with the musical interactions. EMC has emerged as an influential area in music research and it was explicitly proposed as a musical research paradigm in Leman (2008). Its adoption is being facilitated by the improvement in sensor technologies, including camera systems, that have enabled the recording of body movements during musical activities and the subsequent data analysis, for example using multivariate, and functional data techniques. These methods have been integrated with novel approaches in audio analysis, which rely on feature extraction and machine learning methods. The EMC perspective is promising as a valuable contributor to the enhancement of remote music playing activities for users.

b) Embodied Musical Prediction Interface (EMPI)

With reference to Godøy and Leman (2010), a prototype technology for analysis of musical communication via bodily movements and gestures was presented in Martin et al. (2020). This was described as an Embodied Musical Prediction Interface (EMPI) which could streamline the pathway from musical interactions to predictions as a continuous and single input-output dimension. To connect physical and sonic predictions with performers' actions, this work employed a REcurrent Neural Network (RNN) model integrated into the physical music instruments. It contains a physical input lever (from the performer), and a similar motorized lever to represent predicted output from the RNN model. The goal of the study was to assess how these representations might impact their understanding of their instruments. /it was posited that this interface could be integrated with Smart Musical Instruments (SMI) for remote musical interactions. This could formulate an environment of predictions through real-time tracking of bodily movements, and suggesting future musical activity.

5.2. The Model

This paper employs a subset of IoMusT enabled interaction possibilities. We refer to this as a dyadic therapeutic interaction which mainly includes: i) client, ii) therapist and iii) Smart Musical Instruments (SMIs). The client-therapist dyad connects remotely to a ubimus therapeutic context. The proposed framework establishes remote connectivity through SMIs, which enable ubiquitous musical interactions, to perform a cooperative musical activity (e.g. free improvisation). For example, the in-session audio is transmitted to the therapist who in response can produce music to accompany their clients. The data from various sensors such as mobile sensors, wearable sensors and on-instrument sensors will then be used to monitor and analyze the musical output of a client. The aim is to track and analyze musical and physical activity of clients for prediction of their behavior, emotion, and future musical

activity. This would enable the dyadic interaction that builds a virtual client-therapist relationship across the internet.

During the session, the data about clients can be collected in two manners; i) data captured through the sensors and ii) data about the music. The sensors employed can be biosensors to sense the client's physical actions (corporeal interactions associated with the musical activity) during the therapy session. The incoming data will be processed for Embodied Music cognition (EMC) and analyzed by the Embodied Musical Prediction Interface (EMPI) models to track and analyze a client's performance throughout the session (Martin et al. 2020). It will then try to recommend future musical activity in line with the overall therapeutic goals. The music performance provides data, for example his active and idle states during activity, associated behavior and emotions (Music Emotion Recognition). Then all this information is merged before it goes to the model informed by the therapeutic goals. The study of machine learning techniques is required to classify the data and map it to the therapeutic parameters. The data is unstructured, and AI techniques are widely proposed to deal with this situation, yet a deeper analysis for such applications is needed. The session outcome and visualizations are customized to the clients and their therapist. This will help therapists understand their clients even when there is no verbal communication. Ubimus creative practices can facilitate how and what type of music activities can be performed within a remote therapeutic session.

The quantitative analysis of musical activity depends on its definition and the data (musical features e.g. number and range of musical events used, the pitches used, and the time of activity) extracted through musical information retrieval techniques. The aim of IoMusT based music therapies would be to extend therapies from conventional clinical and in-patient environments to everyday life e.g. workspace, home or wherever is suitable and feasible.

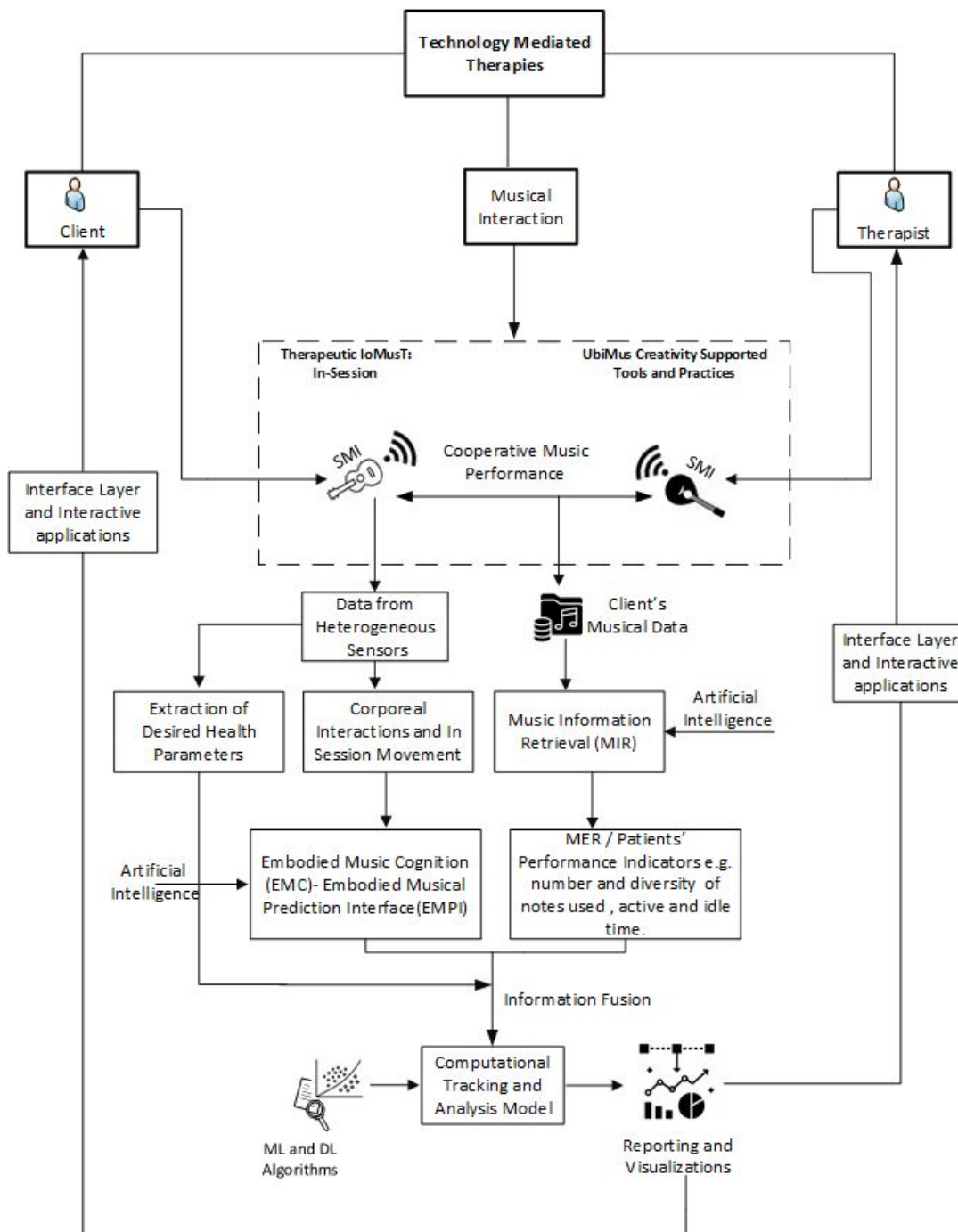


Figure 3. An abstract representation for the proposed framework; the client, therapist and remote musical interaction are primitive entities of the model.

5.3. Sample Application: Technology-led Free Improvisation

a) Theoretical Explanation

When providing music therapies, there are scenarios where IoMusT, as an intermediate layer, can provide a bridge between patient and therapist. Let us think about a IoMusT mediated music therapy session in which a client and a therapist freely improvise music in collaboration with each other. Free improvisation is an expressive and non-verbal technique adopted in active music therapy (Albornoz 2011). The therapist directs the patients to play music without imposing any rigorous rules letting them engage through their own feelings

and creativity. The creative instincts of all human beings enable them to generate spontaneous musical sounds. The improvisational activities are accessible: this approach does not require any formal technical skill. The IoMusT framework ensures the effectiveness of the communications on the infrastructure. In the health context, the parameters of musical improvisation need to be underpinned by their overall effects on human health and wellbeing (MacDonald et al. 2014). The performance measurement of such therapeutic improvisations requires a complex analysis of improvisational parameters. These parameters could be calculating or measuring: i) the amount of time spent in active or idle state; ii) the number of notes used and keys pressed in a specific time; iii) octave patterns; iv) dynamics; v) selected pitch classes and vi) synchronization between pressing a pedal and other events (Liang et al. 2018). Sandak et al. (2019) use these parameters to establish a tracking model for computational music therapy.

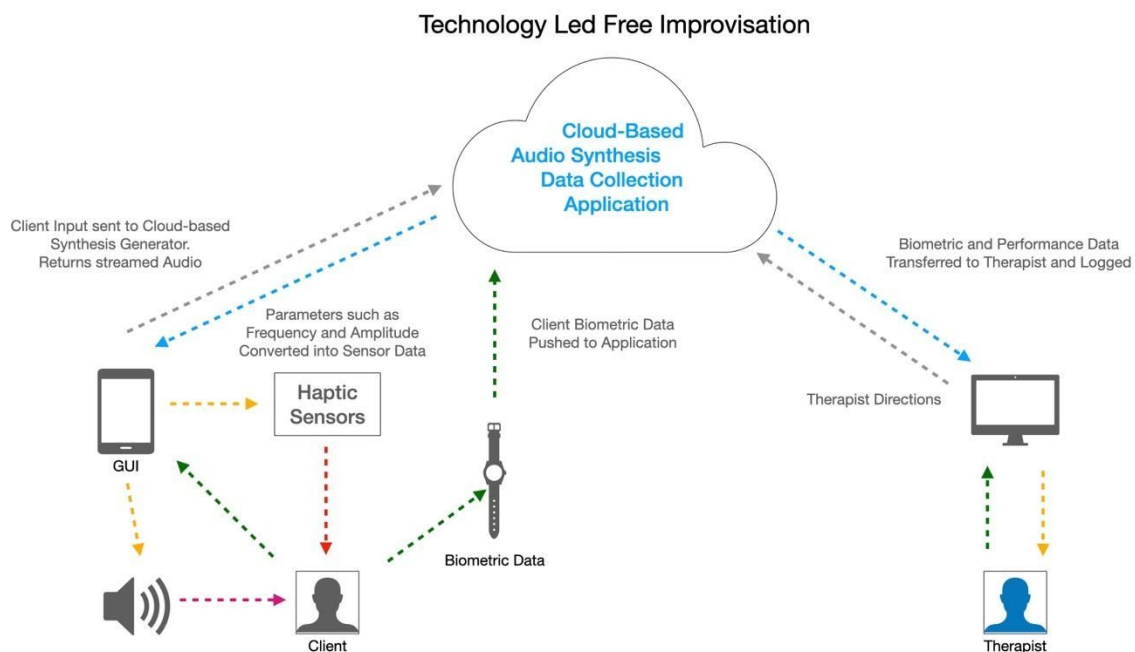


Figure 4. An abstract representation of client-therapist interaction in a Technology Led Free Improvisation musical therapy session.

b) Visualization and Technical Description

In practice, ubiquitous technologies combined with biometric data sent over the internet are well placed to develop creative music therapies. If the aim is to reduce anxiety and to enhance wellbeing, a form of improvised, non-pulse-based music could be successfully created with current infrastructure. This could be an audio signal generated by server-based synthesis applications, with a graphical user interface loaded on a touchscreen device, and equipped with haptic feedback sensors, motion sensors or fitness trackers to transfer patient biometric data. This data can be logged on the therapist system. In a scenario such as this, tempo, time and key signature may be irrelevant. Therefore, as long as the patient has a good sense of gestural control, any latency in the system will not impact the musicality of the application.

Networking of Musical Events

For creative and collaborative efforts which may rely on pulse-based music, the streaming of musical event data would be more efficient than server-based audio synthesis. Musical event data can be sent in many forms such as MIDI or Open Sound Control (OSC). Physically modelled synths, and Digital Audio Workstations installed on each device in the collaboration could receive the musical event signals over the internet, giving rich timbres at low latency. Experiments have been conducted using MIDI sending data through the internet from Australia to Scotland with roughly 100-150ms of latency (Bray 2017). Depending on the session parameters such as tempo, time signature, this translated as a semiquaver or 16th note latency. However, it is possible to adjust the system to compensate for a measurable delay. This would lead to both the sender and receiver to believe that the events are happening in real time but are in fact different moments in time.

An AI-based system could manage the signal flow and anticipate latency and dropouts to keep the continuity of the performance (Camporez et al. 2018). Training an AI to interpret a music event data stream would allow the AI to monitor the data stream for technical errors. For example, it is common in networked musical sessions for event messages to be lost or to arrive in a cluster. An AI system trained on such data could anticipate such a situation. Hypothetically the AI would pick up the tempo and see that a cluster of musical events with associated control messages are about to arrive to be delivered not as the performer intended. By scanning the timestamp at the source, the AI could release the notes as intended or if unable to connect to the source, the cluster could be deleted. A delayed or non-existent note-off message could be inserted by the AI. Furthermore, an AI also trained in composition, aware of the initial input sent by the performer, could insert musical materials based on what was played. For both the sender and the receiver there would be no musical dropout and the session would continue. In such a scenario, real-time musical collaboration could possibly enhance the well-being of the patients giving them a sense of connectedness and purpose.

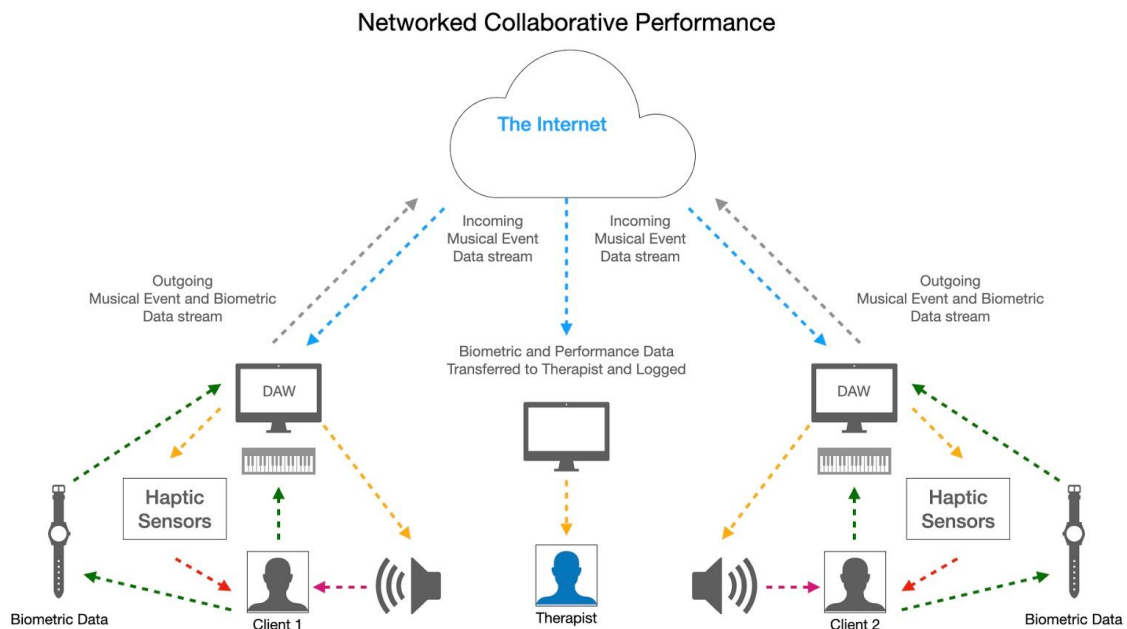


Figure 5. An abstract representation of possible client-client collaboration over the Internet monitored by the therapist.

5.4. Value of Artificial Intelligence (AI) to IoMusT and Ubimus

Artificial intelligence (AI) is emerging as an influential technology for the analysis and prediction of musical activities. There has been a dramatic increase in the integration of AI and machine learning technologies in the last 5 years. Deep learning has been a major driver for this. Awareness by the public in this technology has come from media publicity for applications such as Siri and AlphaGo. A strength of deep learning is its ability for unsupervised learning with unstructured data. The Music-as-medicine Sync project uses Deep learning (Ahtisaari 2020). Another example includes predicting music therapeutic effectiveness using Decision trees and Random Forests (Raglio et al. 2020). Also, the Sound Control project developed at Goldsmiths, University of London uses K-nearest neighbors and Neural networks in UI design for children with disabilities (Parke-Wolfe et al. 2019). Therefore, it is certain that the coming years will see more IoMusT applications with integrated AI components, and will add extra value to the user experience.

6. Conclusion and Future Work

This paper has considered the new developments in the Internet of Music Things and how they relate to ubiquitous music. Using the example of music therapy, a framework was presented illustrating the interaction between a client and a therapist. This was further illustrated through a technology-driven, improvisation-based therapeutic proposal for an application. With respect to the future work, this framework can be described using a modeling language. More research into the benefits that AI, beyond Deep Learning, can bring new elements to therapeutic applications. AI technology could drive the effectiveness and user-value of future applications. Lastly, it would be highly desirable to develop a relationship with the clinical community to find a way to gather data and obtain user feedback.

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Musical Smart City: Perspectives on Ubiquitous Sonification

Pedro Sarmiento¹, Ove Holmqvist², Mathieu Barthet¹

¹Centre for Digital Music – Queen Mary University of London

²Holonic Systems Oy.

{p.p.sarmiento, m.barthet}@qmul.ac.uk, ove@holonic.systems

Abstract. *Smart cities are urban areas with sensor networks that collect data used towards efficient management. As a source of ubiquitous data, smart city initiatives present opportunities to enhance inhabitants' urban awareness. However, making sense of smart city data is challenging and there is a gap between available data and end-user applications. Sonification emerges as a promising method for the interpretation of smart city data and the production of novel musical experiences. In this paper, we first present the smart city paradigm. We then cover the topics of ubiquitous and mobile music, followed by an overview of sonification research. Finally, we propose an approach entitled ubiquitous sonification and present the initial design of a speculative use case for musical smart city systems, leveraging user and urban data to inform behaviour.*

1. Introduction

The rapid increase in the availability of large volumes of data justifies the search for new methods to facilitate its interpretation. In a smart city environment, data-gathering devices can range from user products to infrastructure and service sensors, thus congregating multiple modalities. In the context of the internet of things, data visualisation techniques for smart city data have proliferated [Ramos et al. 2018, Jing et al. 2019], but much less work has been done to leverage the audio modality. Due to the density and heterogeneity of the data involved, there is a need for new means of representation in order to support (or extend) existing visualization techniques, allowing users to *get away from the screen* and preserve (or even increase) awareness. Sonification techniques [Kramer et al. 1999] can be considered well-suited for this task, as they provide an alternative to the visual domain. Furthermore, the smart city paradigm involves a source of ubiquitous data, present everywhere. This notion also takes into account the fact that its inhabitants' data is an intrinsic part of the system. This idea of ubiquitousness of data shares conceptual common points with the field of ubiquitous music, described as the use of musical environments that integrate different types of users and objects [Pimenta et al. 2009]. Ubiquitous music argues that in modern societies music is available everywhere, and that, from a musical perspective, there is no possible dissociation between agents and devices, both contributing equally to the final outcome. Thus, a combination of sonification and ubiquitous music techniques emerges as a possible solution towards the representation of data in the smart city context. It is worth clarifying that this work differs from environmental soundscape studies within the city [Steele et al. 2019] and from urban sound monitoring [Bello et al. 2018]. Indeed, we propose to generate new sound content based on urban

related data, and do not focus on analyzing sounds from the city. This paper begins with Section 2, presenting a broad description of the smart city archetype. In Section 3, the topic of ubiquitous music is addressed. Section 4 starts with an overview of sonification research, presenting its definitions and taxonomies. Moreover, it outlines interactive sonification and musification as subsets of sonification, and provides a comparison between the approaches in musification and sonification. In Section 5 we propose the novel concept of ubiquitous sonification which integrates principles from sonification, and ubiquitous and mobile music. We then describe a musical smart city system that relies on machine learning techniques for data dimensionality reduction or cross-modal mapping between data and sound. Furthermore, Section 6 discusses the aforementioned topics as well as the opportunities, challenges and paths for ubiquitous sonification. Finally, Section 7 concludes with emphasis on the proposed approach, presenting future research directions.

2. Smart City

Dainow states that there is not an unified, formal definition of what constitutes a smart city [Dainow 2017], while some authors even argue that a definition is impossible [Albino et al. 2015]. Nonetheless, smart cities are often characterized by the presence of a ubiquitous and heterogeneous network of sensors, which provides information about inhabitants and their environment. Smart city sensors are *'embedded in the civic environment, worn on the person and implanted within the body'* [Dainow 2017]. Such urban areas encompass wireless sensor networks that collect multiple types of data, which is used in the process of governance, decision-making and planning. Broadly, a smart city ecosystem may consist of sensors for infrastructures, transportation/mobility, environment, services and user devices (such as smart phones, smart watches and smart home appliances) [Anthopoulos 2017]. This system is underpinned by computational power sufficient to process the data acquired. Recently, a growing number of studies point towards the profusion of smart city initiatives across distinct geographical locations as being responsible for shaping new and already existing urban settlements [Cugurullo 2018].

3. Ubiquitous and Mobile Music

Supported by technological advances regarding music generation, distribution and consumption, the field of ubiquitous music is supported by the notion that in modern society music is available everywhere [Holmquist 2005]. By definition, ubiquitous music is comprised of musical computational environments that allow the integration of multiple users, devices, sound sources and activities [Pimenta et al. 2009]. It stands at the *'intersection of mobile and networked music with ubiquitous computing technology and concepts'* [Weiser 1991], where technology, although not visible to the user, is embedded in everyday objects [Mandanici 2019]. As stated by Pimenta et al., in ubiquitous music *'a device is not a passive object that a musician can play, but an agent in a dynamical system that adapts itself to the musical activity, to the local environment and to other agents that interact with it'* [Pimenta et al. 2009]. This contrasts with the most commonly adopted vision within computer music research, whereby the musical instrument is seen as the ideal *'metaphor of interaction'*.

Of close relation to ubiquitous music is the internet of musical things, described as *'networks of musical things (e.g. smart musical instruments or wearables) that sup-*

port the production and/or reception of musical content', focused on the interactions between audiences and musicians [Turchet et al. 2018]. Strong links are also shared between ubiquitous music and the field of mobile music, the latter focused on the development and usage of mobile devices that act as interfaces for music creation and listening [Essl and Lee 2017, Gaye et al. 2006]. As demonstrated by Bryan et al. with MoMU, a mobile music toolkit implemented for iPhone's OS, these devices present opportunities for new means of musical expression [Bryan et al. 2010], by leveraging mobile sensor data (e.g. accelerometers, compasses and location tracking technology). A particular asset of mobile music is its location-based nature. In this sense, location-based music can be described as sound experiences, normally GPS-driven, in which users' movement in specific zones triggers the playback of sound or music [Hazzard et al. 2015]. In their project of a mobile musical soundtrack, Hazzard et al. demonstrate how locative technologies can be used to create rich interactive musical experiences, suggesting that this use case could be transferred to other settings such as a daily commute in a city environment [Hazzard et al. 2015].

4. To Sonify or to Musify?

4.1. Sonification

The emergence of the research field of sonification is marked by the occurrence of the first conference of the International Community for Auditory Display (ICAD) in 1992 held in Santa Fe, USA and founded by Gregory Kramer [Kramer et al. 1999]. Since its beginnings, sonification has seen a rise in popularity [Supper 2012a], linked to an increase in the availability of *big data* and the consequent notion that humans expect additional ways to enhance the comprehension of their surroundings [Scaletti and Craig 1991].

The most popular definition of sonification can be posed as '*the use of non-speech audio to convey information*' [Kramer et al. 1999]. According to [Hermann et al. 2011], different types of sonification techniques can be classified as: (i) audification, where data is mapped to sound pressure levels, thus becoming an audio waveform [Dombois and Eckel 2011]; (ii) parameter-mapping sonification, in which each of the data points are mapped to parameters of a sound event, being considered the most common technique of sonification [Grond and Berger 2011]; (iii) auditory icons, understood as aural metaphors in which the sound that is heard is a representation of an event, thus informing the listener of its occurrence, assuming prior knowledge about the link between sound and event [Brazil and Fernström 2011], and (iv) model-based sonification, the use of an acoustic model that generates an output when excited, comprising a set of instructions towards interaction [Hermann 2011]).

Other authors present different subdivisions of the field [Barrass 2012], referring techniques such as sinification (mapping data to sine-tones), MIDification (data mapped to MIDI notes), stream-based (granular synthesis techniques for data mapping), vocalization (use of synthesized vowel sounds), iconification (utilizes auditory metaphorical connotations), although it can be argued that these techniques are subsets within parameter-mapping sonification, and iconification can be seen as a class of auditory icons [Bonet 2019].

4.2. Interactive Sonification

Interactive sonification can be described as a specialized research topic within the field of sonification, in which a human user modifies the sonification process in an interactive control loop [Yang et al. 2019]. According to Hermann and Hunt, interactive sonification is defined as ‘*the discipline of data exploration by interactively manipulating the data’s transformation into sound*’ [Hermann and Hunt 2004]. Of great relevance to the field is the Interactive Sonification Workshop. A survey of papers published in its recent editions suggests an emphasis on a more practical, information-driven approach of interactive sonification, comprising works mostly concerned with health issues and biofeedback (e.g. Parkinson and tremor diseases [Schedel et al. 2016], ECG and heart conditions [Aldana Blanco et al. 2019], blindness [Radecki et al. 2016]) and mobility (e.g. air traffic control [Rönnberg et al. 2016]).

4.3. Musification

Barrass defines musification as a sonification technique that uses scales, chords, key and tempo changes [Barrass 2012], however it can be argued that this definition doesn’t account for all compositional practices (e.g. musique concrète). In her doctoral dissertation, *Data Sonification in Creative Practice*, Bonet follows an approach on sonification from a more artistic perspective, extending the notion of musification as a sonification that is subject to musical constraints [Bonet 2019]. Within this scope, a few possible interpretations can be considered: one that comprises a purely functional sonification that is bound to musical principles, other that is solely focused on artistic purposes, and something that an approach in-between. Bonet supports her argument with Varèse’s definition of music as ‘organized sound’ [Risset 2004], thus implying that a ‘*musification is an organised sonification*’. A framework for the composition of musifications, entitled *Data-Mapping-Language-Emotion*, is described by the author, ‘crafted to suit the specific requirements of composers working with a scientific method such as sonification’ [Bonet 2019]. Within the framework’s first step, *Data*, Bonet stresses the need for a comprehensive understanding of the data by the sound designer/composer, concluding that not all types of data are equally suitable for sonification. Concerning *Mappings*, the process whereby data is transformed into audio, thus becoming perceivable, the author highlights that this is a core stage, often incorrectly understood as the whole sonification process, in which knowledge about human auditory perception and psychoacoustics is important. Due to the enormous range of mapping possibilities, this is also considered the most creative aspect of the technique. In *Language*, the selection of the musical language chosen to transmit the data is addressed, whereby the first must serve the latter. The author claims that ‘*the aesthetics of the sonification should be appropriate to the purpose of sonification; alarms should be disruptive but displays for long-term monitoring should not be irritating*’. Regarding *Emotion*, Bonet reflects about the parameters that contribute to the storytelling of the sonification.

4.4. From Sonification to Musification

On their systematic review of mapping strategies for sonification of physical quantities [Dubus and Bresin 2013], Dubus and Bresin reflect on the prevalent duality within sonification. Some researchers are concerned with the need of having a stricter definition [Hermann 2008], somehow prioritizing the conveyance of information within the method,

while others are ‘*willing to step over the border to data-driven music*’, supporting a more inclusive perspective and highlighting the importance of musical aesthetics. As described by Walker and Kramer, such divergences are based on the interdisciplinarity of the field, meaning that the sonification process usually involves concepts from both the arts, science and engineering [Walker and Kramer 2004]. Collaborations between researchers and composers (or experts in sound related fields) are frequent within the practice of sonification. Likewise, the increasing significance attached to artistic works in the ICAD programme is also a consequence of this ambivalence [Dubus and Bresin 2013]. Neuhoff noted that ‘*there are 1,103 conference papers in the ICAD proceedings, from the years 1994 to 2018, and that the word ‘music’ appears in 74% of these works*’ [Neuhoff 2019]. In an attempt to find a new definition for sonification, Hermann states that a technique that produces sound signals from data, may be called sonification if and only if [Hermann 2008]: the sound reflects *objective* properties or relations in the input data, the transformation is *systematic* (meaning that there is a precise relationship on how the data and possible interactions cause the sound to change), the sonification is *reproducible* and the system can intentionally be used with *different data*, and also be used in repetition with the same data. According to Supper, this definition represents an attempt to ‘*narrow down the boundaries of the field*’, implying that it emphasizes more the scientific aspect of sonification, omitting consideration for its artistic side [Supper 2012b]. Another perspective presented by Barrass is concerned with how sonification can be used in design research, stirring sonification *beyond the science laboratory and artistic exhibition*, to create novel products and further investigate human behaviour through interaction with them [Barrass 2018].

5. Musical Smart City

5.1. Ubiquitous Sonification

The combination of topics covered in this article points towards an approach that combines sonification and ubiquitous and mobile music techniques. Thus, the notion of a ubiquitous sonification technique can be posed as a *type of sonification that leverages ubiquitous computing environments*. Following Satyanarayanan’s pervasive computing vision, this assumes that a user is permanently immersed in a personal, unobtrusive, digital space that mediates interactions with other surrounding ubiquitous computing devices [Satyanarayanan 2001]. It is worth to clarify that a major distinction between ubiquitous music and ubiquitous sonification is that the latter involves a component of information conveyance, aiming to raise awareness in the user, not focusing solely in the musical value of the system. Furthermore, due to the role of the user in this scenario, the subfield of interactive sonification presents multiple synergies with ubiquitous sonification, the latter following some of the suggestions proposed by Hermann and Hunt [Hermann and Hunt 2004], namely those concerned with the way humans deal with different modalities and how a user’s activity influences perception. Finally, previous works have employed the term *ubiquitous sonification* [Nees 2018, Beilharz and Ferguson 2009, Macdonald and Stockman 2014], but they all use the word *ubiquitous* in order to refer to a well-established and widely used sonification process (e.g. the Geiger counter, which aurally displays information about ionizing radiation). However, our use of the term ubiquitous is different and focuses on the use of data provided from ubiquitous devices.

5.2. Musical Smart City System

5.2.1. Vision

The smart city paradigm, due to the large volume of data generated by its ubiquitous, heterogeneous sensor network, presents a promising opportunity for the application of ubiquitous sonification. Following the ubiquitous computing proposal, whereby technology is embedded in everyday objects, ubiquitous sonification presupposes that technology enabling sonic interaction is readily available to the user (e.g. through usage of smart devices such as watches, bracelets, phones). Beyond standard daily human interactions and behaviour within a social context, it can be envisioned that in the smart cities of the future, inhabitants will implicitly communicate with smart devices through a digital medium. This relation is also regulated by the inputs received from those same devices and applications.

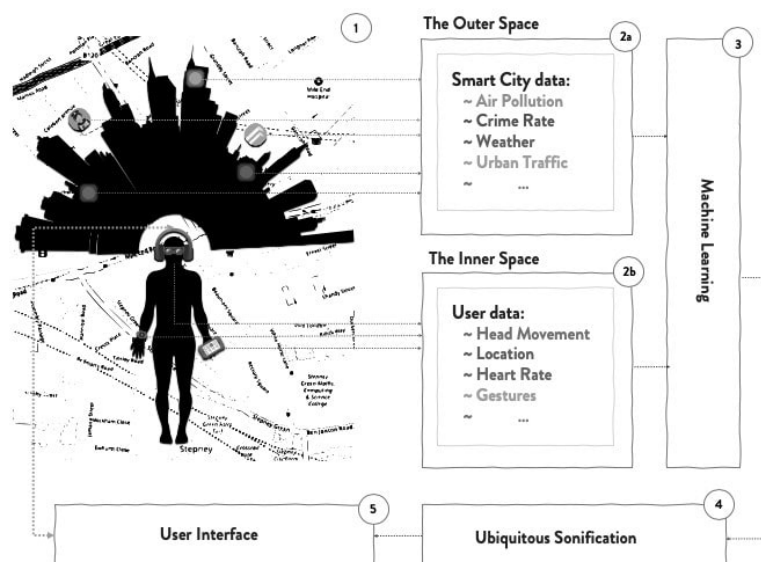


Figure 1. Conceptual diagram of a musical smart city system.

A conceptual diagram of a musical smart city system is presented in Figure 1, describing a location-based system that is able to increase inhabitants' urban awareness within a city, while accounting for an exploration of their environment in a musical way. Conceptually, its structure comprises *outer space* and *inner space* (respectively, 2a and 2b in Figure 1), the first being related with data from inhabitant's surroundings (such as air pollution, crime rate, land usage, urban traffic) and the latter connected to a user's physiological, inertial and location data provided by smart wearable devices and phones (such as heart rate, hand gestures, head movement and location). In order to extract relevant features from large volumes of data, machine learning algorithms are used to achieve dimensionality reduction (depicted as item 3 in Figure 1) [Winters et al. 2019]. Furthermore, as proposed by Fried and Fiebrink, a cross-modal mapping between data and sounds (e.g. inputs from smart city sector data sets mapped to a large collection of samples, musical motifs or tracks) could be carried out by deep learning algorithms (e.g. deep auto-encoders) [Fried and Fiebrink 2013]. Processed data is sonified using concepts of ubiquitous sonification (item 4 in Figure 1). An initial approach might consider using

parameter-mapping sonification for data that concerns the inner space, mapping user data to musical parameters, and model-based sonification for outer space data, creating a musical particle system a user can navigate in. This will also require the development of a framework that accounts for the interactions between inhabitants and environment, relating the musical output of the inner space with the one from the outer space (e.g. user's gestures generating a rhythmic pattern that is fused with the soundscape generated by air pollution data). Finally, mediated by a user interface, this will result in a mobile music platform which supports musical mappings from physiological and urban events, raising user's awareness (item 5 in Figure 1).

In this setting, what would be a use case for a musical smart city system? A possible scenario envisions a user connected to the musical smart city mobile application while walking in the city. Aurally, this user is able to perceive that the levels of air pollution in her usual route to work are abnormally high and thus decides to take an alternative route, sonically depicted as less polluted by a smoother, sparser soundscape. On her way back, alone at night, the musical smart city application conveys sonic information about which direction to take in order to travel through streets/areas that have lesser indexes of crime rate (e.g. pointing towards the ones covered by CCTV).

5.2.2. Challenges

This vision paper raises many questions and challenges that will stir upcoming research. **Data gathering and characterisation:** it is important to identify IoT data streams and characterise their nature, temporal and spatial scales, reflecting on their suitability for sonification. **User requirement identification:** reflect on different sectors of the city environment and the usefulness of sonifying them from a user perspective; take into account what city aspect's users would like to learn more about or experience in an enhanced way using the auditory modality. Of interest are considered topics related with the environment (pollution, waste water treatment, weather and climate) and mobility, but other areas concerning service delivery (health and medical care, crime rate and security) could be posed as relevant research paths. **AI for sonification/musification:** anticipating large volumes of data from the aforementioned modalities, it is important to select suitable machine learning algorithms to achieve dimensionality reduction. It would also be of interest to study the combination of multiple modalities exploring multimodal data fusion techniques. Unsupervised machine learning techniques could be taken into account in order to explore possible patterns between different types of data. As for sound content creation, mappings between data and music could be mediated by deep learning approaches for music generation, conditioning their output on data. **Design and evaluation of the system:** the design of user interfaces and suitable protocols for its evaluation should be considered. These methods should investigate the system's ability to convey information about a given subject and also assess its creative and aesthetic merits.

5.2.3. Related Work

The project *Sonic City*, by Gaye et al., represents an early exploration of the city environment as an interface for musical expression [Gaye et al. 2003]. The authors implemented

a wearable prototype that retrieves information about user mobility and maps it to real-time audio processing of urban sounds. Future work points towards the usage of smart devices (e.g. wireless devices with built-in sensors and computational power) instead of the developed prototype, which clearly serves as a motivation for the vision presented in this paper. Furthermore, in the work carried out by Winters et al., the authors present *The Decatur Civic Dashboard*, a multi-modal dashboard for the sonification of data in the context of smart cities using the Web Audio Javascript API as an attempt to turn the process *away from the desktop* [Winters et al. 2016]. This approach is supported by a specially built Javascript library called DataToMusic that serves as a helping tool in the sonification process. The generated audio represents an informative complement to the graphical display in the dashboard. From an informative perspective, the work of Winters et al. shares multiple common points with musical smart city, but one of the distinctions could be posed as a difference of focus on the notion of the city as a musical interface, somehow putting aside the more creative aspect of the process. Moreover, in *The Decatur Civic Dashboard* project, sonification of user data is not emphasized, which in the case of musical smart city represents an important part of the system. Pigrem and Barthez propose the concept of *datascaping* as the usage of data as a medium in soundscape composition. This technique is used to sonify real-time data of Transport for London API, conveying information about levels of traffic in stations and lines of underground transportation. Interestingly, the authors argue that *‘when data used in the production of an artwork describe or correlate with some human activity or state, the people represented by the data hold a participatory role in the realisation of the art work’* [Pigrem and Barthez 2017]. This is an important aspect of musical smart city, whereby data from inhabitants is an integral part of the system. The work in *DataScaping* represents what would be considered a successful case of applying sonification in a specific sector of a smart city and the authors conclude by suggesting the need for assessment of this techniques in the case of multiple modalities of data. Finally, the work of Steele et al. tackles awareness of the role of sound in urban settings [Steele et al. 2019]. In *Sounds In The City*, the authors propose two workshops held in Montreal, the first focusing on using sounds to create audible experiences in pedestrian zones, and the second about the preservation of good-quality sound environments. Furthermore, with *SONYC*, Bello et al. presents a system to mitigate noise pollution within the city environment. By employing machine listening techniques over sound recordings collected from *ad hoc* sensors, different outdoor sounds are classified and characterized according to its source, thus supporting further decision making regarding noise mitigation. Despite some common factors, namely the exploration of the sonic dimension within the city context, both projects differ from the work proposed here, which will leverage data (not urban sounds) as source material for the generation of musical content.

6. Discussion

In this paper, the technique of ubiquitous sonification was proposed, presenting possible applications that exploit the smart city environment, envisioning a musical smart city system. This system would be user-centered, allowing for the creation of musical content and, at the same time, to raise awareness about inhabitants’ surroundings. One of the motivations for this approach would be not only to *‘bridge the gap between audiences and artists by blurring the roles of creators and receivers’* [Pigrem and Barthez 2017], as happens in participatory art, but also to follow an analogy between layman and specialist,

concerning data interpretation, by inviting the user towards an auditory manipulation of information. As discussed in Section 4.4, in which the dichotomy between a more formal, information-driven approach, and a more artistic, creative-based one in the field of sonification was addressed, some considerations are worth to be discussed, which might benefit the concept of ubiquitous sonification. Following a pure empirical/informative perspective, Bonet's suggests an analogy between Shannon-Weaver's model in *The Mathematical Theory of Communication*, in which the act of communication is composed of an information source, a transmitter, a channel, a receiver and a destination, and the conceptual process of sonification. According to the author, in this scenario, the source of information would represent the sonification designer's output, the transmitter (or encoder) would be equivalent to the chosen mappings, the channel would be considered the used musical language, the receiver (or decoder) would stand as the knowledge of the mappings and musical language utilized, and the receiver would function as the listener [Bonet 2019, Shannon and Weaver 1949]. Within this analogy, being a mathematical theory of communication, the emphasis is kept on the conveyance of information between the transmitter (the sonification designer) and the receiver (the listener). Concerning a more artistically-driven approach, the focus should be stressed on the channel (the musical language). As McLuhan postulates in his work *Understanding Media: The Extensions of Man*, the global impact generated by the channel, or the media environment, is more significant than the content it conveys [McLuhan 1964]. Affirming that '*the medium is the message*', McLuhan was clearly addressing the most popular media of his time, television and radio. The author postulates that the impact of the media itself, the *channel*, is higher than that of single programs or content they emit. An analogy can be made in the case of a music driven ubiquitous sonification, thus inferring that, from a global perspective, the choice of the musical language, the structure of the 'creative material', would be the most central aspect of the process. An ubiquitous sonification application, framed within the context of smart cities, could perhaps tackle these questions by allowing the user to navigate between both a more information or artistically-driven output.

7. Conclusions

In this vision paper, the paradigm of smart cities was addressed from a data and agent perspective, framing it as an integrated domain of both digital and human actants. We established a conceptual link between the latter and aspects of the fields of ubiquitous and mobile music. Moreover, a literature survey concerning sonification revealed common used techniques and approaches in the field. We addressed the distinctions between the specifications of musification and interactive sonification, encouraging a discussion about the concepts behind those approaches. Furthermore, we defined ubiquitous sonification as a concept integrating approaches in sonification and ubiquitous and mobile music. Finally, a vision towards a musical smart city system was described, pointing towards future research questions and directions.

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Everyday Use of the Internet of Musical Things: Intersections with Ubiquitous Music

Rômulo Vieira¹, Mathieu Barthet², Flávio Luiz Schiavoni¹

¹ Arts Lab in Interfaces, Computers, and Everything Else - ALICE
Federal University of São João del-Rei - UFSJ
São João del-Rei - Brazil

²Queen Mary University of London
London - United Kingdom

romulo_vieira96@yahoo.com.br, m.barthet@qmul.ac.uk, fls@ufs.j.edu.br

Abstract. *Internet of Musical Things (IoMusT) is one of several subfields of the Internet of Things (IoT) and it relates to several areas of study, such as ubiquitous and mobile music, human-computer interaction, new interfaces for musical expression and participatory art. This paper makes a bibliographic review on the general definitions of this field, explaining what Musical Things are, classifying them according to their behavior and communication role, in addition to discussing their applications in Ubimus. Among the contributions to IoMusT research, the authors also discuss the social, economic and environmental challenges faced in this area.*

1. Introduction

Internet of Things (IoT) is a term that is widely publicized and debated, and gained numerous definitions and applications. The initial idea was developed by Kevin Ashton [Ashton 2009], in 1999, to refer to a Radio-Frequency IDentification (RFID) technology applied in supply chains, acting as pointers to databases on the Internet that contained information about the objects that were present in stock [Serbanati et al. 2011]. This context of use lasted until 2004, when Gershenfeld stipulated the concept of everyday objects with the ability to connect to a data network, also addressing the heterogeneity of devices and the stack of protocols used for communication [Gershenfeld et al. 2004].

Atzori [Atzori et al. 2010] further classifies the basic concept of the IoT as “*the widespread presence around us of a variety of objects, which through exclusive addresses, are able to interact with each other and cooperate with their neighbors to achieve common goals*”. In common, all of these definitions agree that the Internet of Things is a network infrastructure, related to the integration of the physical world with the virtual, using automatic connections and identifications, also applied for data collection. The central point of this technology is based on the automatic identification of objects and one of its most important aspects is breadth and scope [Borgia 2014]. Due to its versatility, IoT began to enter in the most diverse fields of application, such as supply chain management, the energy grid, health care, public safety [Haller 2010], and more recently, music [Turchet et al. 2018a].

In this paper, everyday objects refer to Information and communications technology (ICT) objects commonly found in the daily life of people in developed or developing

countries. Thus, these can refer to electronic devices for communication and entertainment, such as smartphones, televisions and audio equipment, as well as wearable utensils, such as bracelets, watches, glasses and other devices that can be attached to the body. Among communications technologies, those aimed at wireless communication are more present, such as 3G, 4G, Wi-Fi, and more recently, 5G.

2. About the Internet of Musical Things (IoMusT)

Internet of Musical Things (IoMusT) is an area of research that also integrates aspects of ubiquitous music [Keller et al. 2014], mobile music [Gaye et al. 2006], artificial intelligence [Burgoyne et al. 2016], human-computer interaction [Rogers et al. 2011] and other fields of computing. It can be defined as an interconnected network of physical devices aimed at producing or receiving musical content. [Turchet et al. 2018a], in turn, attributes a broader meaning to the term, defining it as

“the ensemble of interfaces, protocols and representations of music-related information that enable services and applications serving a musical purpose based on interactions between humans and Musical Things or between Musical Things themselves, in physical and/or digital realms. Music-related information refers to data sensed and processed by a Musical Thing, and/or exchanged with a human or with another Musical Thing”.

The interconnection of objects and people is supported by networks such as the Internet, LANs (Local Area Networks) and protocols, as well as applications and services to assist musicians, audio engineers and audience members. This ecosystem ranges from computational devices, wired and wireless networks, musical instruments and means of sound production. Given this scenario, we will discuss Musical Things in the next subsections according to aspects like communication roles, devices, behavior, ecosystem, and target audience.

IoMusT Communication

In computer networks, one of the methods for initiating communication depends on an entity that requests data and one that provides and sends that data. In TCP/IP communication, these roles are called client and server, respectively. Once communication begins, these functions are no longer important, as the two entities can send and receive messages [Schiavoni 2017]. However, it is necessary to understand these roles and the flow of data exchange between musicians/audience and devices. Despite these classic roles in TCP/IP communication, some Musical Things will also send control signals to other Musical Things that receive and process these signals to do something.

Client/Server is a very common communication architecture to Internet services and it is a model centered in the server as the main resource provider, sometimes acting as a relay to interconnect user directly but always present in the communication process. However, the IoT communication can escape this centered architecture and use a peer to peer connection model where the presence of a central node in the network is not necessary and several nodes can provide resources to other nodes in the network. Thus, a resource provider can be the **source** of a information while other nodes can consume this

information acting like a **sink**. It is also possible to have nodes that consume a information to provide another information, like a **filter**. These information flows can be real time audio data, control data, like MIDI and OSC or even musical files.

IoMusT Devices

The ecosystem underlying the IoMusT is based on Musical Things, which have been defined as “*a computing device capable of sensing, acquiring, processing, or acting, and exchanging data serving a musical purpose*” [Turchet et al. 2018a, Turchet et al. 2020a]. A Musical Thing has characteristics similar to other devices, such as sensors and actuators, extending to intelligent instruments, intelligent mixing consoles and speaker systems. Basically, a Internet Musical Thing must have a Internet Connection and capability to process musical information. The presence of sensors to receive data from the physical environment allow a node to act like sources of data, and the presence of actuators allow the node to give feedback to the real world, acting like sinks. A filter device can have only communication capability, receiving musical data and forwarding it to another node, just like an audio effect. An example of device is an equipment that assists in remote control rehearsals. This device will need the ability to reproduce and store audio, so that they can have better control of latency and allow communication between musicians.

The concept of Musical Things encompasses also digital/virtual things. Virtual Musical Things can be realised through software services capable of collecting/analysing, receiving/transmitting information serving a musical purpose (e.g. in a virtual environment) [Turchet et al. 2018a].

IoMusT Roles

Roles can be defined, in this context, as the set of actions that a device presents in a musical activity, for example: smart instruments [Turchet and Barthet 2019a], such as the Sensus Smart Guitar [Turchet et al. 2017] and Smart Cajón [Turchet et al. 2018b], used to create music; augmented/mixed reality glasses, used to increase the audience’s immersion in a presentation (see e.g. [Selfridge and Barthet 2019]) and bracelets that vibrate according to the rhythm of the music (see e.g.[Turchet et al. 2019]). The role will directly impact the design of the device’s hardware and software, since functionality and components are interrelated.

But since without the action of a user, non-autonomous objects are unable to perform an action, it can be essential that there is human action for them to work. Thus, the impact exerted by users and musicians in handling musical things is directly reflected in their roles. From the musical and technological capacity of each one, the equipment can only accomplish what was programmed or even fully exploit its capabilities. On the other hand, the creative use of these tools allows to extrapolate the field for which they were created and to contribute to other forms of art.

The software that makes up this device, in turn, allows greater adaptability of use, since devices with the same hardware configuration can run applications with different functionality, according to the user’s desire. Software applications for musical things

should take into account usage information over time and respond to the environment in which they are used. For this to happen, artificial intelligence techniques can be used to analyze the behavior of the device in different contexts and adapt it based on heuristics or the solving of optimization problems.

IoMusT Ecosystem

In the IoMusT ecosystem, it is no use just having one device that plays music if there is not another device capable of sending music to be played. Thus, the IoMusT is based on the idea of several interconnected devices working together, creating flows of information and creating an ecosystem or a musical environment. The advantages of planning the ecosystem in this way is that it improves the connection capacity and the project's workflow, since users will have several points in common, alignment of expectations with reality in musical creation and construction of flexible applications.

Therefore, this environment can be configured in a way that all the possible scenarios are possibly different, adapting the preferences and characteristics of users needs and comprising different profiles. This opens the way for small sound features to be combined with different types of architectures, such as pipes-and-filters, for example.

IoMusT Target Audience

[Turchet et al. 2018a] provides five main categories of users for IoMusT: musicians/artists, sound engineers, audience members, music students and music teachers. For musicians and artists, these tools can be useful allowing remote rehearsal, interaction with musical devices through local networks or cloud, and the use of smart instruments. For sound engineers, the possibility of intelligent productions arises, whether in studios or in live performances, in addition to the support of smart instruments [Turchet et al. 2020b]; for audience members, multi-sensory experiences of a concert can be envisioned, as well as allowing greater participation in the execution and creative process of a presentation [Turchet et al. 2019].

In view of the fact that Ubimus works to make music universal and accessible, the application of IoMusT in this medium also allows us to think of helping lay people in musical creation, taking into account that everyday and easy-to-use equipment begins to adopt the ability to create and play sound. Finally, music students may be provided with means for remote learning and greater access to new sound interfaces while for music teachers, features can be provided for remote monitoring and learning feedback and web applications to assist in teaching [Turchet et al. 2018a].

3. Related Research Fields

There are several research fields that can be related to IoMusT, some of which are described below. Since IoT aims at developing smart environments for people, we reviewed fields which take into account users in the context of everyday activities as well as neophytes in computing and music, in addition to experts.

3.1. Ubiquitous Music

[Keller and Lazzarini 2017] defines Ubimus as an environment that supports multiple users, devices and sound sources in an integrated manner. It should also provide ways to improve social interaction and device independence. The authors use the term for music or musical activities present in everyday life supported by ubiquitous computational concepts. Ubiquitous music research generates creativity support tools (CST), focusing especially on lay-musicians.

Like other domains of research, Ubimus proposes its own ecosystem. This ecosystem supports the integration of audio with tools that allow the interconnection of equipment and people, support local and remote interactions and provide means that spread the computational load over a heterogeneous collection of units. In this way, Ubimus not only contributes to the expansion of the IoMusT, but also opens up new opportunities for artistic applications in this field [Turchet et al. 2018a].

Another contribution that Ubimus provides concerns the means of implementation and reachability. Aiming at concepts that do not depend on specific implementations and focusing on high level methodologies, helps in the development of new technologies, such as reducing technology cost. Thus, it allows a widespread implementation of IoMusT without requiring large investments in resources [Turchet et al. 2018a, Turchet and Barthet 2019b].

3.2. Interactive Performance

Another theme related to the IoMusT is the Technology-Mediated Audience Participation (TMAP) [Hödl et al. 2017, Wu et al. 2017], which uses technology to facilitate the creation of music and increase public engagement in live performances. Among the presentations that fit this topic can be mentioned “Chaos das 5”, an audiovisual performance that uses three layers for audience immersion, two of which are related to technology. The first one, based on music, allows the audience to take part of a composition of the program’s soundtrack from a web application. The second one, turned to the digital medium, uses images in real time to compose the scene. After the production, the people who contributed to the play are credited together with the artists [Schiavoni et al. 2019].

Another presentation of this type is SWARMED [Hindle 2013], which uses smartphones from the audience as a Digital Music Interface (DMI). TweetDreams, a system for interactive concert, uses tweets collected during the presentation to generate melodies [Dahl et al. 2011]. This type of approach differs from the others, since a tweet is not directly related to other people, but to the feeling captured by posting on the social network. Thus, music is not constructed in a lexical way. Mentions should also be made of other presentations, such as Open Symphony [Wu et al. 2017] and Mood Conductor [Fazekas et al. 2013]. The similarity is that they support audience-performer interaction through mobile devices and visualisations, communication protocols and computational applications to allow the public greater immersion and/or participation in the works presented.

4. Challenges

IoMusT faces the same problems as the comprehensive IoT field, such as issues involving security and privacy [Køien and Abomhara 2014]. There are also specific challenges in

this area, such as technological and artistic, as pointed out in [Turchet et al. 2018a]. Then, we propose and discuss other challenges related to this field.

4.1. Technological Challenges

The challenges discussed here are divided into three different parts, where the first deals with **latency and synchronization** between equipment, which is perhaps the most critical point to be addressed. This is due to the fact that the current state of equipment and network technologies does not meet some basic needs of IoMusT, such as providing good quality to multimodal content, allowing synchronization between devices at different times and offering good audio/video quality over remote connections.

The solution to this issue would be to develop new devices and communication protocols or to optimize those that already exist and direct them to this field. However, this can represent a commercial challenge, since the wireless communication protocols, such as WI-FI, Bluetooth and 5G are already well defined, in addition to requiring a large investment to adapt to other forms of performance [Mitchell et al. 2014].

However, when thinking about the IoMusT local environment, these issues have less impact since in a local area network it is possible to increase network speed if it is necessary upgrading the devices involved in the communication. The latency in a network connection is strongly attached with the hops (network devices) in the network path between two nodes and in a peer to peer connection it is possible to connect devices directly, without extra network hops.

A second challenge is the **interoperability and standardization** of the devices and communication protocols, representing a pillar of this field and being extremely important to make its implementation viable. This is because it is the application that will grant compatibility between devices and operations at local and global scales and in a distributed environment maybe it is not possible to have previous information about which devices and operations are part of the environment. In this context, it is interesting to create or adapt protocols and interfaces aimed at creating music. It can be extremely important to have group communication, like multicast or broadcast to discovery devices and announcement protocols to auto setup devices in the same network.

A third technological challenge to be faced is the **design of the equipment** used in this activity. Given the diversity of its ecosystem and the application of music outside traditional environments, the devices used do not always have a direct relationship with music, as defined by Keller and Lazzarini [Keller et al. 2014]. Among the issues related to the creation of new interfaces and Musical Things are energy consumption, the need to support connection between users and the requirement for devices to have low latency, sound processing and communication [Miranda Carpintero et al. 2015, Koreshoff et al. 2013a, Koreshoff et al. 2013b].

4.2. Artistic Challenges

One point that differentiates IoMusT from IoT fields is its concern with artistic applications. In view of the infinite number of objects that make up this field and the different forms of artistic expressiveness, some discussions arise. One to stand out is the creation of geographically-distributed music. As the process of music performance depends on a great exchange of sounds and information, challenges to be faced range from preventing

the musicians involved from having their performance impaired due to their devices, to reducing latency and creating a system of backup in case of loss of connection. Still, this new form of artistic creation allows new styles and manifestations of art to emerge.

Currently, technological developments in mobile devices and wireless communication networks have allowed lay musicians to use new tools to create music in an easy and intuitive way. The help provided by computational means, such as software for creating and editing music and scores, helps both in the theoretical part, instructing the user in the formation of chord sequences, in the composition of base melodies and keeping the music in the correct tempo, as well as in the practice part, by providing the musician with samples and pre-programmed sound sequences, which would be difficult for a layman to perform. Examples of software that provide these functions range from MuseScore, Guitar Pro, Ableton Live and GarageBand, to mobile applications, such as Caustic and SoundPrism.

The infrastructure to be configured to support this new art creation model is also a point to be discussed. Public policies that deal with communication systems should be developed or improved to make electronic devices that help to create music cheaper and more accessible to the population. There are also investment issues, which require a lot of time and resources for this to happen. The collaborative creations that emerge from this structure can also imply copyright problems, as there would be debates about who owns the work and whether a recording and possible sale of it would be legal.

[Martinez-Avila et al. 2019] proposes other challenges and artistic benefits from the use of IoMusT, e.g. the potential lack of ergonomics if an instrument needs to be handled along with a separate technological artifact. However, smart musical instruments are envisioned as standalone instruments integrating both the instrument and the technological components enabling augmentation, intelligent sound analysis/production processes and network communication [Turchet and Barthet 2019a]. Sensus Guitar is pointed out as a possible solution for this, since it allows control of the Digital Audio Workstation (DAW) through gestures captured by the guitar itself.

4.3. Social Challenges

One of the first philosophers to analyze the impacts of technology was Herbert Marcuse [Marcuse and Kellner 2001]. According to him, technological development has formed awareness or rationality in patterns of individuality, which have been disseminated in society. In this way, technology has become a social process. Among the impacts mentioned by the author, the following stands out: abundance of technology for a portion of the population and continued scarcity for another; establishment of standards and demands by the ruling class, which are not always in accordance with most of the interests of the individuals themselves; submission of workers to large companies; economic power retained in the hands of those who control production and loss of individuality of thought. All of these problems are influenced by the advancement of IoMusT.

Allied to this, three other problems can be accentuated by IoMusT. The first one is the non-heterogeneous access to technologies, since people living in more densely populated territories have easier access. The second one is the lack of infrastructure, which can lead to an increase in socio-cultural differences between urban centers, peripheries and the rural population [Lysloff 2008]. Here, there is a point of contact with Ubimus,

which, among others, also depends on the communication networks and technologies present on the web. There is also a concern with excessive consumption, constant need to generate innovation and social apartheid, as defended in [Junior and Schiavoni 2019a].

Still according to [Junior and Schiavoni 2019a], possible solutions to these problems lie in the idea of the Solidarity Economy, which consists of reciprocal exchanges of knowledge and non-hierarchical relationships between suppliers and users. Adapting to new cultures and generating accessible products are also practices that help to reduce this gap.

Positive social impacts around technologies related to the concept of the IoMusT can be observed. The emergence of open source software is one of them. Take Elk Audio OS¹ as an example, an operating system that runs plugins on hardware or on low latency audio systems. The idea around Elk is to create a new generation of digital instruments and experiences through computer networks. It also intends to connect people around the world and allow the creation of new forms of musical creativity, in addition to being a low-cost solution. Another positive factor is the possibility of personalization through the analysis of user data [Turchet and Barthet 2019a]. For example, the smart speaker Prizm monitors people's moods in an environment and recommend adapted playlists [O'Brien 2015]. It is also important to highlight the independence granted to artists in the management of their careers, allowing the control of the inventory of instruments through the smartphone and also applications to control their merchandising stores.

4.4. Economical Challenges

The music industry always undergoes drastic changes. The gradual replacement of LP by CD, even the sharing of songs in mp3 format and the emergence of streaming platforms, forced musicians to adapt to a new reality, often requiring a certain independence from them in the management of their business.

This independence can be aided by the IoMusT. An example to be cited is Sonibal SmARTEQ², an equalizer plugin that, through an artificial intelligence system, collects information passed to the mixer and changes the sound, like a mixing engineer. On one hand, this can be seen as reduction of production cost removing the need of a sound engineer, on the other hand, such technology could negatively impact the creative sector by replacing human creative roles by machine-based solutions (along with a potential loss in artistic quality). In any case, there is a change in working relationships [Matthews 2020].

Another important contribution concerns decision-making, based on data obtained from streaming platforms and social networks. Using artificial intelligence techniques and sentiment analysis algorithms that could emerge in IoMusT ecosystems, artists would be able to understand in which regions their music are most popular, the average characteristics of listeners, what activities they perform while listening to music and with which device they prefer playing songs [Martinez-Avila et al. 2019]. This could help musicians make better decisions about their careers and how to generate more impact and revenue [Matthews 2020]. Crowdsourcing, crowdcomputing, crowdfunding and other initiatives have also allowed an exchange of cultures and professional experiences of those involved in the music area, in addition to leaving this environment financially healthy.

¹Available on: <https://elk.audio>.

²Available on: <https://www.sonible.com/smarteq2/>.

IoMusT could lead to economical growth in the music industry sector and may imply changes in the speed and in the way music is produced, also involving public and private services. From this, some questions arise, such as: what will this emerging market look like? Would this large amount of machinery have a negative impact on music and other arts or on the contrary enhance creativity for the better? Would prices be restrictive for the poorest people? Would prices be restrictive for the poorest people or affordable solutions can emerge?

4.5. Environmental Challenges

With the increase in equipment and “things”, there is also a growing concern about the environmental risks that they can cause from the production process to disposal. Among the problems generated by technological means are: pollution; chemical composition of materials; consumption of renewable resources or not; generation of waste resulting from the disposal of obsolete electronics; disturbance in ecology and health hazards [Cubitt 2016, Eren 2002].

Possible solutions are: sustainable technologies [Junior and Schiavoni 2019b], such as materials that consume less energy or are able to perceive a routine of use and automatically turn off when no one is using; monitoring of production meshes, in order to avoid waste; virtualization of activities and implementation of recycling and device reuse policies.

IoMusT can bring scalability to a music environment where devices can be added and set up according to the need. The possibility to reprogram a device is another interesting fact that can bring possibilities to reuse devices and fights against programmed obsolescence. When compared with large systems, an IoMusT ecosystem can save energy consumption and also bring new forms to reuse devices, saving resources and the environment.

5. Conclusion

In this paper, we present an overview of an IoT subfield, known as the Internet of Musical Things. This field is related to several areas of Computer Science and the Arts, such as ubiquitous music, human-computer interaction, new interfaces of musical expression and participatory art. The techniques discussed here aim to facilitate communication between musicians, audio engineers, lay-musicians and the public, whether they are in the same place or not, and facilitate the process of musical performance and composition. The emergence of IoMusT and these musical devices also extend some possibilities of research to other fields, such as music education, where this technology can help teachers and students to learn music, making the play process cheaper and faster.

From a technical point of view, IoMusT proposes a new path in the Information Age, creating objects and intelligent instruments that will help in the understanding of music and the process of creating and consuming music. In this paper, we brought some considerations about the devices involved in this field, the communication between these devices, the possible roles, the ecosystem and the target audience for this technology. However, all proposed concepts presented here are still experimental and shows what we think that this technology could be and do not intend to define what it might or should be.

We also discussed the impacts and challenges that this new area faces in the social sphere, such as the possibility of increasing the disparity between urban and rural areas; economic, indicating how the IoMusT will interfere and suffer interference from the private market, having to deal with issues of copyright, patents and industrial secrets, in addition to concern about the availability of this technology in underdeveloped countries and how they help musicians and artists to manage their businesses and cut expenses. Finally, environmental issues are discussed, showing concern with material disposal and recycling.

An important concept that we want to disseminate in this paper is how important IoMusT is in many ways and how it can be related to Ubimus concepts, using everyday objects to generate music and new artistic expressions. The results of this directly affect human life and how we understand the concept of creating, performing and participating in musical events.

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RoboMus: Robotic Musicians Synchronization

Higor Camporez¹, Jair Silva¹, Leandro Costalonga², Helder Rocha¹

¹ Departamento de Engenharia Elétrica – UFES
Vitória - ES, Brasil

² Departamento de Computação e Eletrônica – UFES
São Mateus - ES, Brasil

higorcamporez@gmail.com, jair.silva@ufes.br

leandro.costalonga@ufes.br, helder.rocha@ufes.br

Abstract. *Technological evolution has provided the growth of new research areas that combine music and technology, such as ubimus (ubiquitous music) and IoMusT (Internet of Musical Things). This paper presents synchronization strategies applied to musical robots, using as a practical example a robotic bongo connected with the RoboMus platform. Thus, we present clock synchronization by SNTP and robot mechanical delay compensation through neural networks. We also applied real-time audio processing for synchronization with other robots or humans, creating rhythm patterns. Experimental results for delay compensation achieved an average delay of $6.65ms \pm 4.35ms$ and results for real-time processing archived an average delay equal to $5.68ms \pm 4.12ms$.*

1. Introduction

Human beings have found in music a way to express themselves creatively [Deliège and Wiggins 2006]. Technological advances, mainly computer emergence, have provided them a new musical tool for creation. Thus, researchers also have been interested in this form of creation, which provided the development of areas that combine technology and music.

Ubiquitous music (ubimus) [Keller et al. 2014] uses ubiquitous systems of human agents and material resources aiming music purpose. This research area supply musical activities supported by technological devices, based on concepts such as portability, mobility, connectivity, and availability (even to non-musician). In addition, another important area is the Internet of musical things (IoMusT) [Keller and Lazzarini 2017, Turchet et al. 2018], which uses electronic and computation through sensors, actuators, and connectivity to provide musical activities, including networked musical performances. Some IoMusT examples are: wearable device [Turchet and Barthet 2019] and multimedia interactive installations [Netto et al. 2015].

The widespread use of electronics has provided the creation of robots for many uses, including for musical propose. Robotic musicians [Bretan and Weinberg 2016] use sensors, actuators, and electronic devices, relating them to ubimus and IoMusT. An example is a robot named Shimon [Hoffman and Weinberg 2010], a robotic marimba which includes a module to interact with another musician in real-time. In addition, there are robots controlled by MIDI messages such as the LEMUR GuitarBot that is a type of slide-guitar with four strings, where each string has an independent slide. Robot musicians can

also include autonomous mode or controlled mode using a computer network such as the RoboMus platform [Camporez et al. 2018] described in Section 2.

Human beings can detect the time difference among two successive acoustic events (between 500 and 1.500 Hz) in up to 20 milliseconds [Pisoni 1977]. However, in robotic musicians, there are many mechanical delays caused by electromechanics components. Thus, robotic synchronization (even between humans and robots) can be achieved by compensation techniques to keep the system delay less than 20ms.

In networked musical performance [Rottondi et al. 2016], there are network latency and jitter (latency variation). Protocols for communication among computers, sound synthesizers, and other multimedia devices such as OSC (open sound control) [Wright and Freed 1997] uses time tags, an absolute time to execute the message, to control this problem, thus messages can be sent in advance. However, the OSC does not provide techniques for clock synchronization, which can be achieved by using additional protocols, such as NTP (network time protocol)[Martin et al. 2010] or STNP (simple network time protocol)[Mills 2006], where the second is a simple, less accurate, version of NTP recommended for micro-controller, embedded systems, and others because consumes less computational complexity.

This paper describes improvements for the RoboMus platform, presenting the construction of a new robotic bongo and strategies for macro-synchronization and micro-synchronization using this robot on the tests. It presents the SNTP use for clock synchronization, neural networks for learning the robots mechanical delay profiles, and real-time audio processing for rhythmic synchronization with other musicians (humans or robots). The remainder of this paper is organized as follows. Section 2 presents the RoboMus platform. Section 3 describes the robotic Bongo components. Section 4 illustrates strategies for robot synchronization used in RoboMus. The experiments and results are presented in Section 5 and conclusion remarks are described in Section 6.

2. The RoboMus Platform

The RoboMus platform [Camporez et al. 2018] aims, essentially, at the interaction among musical robots and humans. The platform is open source, targeting low-cost robots. Its focus is on robots controlled by humans, however autonomous and semi-autonomous modules are considered to assist users in performances. Thus, the platform uses a predefined musical messages format, using the OSC protocol, to enable robot control and mutual collaboration. In addition, as multiple robots structure is desired in a real-time performance, synchronization strategies are applied through a musical message synchronization server (MMSS), and algorithms embedded in the robots to promote micro-synchronization.

Figure 1 depicts the platform architecture, which can be divided into three parts: a) control interfaces, which provide interaction among users and robots, b) musical messages synchronization server, that is a messages centralizer among control interfaces and robots, where techniques to compensate the mechanical delays are applied, and c) musical robots.

3. BongoBot prototype

We develop a robotic bongo, named BongoBot, for the first tests on the RoboMus platform. The platform aims low-cost robots, thus the project was built with reused wood,

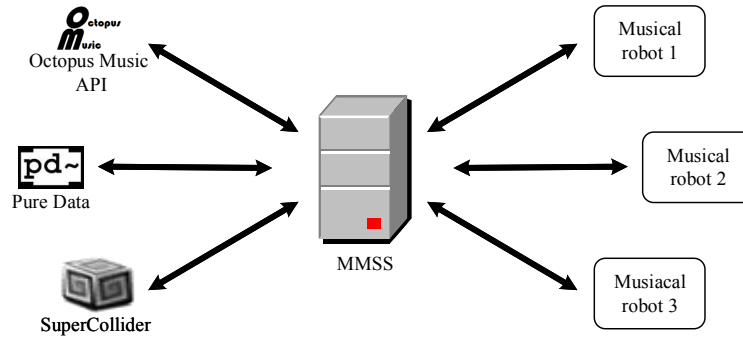


Figure 1. The RoboMus platform architecture. The left side presents possible control interface, in the center is shown the musical messages synchronization server, and on the right side are depicted musical robots.

four solenoids (12 Volts and 5 Newtons), and two piezoelectric elements. The Figure 2 shows a 3D model and its construction.



Figure 2. BongoBot 3D model and real model

The RoboMus communication patterns were implemented in a Raspberry pi 3 Model B¹. However, an auxiliary circuit was necessary to control the solenoids, because Raspberry’s digital output pins did not supply the voltage and current required by the solenoids (12V and 300 mA), thus a driver circuit was implemented, working like a switcher, in which its schematic is shown in Figure 3 (a). We also implemented piezoelectric sensors under the bongo skins to capture its sound and support the Raspberry to detect beats, allowing the mechanical delay estimation. Furthermore, we use an amplifier circuit (Figure 3 (b)) to allow the Raspberry to read weak beats. However, strong beats can generate voltage above the Raspberry’s maximum input limit (3.3 Volts) and also below the minimum input limit (0 Volts), thus this circuit limits the voltage range from 0 to 3.3 Volts. The Figure 3 (c) shows the robot’s components and its connections.

3.1. Robot Delay Characterization

The robot delay depends on the distance between the solenoid and the bongo skin, and the solenoid velocity. The solenoid is an electromechanical device and when it receives elec-

¹raspberrypi.org/products/raspberry-pi-3-model-b/

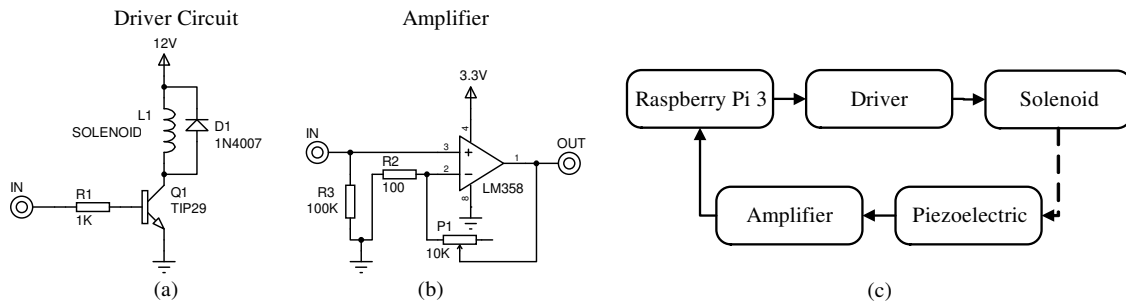


Figure 3. (a) Driver circuit, (b) amplifier circuit, and (c) the robot system diagram.

tric current the armature moves in a velocity that depends on the voltage. We use a PWM (pulse width modulation) to control the average voltage, consequently the solenoid velocity and beat strength. Figure 4 shows solenoids' mechanical delays, varying the PWM value from 0 to 1023, in other words, from 0 to 12 average Volts, respectively. These delays were measured from the moment that the Raspberry Pi sent the electrical command until the effectively sound, captured by the piezoelectric placed under the Bongo skin and read by the same Raspberry, the Figure 3 (c) shows the diagram. Note that the maximum wait time was $200ms$, values equal to it means that there was no beat or very weak beat. Thus, there are minimum PWM values to make the solenoid works, for the solenoid 1 (Figure 4 (a)) this value is about 500 and for the solenoid 2 (Figure 4 (b)) is about 400, the difference can be explained by the installation height.

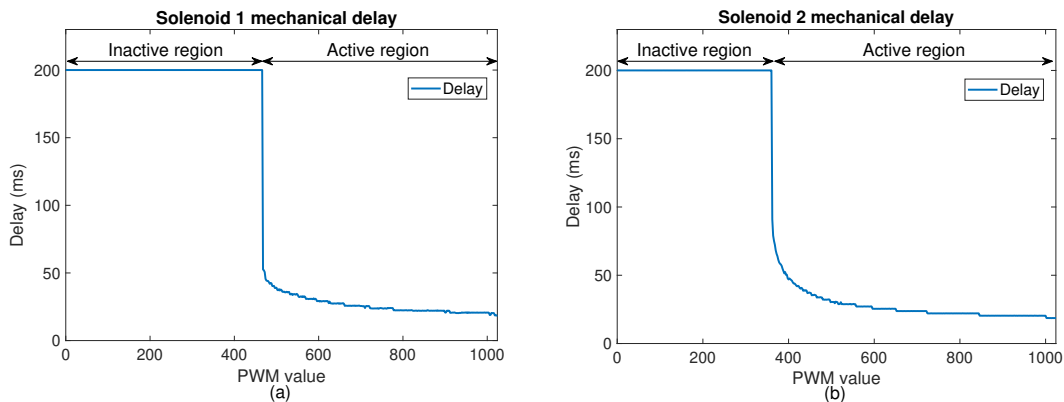


Figure 4. Robot delay characterization.

4. RoboMus Synchronization

4.1. Macro-synchronization: Mechanical Delay Learning

Human beings have mechanical delays (limb movements), however, they solve this problem by initializing the limb movements before the desired sound response. For example, when clapping it is necessary to anticipate the movements to keep time. The robots also present similar delays caused by the components. Thus, macro-synchronization strategies aim to learn and anticipate the actions of the robot to keep time.

Each robot may have its own structural design and, consequently, its own delay profile. This profile can also change due to components wear and other factors

such as clearance. Thus, the MMSS must know the delay profiles to provide macro-synchronization and these profiles can be learned by using neural networks. For example, the MMSS sends hundreds of messages to a robot and when this robot finishes an action execution, it sends back a message containing the spent delay. After, with all the messages, the MMSS can train a specific neural network to learn this robot's delay profile. Note that the data acquisition and network training demand some time, however, it can be done in the background.

The message delay format is not defined in the RoboMus platform. Thus, we defined a new format that is described in Table 1, where in the first line is depicted the OSC address, represented as a joint of OSC server address, the word *delay*, and the robot OSC address. The message's first parameter represents the identifier and the second represents the delay.

Table 1. Delay message format.

Component	Type
/MMSS OSC address/delay/robot OSC address	OSC address
Identifier	Integer
Delay	Integer

The platform describes a handshake among the MMSS and a robot. Thus, when a new robot connects to a RoboMus concert hall it must send a handshake message containing its information and what it can do, in other words, it sends its specific actions and its parameters. After receiving this information, the server can generate hundreds of random messages, however, it is necessary to know a set of valid values to each parameter, enabling the MMSS to generate valid messages. Specific actions of RoboMus handshake message does not provide these sets of valid values, as can be seen below:

$$\langle /action_1; parameter_{11_type}; \dots; parameter_{1N_type} \rangle \dots \langle /action_N; parameter_{N1_type}; \dots; parameter_{NN_type} \rangle,$$

where each action is represented among $\langle \rangle$, and inside of each action the information is divided by $;$, in which the first symbolizes the action OSC address and the rest represents the parameters that are divided in name and type by $..$

We defined a new format to the specific actions that include a set of valid values for each parameter. Thus, at the end of the previous format, we added a set of valid values represented inside parentheses, in which each set is divided by $;$, except the first one that is the action name. The new pattern model is shown below:

$$\langle /action_1; parameter_{11_type}; parameter_{12_type}; \dots; parameter_{1N_type} \rangle \dots \langle /action_N; parameter_{N1_type}; \dots; parameter_{NN_type} \rangle (/action_1; set_{11}; set_{12}; \dots; set_N) \dots (/action_N; set_{1N}; set_{2N}; \dots; set_{NN}),$$

where each set can be described in two forms: 1) defining the extremities of the interval following mathematical notation, for example, $]a, b]$, where $]a$ denotes values greater than a and $b]$ denotes values less than or equal to b ; or 2) defining a list of elements, in this case, the elements can be written inside curly brackets and separated by comma, for example, $\{p1, p2, p3, \dots, pn\}$. Thus, follows a practical example:

$$\langle /playNote; string_i; fret_i \rangle \langle /playString; string_i \rangle$$

$$(/playNote; \{1, 2, 3, 4, 5\}; [1, 4]) (/playString; [1, 6]).$$

In the example above, the robot can do two actions, the action *playNote* contains two integer parameters *string_i* and *fret_i* (denoted by final character *i*), their set of values are $\{1, 2, 3, 4, 5\}$ and $[1, 4]$, respectively. The other action *playString* contains only one integer parameter *string_i* with a set of value defined by $[1, 6]$.

In most cases, the mechanical delay depends on the last executed action and the next action, because the last action defines the current mechanical components position. For example, the delay in sliding between frets in a robotic lap steel guitar depends on the current position (last executed action) and the next action. Thus, We define a generic model of inputs and output variables for neural networks used to learn delay profiles, however, the internal design depends on the robot characteristics. The input variables structure is defined using information from the previous and the next message, in other words, the action ids and the messages parameters, which is shown in Figure 5. The number of parameters for each message can vary according to action, thus the network input variables number is defined as $2 \times n + 2$, where n is the number of parameters from the action with the highest number of parameters. In addition, for actions that contain fewer parameters than n , the MMSS fills the remaining inputs variables with zeros.

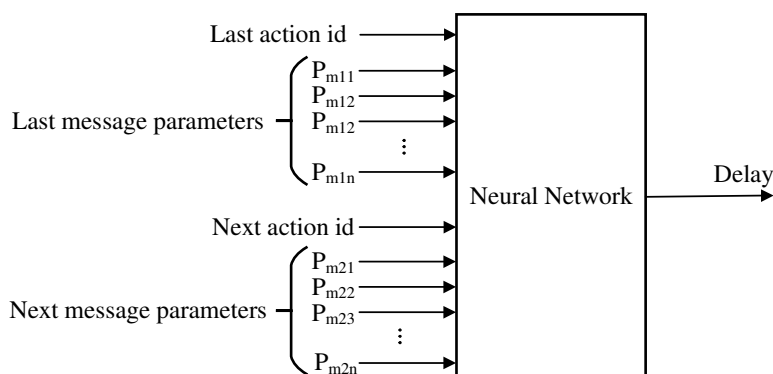


Figure 5. A generic model of inputs and output variables for neural networks used in the MMSS.

4.2. Micro-synchronization: Musical Pulse Synchronization

Generally, in all music there is a sequence of periodic pulse that represents the music speed, even people without musical training can perceive these pulses and it may correspond to tapping the foot with the music [Benward and Saker 2008]. This tapping synchronization is based on forecast next beat (pulse) and mechanical delay compensation. Music, in general, is also structured in groups of pulses that are called bars, the size of the group and pulse duration defines a time signature. These musicals information allow the creation of rhythm patterns for synchronization between participants. Thus, perceptual modules are implemented in the robots for real-time pulse and time signature detection, aiming autonomous synchronization with other robots or human beings.

We implemented a beat tracker [Ellis 2007] in the BongoBot to find musical pulses in real-time and to allow autonomous rhythmic synchronization. The algorithm calculates the spectral flux (onset strength envelope), with hop size equal to 64 samples, from raw

audio recorded by the robot, in which it shows the signal power changes over time, where peaks probably represent onsets. After, the autocorrelation is applied in the spectral flux to find periodic structures, and with the highest autocorrelation value it is possible to estimate the global BPM (beats per minute). The algorithm defines a cost function to find a optimal beat sequence in the signal. Thus, candidate sequences are tested to maximize the cost function that respects the BPM and match with spectral flux peaks.

Music, usually, repeats some bars structures. Thus, the bar length can be determined by finding these repetitions as well as the time signature [Coyle and Gainza 2007]. The algorithm extracts the STFT (short-term Fourier transform) and calculates the similarity, frame by frame, to create a similarity matrix [Foote 1999]. Then, bar lengths candidates, from 2 to 12, are tested and the candidate that presents the highest similarity score is chosen. Finally, the global BPM, the last beat time and time signature allow the robot to create rhythmic patterns for synchronization with other participants. All the perceptual module process is shown in Figure 6.

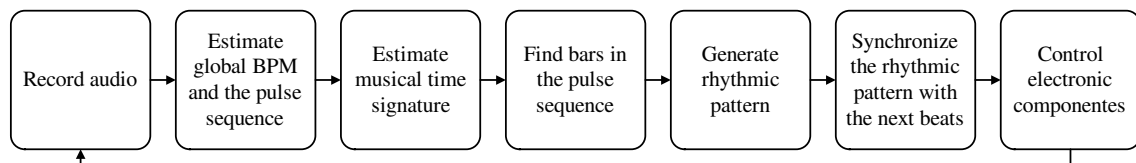


Figure 6. Micro-synchronization diagram process.

5. Experiments and Results

5.1. Macro-synchronization between Clocks

Messages from the MMSS to the robots contain an absolute time to be executed, thus the clocks synchronization among robots is the first step to achieve great performances. We implemented SNTP algorithms in the MMSS and this Subsection aims to evaluate its accuracy.

The synchronization tests were done using two Raspberry pi 3 Model B devices, because it is used on BongoBot. Thus, the MMSS sent hundreds of messages to the devices (the same messages for both). When the internal clock of a Raspberry matches with the message's time tag, it sends a digital pulse from the output pin. An Arduino Mega was used only to evaluate the delay between the devices Raspberry. Then, the Arduino read the pulses from Raspberry devices and calculate their time difference, which consequently represents the difference among the internal clocks. The experimental setup is shown in Figure 7.

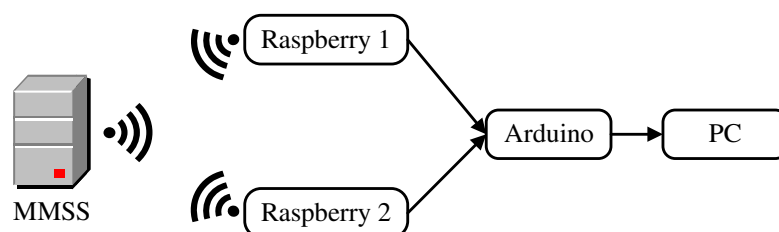


Figure 7. Experimental setup for measure the difference among devices' clocks.

The first test (Figure 8 (a)) was made by synchronizing the clocks with the MMSS, only once, at the beginning of the test. Figure 8 (a) shows an increasing delay that is caused by the clock inaccuracy, this effect is known as clock drift. However, the clock drift may increase slowly, this occurs because the two devices use similar clock hardware and it can be worse when applied to different types of devices.

The drift clock problem can be solved by doing a new clock synchronization from time to time, it was tested with a new synchronization every 30 seconds (defined empirically) to study the behavior. Figure 8 (b) depicts a test with 1000 messages, where the abrupt transitions occur when the SNTP algorithm is executed. However, note that the maximum difference value of the test was $18,81ms$ which is close to the human perception threshold ($20ms$). The difference mean value is about $7,82ms$ with standard deviation equal to $5,55ms$, which presents goods values to MMSS macro-synchronization. However, micro-synchronization strategies, executed by a robot, can achieve a fine adjustment and also determine moments to execute SNTP, for example, a perceptual modulo to listen to the performance and identify the lack of synchronism with the other robots.

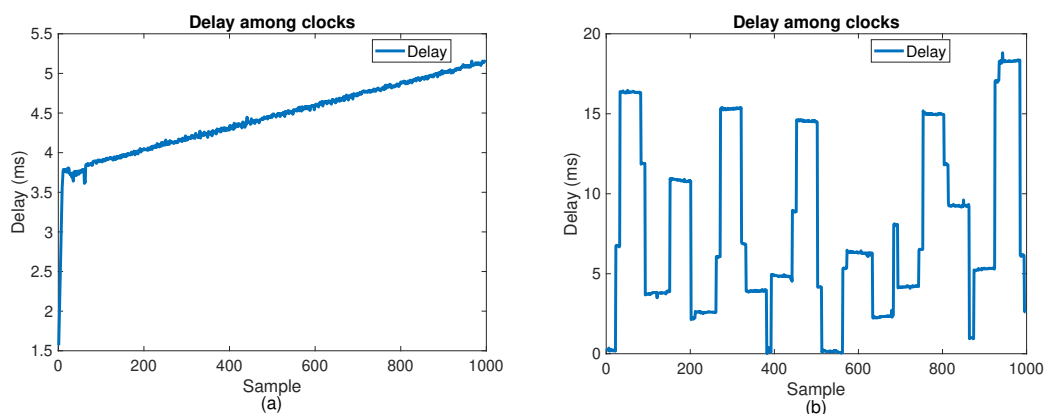


Figure 8. Delay among two Raspberry pi devices: (a) shows the results of the test that was made by synchronizing the clocks, only once, in the beginning, showing drift clock effects and (b) depicts the synchronization results applying the SNTP from time to time.

5.2. Macro-synchronization among Bongos

This subsection aims to apply SNTP algorithms together with mechanical delay compensation learned by neural networks. Synchronization tests required at least two robots, thus we divide the BongoBot (Figure 2) into two robots, where one Raspberry control the larger drum (*hembra*) and the other Raspberry control the smaller drum (*macho*). The RoboMus specific action for each one was define as: $\langle /playBongo; velocity_i \rangle$ ($/playBongo; [500, 1023]$).

An Arduino Mega was used as an auxiliary component only to evaluate the delay, it read each piezoelectric installed below of the drum skins and measure the delay among the robots' beats, the experimental setup is shown in Figure 9. For example, if the two raspberry pi devices receive a message with an absolute time of 9:00:00.000, when each internal clock marks that time, the Raspberry will send a signal to control the solenoid and play the drum, which will generate a signal from the piezoelectric, that will be read by the Arduino.

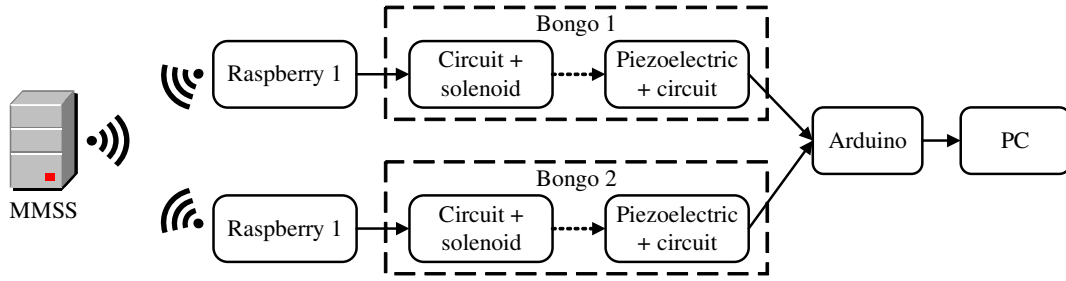


Figure 9. Experimental setup for measure the delay among the robots' beats.

The mechanical delay presented in Section 3 (Figure 4) is almost the same for the two drums. Thus, we applied a $100ms$ delay, defined in the software, to one of the bongo drums to force a lack of synchronism between them, aiming the study of macro-synchronization application. Figure 11 (a) shows an experiment that was done by sending hundreds of messages with the same time tag and different velocity (beat strength) value randomly generated.

The lack of synchronism described above was minimized by applying the process depicted in subsection 4.1. Thus, we use the perceptron multilayer neural network [Haykin 2001] to learn the delay profiles of each bongo robot, Figure 10 show its model. We use a different neural network for each robot, however with the same structure and one thousand messages were sent to training. The neural network for the robot 1 (larger drum) reached an RMSE (root mean square error) value equal to 0.0173 and the robot 2 (smaller drum) obtained 0.0074. After the training, the MMSS sent hundreds of messages with random velocity parameters to test the robots, however compensating the delay given by the neural networks to achieve the sound response at the same time. For example, a message scheduled to execute (sound response) exactly at 9:00:00.00, the MMSS will do the compensation for each robot and send with the new time tag, for robot 1 the new time is 8:59:59.880 (compensation of 120 ms) and for robot 2 is 8:59:59.960 (compensation of 40 ms). Figure 11 (b) shows the result test for hundreds of messages applying the macro-synchronization techniques, in which presented an average delay equal to $6.65ms$ with standard deviation 4.35ms and 2 (0.23%) values above $20ms$.

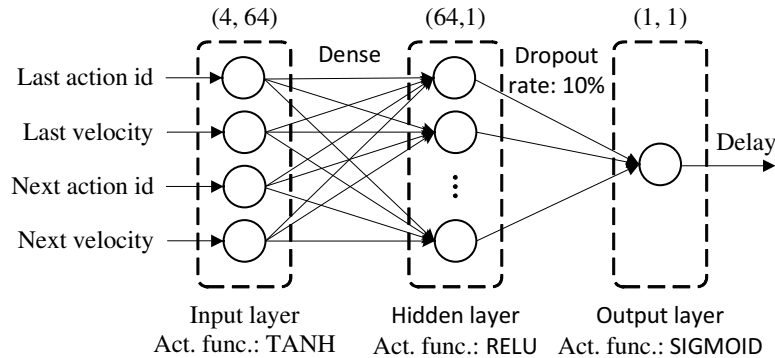


Figure 10. Specific neural network model used to learn the bongo robots mechanical delays.

Macro-synchronization techniques using SNTP algorithm and compensation by

neural networks showed a satisfactory result achieving, in general, delay values lower than human perception. It presented high standard deviation value compared to the average. However, macro-synchronization is one step of the general synchronization, in addition, these values can be improved by micro-synchronization techniques.

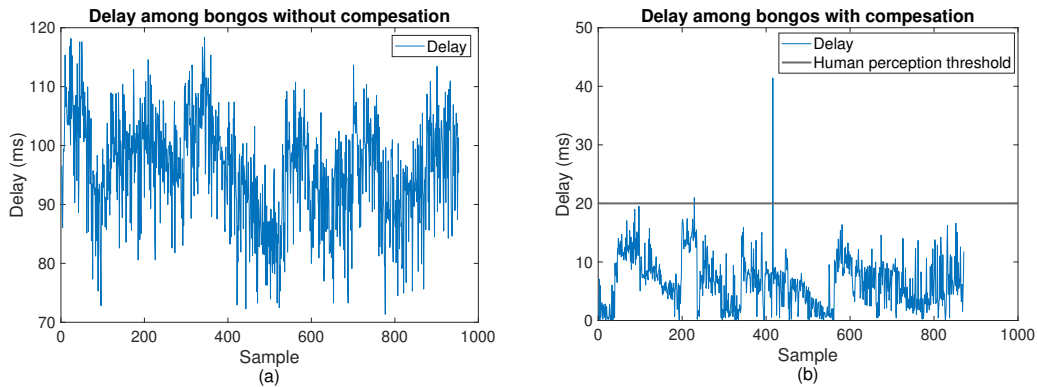


Figure 11. Delay among two robots: (a) shows the delay without compensation techniques and (b) depicts the results with compensation.

5.3. Micro-synchronization Tests

We use a metronome to test the perceptual module described in Subsection 4.2, where the test setup is shown in Figure 12. The robot processes the metronome audio signal captured by the USB audio interface and runs the micro-synchronization algorithms. The USB audio interface 2 records the signal from the piezoelectric, installed on the bongo, on channel 1, and the metronome sound on channel 2. The synchronism between them can be estimated by applying the beat detection algorithm separately for each signal and calculating the absolute value of time difference between the corresponding beats.

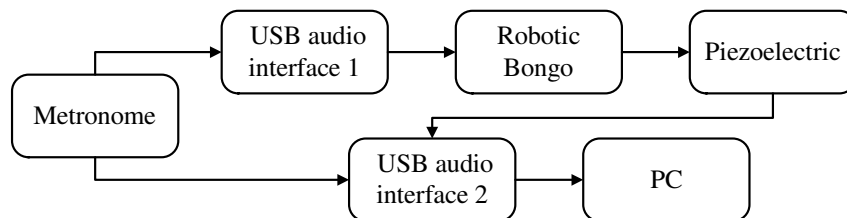


Figure 12. Experimental setup for micro-synchronization tests.

Table 2 shows the results for 10 tests with audios of 1 minute each. The results 5, 6, 8, and 9 exceeded the human perception threshold (20 ms), this may have been caused by the difficulty of associating global computer time with the moment when the audio sample was measured by the audio board. In addition, there is variation in the latency of the audio system due to hardware components (analog-digital converter, buffers, USB communication) and software (communication drivers, audio drivers). Another cause is the difference between metronome's BPM and estimated BPM that increases the delay over time. Thus, analyzing only the first 5 seconds of the tests 5, 6, 8, and 9, the delays and standard deviations are equal to $10.16 \pm 3.75ms$, $24.19 \pm 2.6ms$, $13.93 \pm 1.16ms$, and $28.61 \pm 5.1ms$, respectively. Note that the tests 6 and 9 initialized without synchronization and tests 5 and 8 became out of sync over time due to the difference in BPM. Thus, 4 tests (40%) exceeded the threshold and only 2 (20%) started without synchronization.

Table 2. Results of experimental micro-synchronization tests.

Test	Metronome's BPM	Estimated BPM	Average delay	Standard deviation
1	110	109.96	5.68 ms	4.12 ms
2	70	69.96	11.58 ms	6.94 ms
3	80	79.97	9.36 ms	5.23 ms
4	60	60.01	14.25 ms	3.70 ms
5	120	119.84	35.39 ms	16.29 ms
6	90	90.07	37.88 ms	9.55 ms
7	60	60.01	13.55 ms	4.41 ms
8	75	75.03	21.91 ms	6.79 ms
9	100	100.11	47.51 ms	12.52 ms
10	80	79.97	7.37 ms	4.72ms

6. Conclusion

This paper presented strategies for macro and micro-synchronization applied to the RoboMus platform, that aims to provide robotic musical performances, and a practical bongo robotic development. We use neural networks to learn the robots' mechanical delay profiles and SNTP protocol for synchronization among clock (macro-synchronization). We also use real-time audio processing to detect musical pulse and time signatures, aiming to provide autonomous rhythmic synchronization musical accompaniment.

As future works, for micro-synchronization, we suggest an improvement in the time signature detection algorithm, mainly the first beat of a bar detection; increase the accuracy of the beat tracker algorithm, and development of algorithms for musical genre classification and choose rhythm patterns by the genre. For macro-synchronization, we propose tests with other complex algorithms for clock synchronization, studying the computational complexity and time accuracy, as well as developing strategies to define good moments to a robot synchronize its clock; and finally, the application of synchronization techniques for more mechanically complex robots.

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Interactivity/interpassivity and presence/absence in the *Ntrallazzu* cycle

Marcello Messina¹²⁵, Leonardo Vieira Feichas³⁴⁵,

¹Universidade Federal da Paraíba (UFPB)
João Pessoa – PB – Brazil

²Amazon Center for Music Research (NAP)
Rio Branco – AC – Brazil

³Universidade Nova de Lisboa
Lisbon, Portugal

⁴Universidade Estadual de Campinas (UNICAMP)
Campinas – SP – Brazil

⁵Universidade Federal do Acre (UFAC)
Rio Branco – AC – Brazil

marcello@ccta.ufpb.br leonardofeichas@hotmail.com

Abstract. *Ntrallazzu* is the title of a cycle of works based on interactive live scores, that reflects on the multifaceted philosophical concepts of liveness and interaction both from a creative point of view and in more critical terms. The work is based on a projected score that interacts in real time with the material played by the performer(s). While one of the performers plays, the sound is fed to and processed by patching software, and generates both electronic sounds and a score, which is to generally, but not necessarily, to be performed by a second player. In this paper, we discuss the ways in which subsequent versions of *Ntrallazzu* exist in between two fundamental sets of opposites, namely, interactivity/interpassivity and presence/absence.

1. Introduction

Ntrallazzu is the title of a cycle of works based on interactive live scores that reflects on the multifaceted philosophical concepts of liveness and interaction both from a creative point of view and in more critical terms. The work is a 5-/6-minute piece based on a projected score that interacts in real time with the material played by the performer(s). While one of the performers plays, the sound is fed to and processed by a patching software, and generates both electronic sounds and a score, which is generally, but not necessarily, to be performed by a second player. Both the live score and the electronics run on Max.

In this paper, we discuss the ways in which subsequent versions of *Ntrallazzu* exist in between two fundamental sets of opposites, namely, interactivity/interpassivity and presence/absence. In exploring these two dichotomies, *Ntrallazzu* dialogues with

the multiple modes of liveness examined by John Croft (2007) and situates itself in the broader rubric of “ubiquitous music” [Keller et al. 2010]. From a more critical point of view, the work intends to explore the implications of liveness in terms of possibilities of audience surveillance on the gestures of the performers that are not generally predicated within the concert hall situation. In terms of liveness as surveillance and as algorithmic replica, our main theoretical reference is the work of Joseph Pugliese (2014). The title *Ntrallazzu* is a Sicilian term borrowed from the practice of smuggling locally produced state rationed crops in World War II Sicily, as practice of resistance criminalised by the Italian authorities, that was aimed at contrasting indigence in the island. By establishing micro-patterns of interaction between themselves and with the live electronics, the performers symbolically reproduce the secret exchanges that disobeyed a violent regime of biopolitical¹ and necropolitical² state control on the lives and means of subsistence of the islanders.

Considering the common repartition of roles on which Euro-centred “art music” is predicated [Keller et al. 2010], in this paper we offer multiple perspectives on the work, both from the point of view of the composer Marcello Messina and that of the performer Leonardo Vieira Feichas, also taking on board the perspectives and testimonies of the other performers who have played the piece. In this sense, this work dialogues with and furthers the findings of previous work by Messina and Aliel (2018; 2019): in that case, the authors drew upon phenomenology and deconstructivism in order to turn *Ntrallazzu* into a collaborative improvisation³ experience, resulting eventually in a literal “hijacking” of the original piece. A previous version of this paper was presented at NCMM18 in Lisbon [Messina and Feichas 2018].

Although not conceived as part of it, *Ntrallazzu* is a sort of continuation to The Digital Score [Feltham et al. 2014], a research project funded by AHRC – the Art and Humanities Research Council (UK) –, and hosted by the Goldsmiths College (University of London) and the University of Sussex, between 2013 and 2014. The project was aimed at the creation and development of scores/sets of instructions, which incorporated the creative use of technology within a research-orientated framework. There was also a general intention to use multiple strategies of live interaction with scores, and in fact, the compositions produced within the project involved web networks, live coding, graphic patches, etc.

¹ In Foucauldian terms, “biopolitics” is the rational preoccupation of a (self-proclaiming) liberal state for all “the problems posed to governmental practice by phenomena characteristic of a set of living beings forming a population: health, hygiene, birthrate, life expectancy, race ...” [Foucault 2008: 317]. Essentially, biopolitics could be seen as a strategy of control that also legitimates the liberal state, which in turn appears to derive its sovereignty on the rational maintenance of the population and not on the use of violence.

² Drawing on Foucault (and also abundantly criticising him on various aspects), Achille Mbembe coins the term “necropolitics”, arguing that “the ultimate expression of sovereignty resides, to a large degree, in the power and the capacity to dictate who may live and who must die” [Mbembe 2003: 11]. Furthermore, he adds that “the notion of necropolitics and necropower to account for the various ways in which, in our contemporary world, weapons are deployed in the interest of maximum destruction of persons and the creation of *death-worlds*, new and unique forms of social existence in which vast populations are subjected to conditions of life conferring upon them the status of *living dead*.” [Mbembe 2003: 40]

³ On the concept of “improvisation”, cf. Aliel, Keller and Costa (2018).



Figure 1: *Ntrallazzu 1* in Strasbourg, France, June 2018.

The pieces that compose the cycle *Ntrallazzu* were composed between 2013 and 2018. The first piece was written and developed between 2013 and 2014, and called for an instrument of the flute family, plus one of the clarinet family. This first version of

Ntrallazzu, later renamed as *Ntrallazzu 1*, was premiered in June 2018 by the *lovemusic collectif* (Fig. 1).⁴ The huge gap between the development of the first piece and its first performance in 2018 was due to personal circumstances, such as relocation, that affected both the composer and the performers. This gap eventually led to the development of a new version for violin and piano, that was performed by Leonardo Feichas and Daniel Sanches, just one month before the Lovemusic version. The very first performance of the whole *Ntrallazzu* cycle, therefore, happened to be a premiere of the second piece of the cycle, *Ntrallazzu 2*, for violin and piano.⁵ Other pieces, numbered progressively, have followed since, and as of now, the piece has been performed by several performers in four different countries, namely, Brazil, France, the Netherlands and Portugal.

2 Interactivity, Interpassivity, and Interpassive Music

2.1 On live interaction

Max is a graphical programming environment, also called a patching software, essentially based on boxes and cables. The connections between these graphical objects produce musical mechanisms that are either triggered by calculations that are internal to the computer or interact with external devices such as a MIDI controller or a microphone – the latter happens in the case of *Ntrallazzu*.

The interaction with a microphone is, essentially, an interaction with the external environment — in this case with musical instruments (although the patch could interact with any type of sound). The instrument is, in turn, operated by a human being, therefore we are in the presence of a rudimentary form of interaction between human and machine. Now, we know that people have produced music with instruments for millennia – instrumental music is autonomous and does not need machine interaction, unless we think of the instrument itself as a machine. At the same time, nowadays we have at least one century of electronic music history behind us [Wilson 2017; Mooney, Schampaert and Boon 2017], and we know that machines can play pre-composed music autonomously [Risset and Van Duyne 1996], and they even compose music on their own [Mantaras and Arcos 2002]. In this sense, the use of live electronics in *Ntrallazzu* was not conceived as a groundbreaking characteristic of the composition — rather, it serves to reflect critically on interaction and liveness.

⁴ The first version of the piece ended up being premiered later than the second version, right a month afterwards. On 8 June 2018, in Strasbourg, France, at the Bibliothèque Nationale et Universitaire, *Ntrallazzu 1* was performed by Emiliano Gavito (piccolo) and Adam Starkie (bass clarinet), with Guido Pedicone operating the electronics (Figure 2). This version was characterised by the fact that the piccolo/flute part was a traditional score written on paper, with a fixed linear sequence that involved a predetermined, non-changing route from beginning to end. That differs dramatically from the aforementioned piano part of *Ntrallazzu 2*, as in that instance the fixed linear sequence was replaced by an aleatory sequence of musical fragments.

⁵ *Ntrallazzu 2* was premiered in Lisbon on 9 May 2018, at the Universidade Nova de Lisboa. In this piece, the interaction was originally intended to happen via two different computers, with patches running and functioning as one independent score for each of the two performers. Due to technical limitations, this did not actually happen, and while the violinist Leonardo Feichas was able to follow the interactive score via his laptop, a printed-out version of the score was provided to pianist Daniel Sanches, who applied aleatoric methods to establish the order of the musical fragments. On this occasion, the live score was projected to the audience.

2.2 Responsorial/Proliferating liveness

Part of what John Croft suggests in his seminal essay entitled *Theses on Liveness* (2007) is that live interaction can challenge received ontologies of (Western) art music, where the interposition of the human body between the score and the final sound product is normally regarded as a nuisance or as an accident. Antithetically to this last point, we could add that we may produce live electronics in order to downsize and reconsider the role of human agency in the context of the final sound product. These two reasons, we argue, are both to be considered indispensable when talking about live electronics. The human body, in this context, is both *reclaimed* as a political space of self-determination and *questioned* as the primary, ultimate and sole *locus* of artistic/political agency. Reiteratively, we reclaim the human body not only from the alienation of automation: as suggested above, the musical score as a cultural practice also entails the cancellation of the body, that is literally treated as a disruption that hinders the transition between the score and the sonic product.

Another point on which Croft reflects regards the many types of live musical interaction that are possible. The type of live interaction that happens in *Ntrallazzu* is categorized by Croft as “*Responsorial/proliferating*” liveness, characterised by the fact that “its aesthetic pertinence is determined by the extent to which the response varies in a perceptible way with the noticeably ‘accidental’ characteristics of the performance” [Croft 2007: 62, original emphasis]. In the pieces of the *Ntrallazzu* cycle, then, the main parameters of the piece change dramatically, depending on minimal variations in the performance.

2.3 Interpassivity

While the interaction that characterises *Ntrallazzu* is, as mentioned above, *Responsorial/proliferating* liveness, the work also features important elements of interpassivity as well. The term “interpassivity” was coined as “*interpassivität*” by German cultural theorist Robert Pfaller (1996), and then abundantly used by Slovenian philosopher Slavoj Žižek, who describes it as referring “to a sense of being active through another subject that does the job for one” [Žižek 1998: 483]. Žižek claims that interpassivity, “in its opposition to interactivity”, is “the feature that defines the most elementary level, the necessary minimum, of subjectivity” [Žižek 1997: 116]:

In order to be an active subject, I have to get rid of - and transpose onto the other - the inert passivity that contains the density of my substantial being. In this precise sense, the opposition signifier/object overlaps with the opposition interactivity/interpassivity: signifier is interactive, it is active on my behalf, in my place, while object is interpassive, it suffers for me. Transposing onto another my very passive experience is a much more uncanny phenomenon than that of being active through another: in interpassivity, I am decentered in a much more radical way than in interactivity, since interpassivity deprives me of the very kernel of my substantial identity [Žižek 1997: 116].

Considering Žižek’s reflections on the idea of suffering on behalf of another subject, in most of the pieces that compose the *Ntrallazzu* cycle a relevant interpassive relationship happens between the performers and the audience. The audience appreciates the interaction but delegates action to the performers, while also participating and possibly

formulating opinions on the general dynamics of what is going on. An important element, in this sense, was the projection of the score to the audience (Fig. 2), which was not always possible.

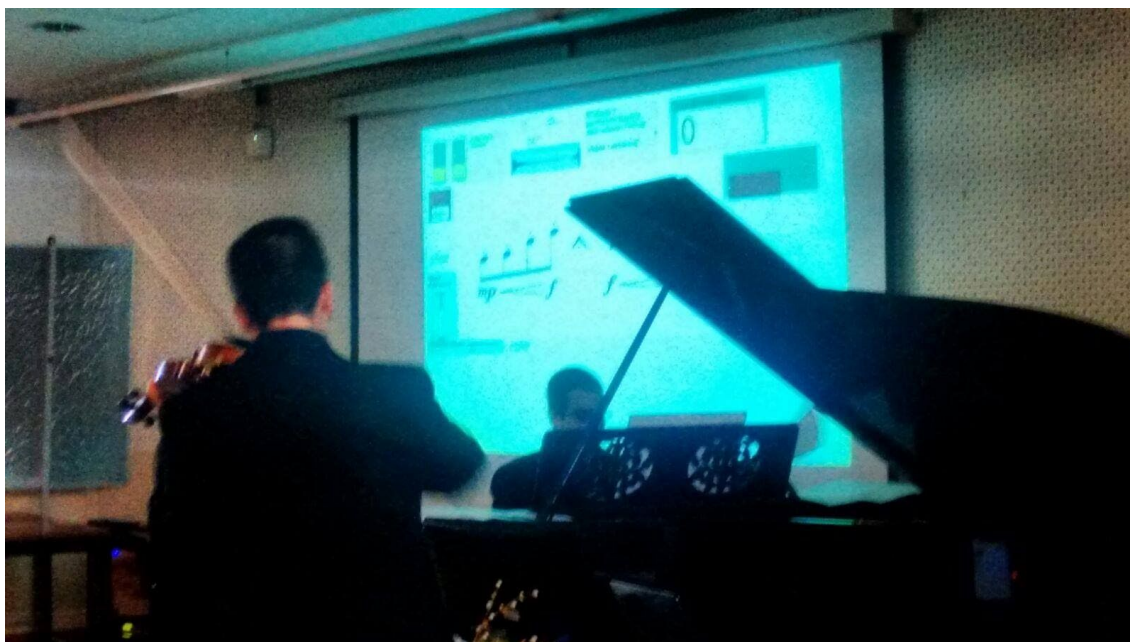


Figure 2. the score being projected during the premiere of *Ntrallazzu 2*, in Lisbon, May 2018.

For example, on the occasion of the VIII UbiMus - Eighth Workshop on Ubiquitous Music, during Luzilei Aliel's performance of *Ntrallazzu 4*,⁶ a sound/video technician turned off the projection in the middle of the performance. Here the coercive and yet bona fide action of the technician operated precisely towards the disruption of the interpassive participation of the audience.⁷ *Ntrallazzu 5*, on the other hand, featured two operative live scores, both projected to the audience: arguably this increased performance anxiety dramatically, and encouraged public vigilance on the part of the audience.

⁶ *Ntrallazzu 4* was performed by Luzilei Aliel on the fife, electric guitar and effects. The performance took place at the Universidade Federal de São João del Rei, in Brazil, during the VIII UbiMus - Eighth Workshop on Ubiquitous Music, on 14 September 2018 [Messina and Aliel 2018]. This version involves a single performer, although Aliel played both the fife and the electric guitar and, thanks to an intelligent use of effects, managed to maintain the feeling of an interaction between two instruments.

⁷ Just to clarify, disruptions such as this one are to be intended as an integral part of the "experimental" rubric that inscribes this piece as well as its technical preparation, compositional process and performance-oriented training. In this sense, the fact that the projection was arbitrarily interrupted does not represent a sort of "failure" of the piece – on the contrary, it reinforces and, basically, proves one of the fundamental points made by the piece itself. Furthermore, if on the one hand the interruption of the projection seems to undo precisely the philosophical premises on which ubiquitous music is predicated, on the other hand, as the deliberate intervention of an agent that exists outside the composer/performer dyad, it may also be categorised as a form of "breaking down" of the "social paraphernalia" that characterize traditional musical practices. In general, unexpected disruptions are a fundamental part of the whole *Ntrallazzu* cycle: reiteratively, by pointing this out we do not claim any originality, as Accidents during music performances where technology is included are normally on the agenda [Cf. Berweck 2012].

Drawing abundantly on Žižek’s thought, Federico Reuben transposes the concept of interpassivity to the realm of musical creativity, composition and performance, coming up with the expression “interpassive music”:

The notions of interpassive and interactive relationships as reflecting an opposition between active and passive roles may also be applied to the way in which a performer might relate to a technological object in a live electronic musical performance. The performer therefore might form interactive relationships with a technological object if s/he seems to remain passive while technology appears to be active: for instance, when a performer plays a note or presses a button that sets an active chain of sound, or the ‘typical’ laptop performer’s role of sitting behind the computer appearing to be passive while triggering musical events that suggest activity. The performer might also form interpassive relationships with technology, when a technological object appears to remain passive while making the performer appear frantically active [Reuben 2011: 49].

Perhaps the best example of interpassive music in Reuben’s creative production is the piece *On Violence* (2012), where pianist Rei Nakamura plays hectically at the mercy of the live score and electronics, only to be able to occasionally enjoy some instants of relative tranquillity. *Ntrallazzu* is characterised by a similar alternation between passivity and activity, that characterises the relationship between the performers. In some moments, the score “waits” for an input from the performers, and vice versa. The performance of *Ntrallazzu 5* in João Pessoa⁸ was by far the one when this tense set of interpassive relationships was most appreciable. The simultaneous operation of two different Max/Msp patches involved the presence of two live scores and the concurrent triggering of two different sets of live electronics, which happened to also interact between each other. Several tweaks were made in order to alleviate the huge disruptions that this complicated set of interactions involved. Nevertheless, during the performance, the cello part did not end when it was supposed to end. In fact, after the appearance of the “end of the piece” sign on the violin projection, the cello score continued to run *ad infinitum*. In this situation, cellist Tom Drummond perhaps interpreted Reuben’s concept of “interpassive music” in its most literal sense: he visibly wanted the piece to end, but he continued to respond, almost mechanically, to the live score. This, in turn, created a palpable atmosphere of tension among the audience, with people distinctly wondering whether something was not working in the way it was supposed to work. Luckily, after some four minutes of interminable torment, the piece did end eventually (Fig. 3).

⁸ *Ntrallazzu 5*, for violin and cello, was performed during an open rehearsal by Rayssa Melo (violin) and Tom Drummond (violoncello), at the Universidade Federal da Paraíba, in João Pessoa, Brazil. In this version, the original intention of playing two Max/Msp patches on two different computers was actually satisfied, so that a complex web of *human vs. human*, *machine vs. machine*, and *human vs. machine* interactions took place successfully.

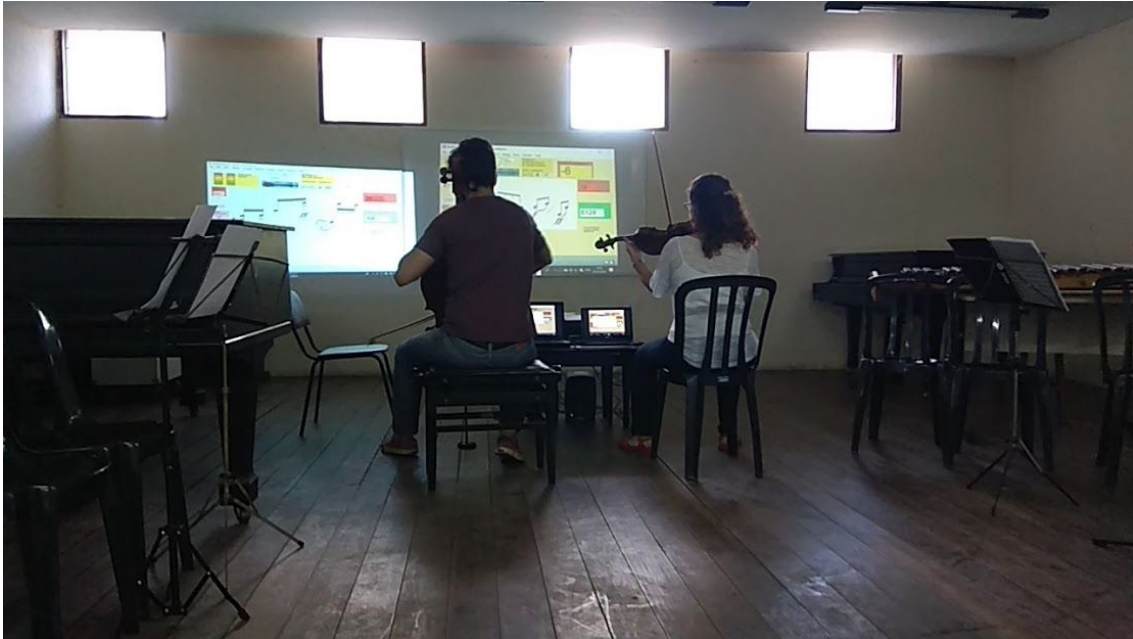


Figure 2. *Ntrallazzu 5*, performed at the Universidade Federal da Paraíba

3 Ubiquitous music, presence and absence

3.1 Metaphysics of presence

This last anecdote might help introduce another important aspect of interaction, that is intrinsic to the patch algorithm, which in turn is very simply calibrated to detect instrumental sound and discard background noise coming from the room and the audience. In this way, through simple operations of calibration, the patch crystallises some of the very discursive binaries that, in other ways, *Ntrallazzu* intends to challenge and question. By calibrating the patch in order not to interact with the “accidental” sounds produced by the audience, the piece explicitly confirms the operativity of these binaries, namely, sound vs. silence and instrumental sound (wanted) vs. background noise (unwanted), hence reproducing the border between performers and audience.

Furthermore, the live score is triggered by sonic activity from the instrument(s), and ends once they stop playing. Now, this is a rudimentary form of biometric detection that boils down to a recognition of the “living presence” of the performers, as well as a detection of their disappearance once they stop playing. At the end of the performance of *Ntrallazzu 2* in Lisbon, for example, the performers resorted to a simulation of their absence, that entailed a theatrical gesture of immobility. Leonardo Feichas and Daniel Sanches simulated their disappearance in order to trick the biometrical detection incorporated in the patch into assuming that they were no longer present, and thus stopping the piece.

Joseph Pugliese, after Derrida, calls “metaphysics of presence” [Pugliese 2014] this algorithmic reliance on detectable traits in order to ascertain the presence or absence of a human subject. As Pugliese notes, this reliance is potentially very problematic, both theoretically and practically. How can one distinguish physical “presence” from “non-presence” if the detection is based on electronic impulses that

might well be simulating the two states? Is it not always already a simulation that is at stake? In this sense, how do we distinguish real simulation from fake simulation? All this, in practical terms, makes *Ntrallazzu* always vulnerable and somewhat unstable, a characteristic that is definitely a distinctive part of the piece.

As anticipated above, a moment from the Lisbon premiere of *Ntrallazzu 2* can be regarded as emblematic of these philosophical problems. Here the performers need to trick the software into assuming that they have become sonically inactive. This is obviously impossible in itself, as the concert hall is full of sounds in that very moment, coming from pretty much everywhere, the audience, the room, the very same performers, the very same program that runs the live score, etc. All the same, the performers managed to simulate their absence by stopping playing their instruments, also hoping that the program would not detect other environment noises and mistake them for instrumental sounds. Now, what happened next is that they excogitated an original way of replicating the simulation of absence in front of the audience, who was also watching them. They remained totally still as if waiting, ready to play the next fragment, which never came. All this theatrical arrangement was ultimately inspired by John Cage's *4' 33''* (1952).

3.2 Ubiquitous music

Ubiquitous music seeks to transcend the rigid separations of roles and social practices on which (Western) art music is predicated, through the use of technological devices that have the potential to grant universal access on the making and consumption of music. Keller et al. illustrate that

Previous musical practices provided the safe refuge of instruments as the physical support for all soundproducing actions. These actions could be encoded as a series of discrete symbols - a score - which would guide the performers through a finite set of possible interactions with their instruments. Performances would occur within a space especially designed for musical activities - the concert hall - guaranteeing acoustic characteristics compatible with instrumental sound source power and projection. Furthermore, a crisp separation between performers and public, following an established ritualized set of actions - play / listen, bow / applaud - reinforced by the physical separation between stage and audience seats, allowed for strictly predefined roles in music making: musicians play, spectators just listen. Most of this social paraphernalia breaks down in the context of ubiquitous musical practices [Keller et al. 2010, p. 320].

We claim that *Ntrallazzu* qualifies as “ubiquitous music”, in that, primarily, it blurs the separation between performers and audience by projecting the score and letting spectators appreciate the interaction. In this way, the “mysterious” ritual of score following, that is normally negotiated among the performers, is opened to the general public. In turn, this allows for a mitigation of the strict protocol of ceremonial actions such as bowing and applauding, as the score flags the end of the piece, leaving no room for surprise awkward doubts. We have already mentioned Luzilei Aliel's premiere of *Ntrallazzu 4* and the fact that a sound/video technician decided to turn off the projection in the middle of the performance. Supposedly, even in that context, the “mystery” of score following was deemed to belong too exclusively to the performer, in a way that

any form of audience participation in the process was unmistakably categorized as an error.

Among other things, *Ntrallazzu 4* has already been the object of research in ubiquitous music, due to the fact that Aliel layered effects generated by other patching programs (Pure Data) with the effects that were already taking place through the *Ntrallazzu Max* patch. This made the live interaction more complex and unpredictable. Messina and Aliel (2019) have sardonically described this process as a substantial “hijacking” of the original piece, that nevertheless had the merit of “opening a wide range of unforeseen possibilities” dialoguing “with ubiquitous music and with the transcendence of the rigid separation of roles (in particular, composer vs. performer) and social practices on which (Western) art music is predicated, through the use of technological devices that have the potential to grant universal access to the making and consumption of music” [Messina and Aliel 2019: 693]. This last sentence needs also to be read in light of the fact that in *Ntrallazzu 4*, a patch compiled in an open source environment such as Pure Data hijacks the original piece that runs on a proprietary software (Max), literally redeeming the piece and opening up new possibilities for its consumption [cf. Puckette 2004; Messina 2017]. The “hijacking” of the original piece was also signified critically through the Heideggerian concept of *Gelassenheit* [Messina and Aliel 2019], that has been abundantly used in the context of ecologically grounded creative work [Carson 2020; Aliel, Keller and Costa 2018].

During the conference Balance-Unbalance 2018, a standalone, unnumbered version of the piece was prepared for a constantly running installation, scheduled on a different time and venue than Leonardo Feichas's performance of *Ntrallazzu 3*.⁹ On that occasion, the audience was able to read and perform a text-based live score from a screen, based on discursive instructions. In this way, the participation in the creative process was extended to the general public, also exploring the potentialities of what Keller et al. (2020) and Keller and Feichas (2018) have described as Creative Semantic Anchoring (ASC). ASC is also relevant to another text-based piece of the cycle, namely, *Ntrallazzu 6*,¹⁰ where articulated sentences were meant to dialogue with the historical and philosophical premises of the cycle. In *Ntrallazzu 6*, the lack of interaction of the voice with any acoustic instrument was compensated by the insertion of a MIDI-Out keyboard plugged to the patch — arguably, this element further decentred the ecological balance of improvisation away from the human being as the principal and exclusive agent of the creative process.

⁹ Again, *Ntrallazzu 3* was developed before *Ntrallazzu 4*, but happened to be performed a few days later by Leonardo Feichas (violin), at the Patching Zone, Rotterdam, Netherlands, as part of Balance-Unbalance 2018, and then again in Pelotas, at the Universidade Federal de Pelotas, as part of the 29th Congress of the National Association of Research and Postgraduate Studies in Music (ANPPOM). This particular version is, contrarily to the last one, characterised by one performer playing only one instrument. Therefore, there are no duets, but also no multiple instruments played by only one performer: this makes the interaction happen only between the performer and the program, with no human vs. human interaction and no instrument vs. instrument interaction.

¹⁰ *Ntrallazzu 6* was performed by Marcello Messina in Marseille, on the occasion of the 14th International Symposium on Computer Music Multidisciplinary Research (CMMR), during the UbiMus workshop that took place on 18 October 2019.

4. Final remarks

Overall, in *Ntrallazzu 2*, as in most of the other pieces of the cycle, the performers found themselves tricking the program into assuming that they had become absent, while at the same time they were tricking the audience into thinking that the piece had not ended yet, and that they were preparing for the next move. As illustrated above, this has worked more or less successfully, depending on the specific performance. In any case, we are in the presence of a double simulation, that involves communicating one thing to the audience and the very opposite thing to the machine. This, again, complicates immensely the concept of “presence” as something that always already exists as a simulation.

In *Ntrallazzu*, the “biometric detection” of the presence and absence of the musicians is always at risk of either being disrupted by unpredictable circumstances, such as audience noise, etc., or of being deliberately simulated or dissimulated by the musicians. As we have seen above, the audience participates in the dialogue between the musicians and the machine, by playing an interpassive role, whereby it can surveil the gestures of the musicians while also disrupting their communication with the machine by altering sound detection. As seen above, the audience has to be taken seriously into account when simulating any status with the machine. This participative role granted to the audience certainly approximates *Ntrallazzu* to an experiment in ubiquitous music, whereby the common rituals associated with music performance are deliberately disrupted.

Finally, and taking another cue from Joseph Pugliese, we need to acknowledge that the bodies of the musicians have “already been technologised” [Pugliese 2014: 665] before the biometric detection operated by the patch. First, that is because the human/instrument combination is a fundamental interaction that is already technological, and that, in the narratives that inscribe (Western) art music, traces a fundamental border between musician and listener. The instrument, here, awards access to some subjects while simultaneously preventing everyone else from accessing music making. More in general, the a priori “technologisation” that marks the bodies of the musicians even before the addition of live electronics might be understood as part of what Pugliese and Stryker call “somatechnics” (2009), that is, the intersection between the body as a physical, natural object and the very same body as a discursive, biocultural artifact that is always determined socially. Somatechnics makes the task of detecting physical presence through physical sound even more problematic, and confirms that *Ntrallazzu*, as a work of art, remains a highly fragile and unstable construction.

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Tapetes Musicais Inteligentes: um artefato musical computacional ubíquo para apoiar a educação básica

Thiago Marcondes Santos¹, Denise Filippo², Mariano Pimentel³

^{1,3} PPGI-Programa de Pós-Graduação em Informática – Universidade Federal do Estado do Rio de Janeiro (UNIRIO) Av. Pasteur 458, Térreo, Urca, 22290-240, Rio de Janeiro, RJ, Brasil.

² Escola Superior de Desenho Industrial (ESDI) – Universidade do Estado do Rio de Janeiro (UERJ) R. Evaristo da Veiga, 95, Centro, 20031-040, Rio de Janeiro, RJ, Brasil

{thiago.marcondes, pimentel}@uniriotec.br, dfilippo@esdi.uerj.br

Resumo. A lei 11.796/ 2008 (BRASIL,2008), ao tornar o ensino de música um componente obrigatório no currículo de artes da educação básica brasileira, aumentou a demanda das escolas por práticas e ferramentas pedagógicas na área de educação musical. Neste artigo apresentamos os Tapetes Musicais Inteligentes (TMI), um artefato que foi desenvolvido com o objetivo de investigar um instrumento musical computacional ubíquo para apoio à educação musical na educação básica.

Abstract Law number 11.796/ 2008 (BRAZIL, 2008), by making music a mandatory component of the arts curriculum in Brazilian elementary education, has increased the demand in schools for pedagogical practices and tools in the field of music education. In this article, we present the Smart Musical Mats (SMM), an artifact that was developed with the aim of investigating an ubiquitous computer musical instrument to support music education in elementary schools.

1. Introdução

As mudanças tecnológicas que os computadores trouxeram ao cotidiano da sociedade multiplicam-se em variados campos de aplicação. Esta multiplicidade de opções acentua-se quando a computação também se espalha fisicamente pelo ambiente. Weiser (1991) anteviu este momento e cunhou o termo Computação Ubíqua. Ele percebeu que a diminuição dos componentes computacionais implicaria em uma revolução na forma de perceber e atuar com os computadores em nossas vidas: cada pessoa teria não só um, mas vários equipamentos computacionais. Sua visão mostrou-se acertada, pois hoje testemunhamos não apenas celulares, tablets, consoles de games, mas também assistentes pessoais, como o Google Home e Alexa, e pulseiras, aspirador de pó, fechaduras, lâmpadas e carros inteligentes. Neste artigo nos concentraremos em implicações da Computação Ubíqua em um contexto específico: a Educação Musical na escola básica. Para tal apresentamos os resultados de minha pesquisa de mestrado (Santos, 2015)

juntamente com o artefato desenvolvido e tecemos considerações e reflexões sobre a relação entre este artefato e a Ubimus.

A Seção 2 aborda nosso entendimento do que é a educação musical e seus objetivos, enquanto a Seção 3 trata da Computação Ubíqua e dos desdobramentos da sua relação com a música e alguns exemplos de linhas de pesquisa da Ubimus juntamente com conceitos importantes que emergiram destas pesquisas. A Seção 4 apresenta um artefato projetado e investigado em contexto para apoiar a educação musical presencial na escola básica juntamente com os aspectos metodológicos desta pesquisa. A Seção 5 traz os resultados de nossa investigação sobre o artefato e concluímos na seção 6 com nosso entendimento sobre o atual momento da relação entre computação ubíqua, música, educação, e seus possíveis desdobramentos para o futuro.

2. Educação musical e algumas conjecturas teóricas

Para melhor entender o objetivo da educação musical na educação básica precisamos definir nosso entendimento sobre o que é educação musical e como os estudantes se relacionam com a música em seu processo de aprendizagem. Para isso trouxemos uma premissa e três conjecturas oriundas de nosso quadro teórico que nortearam a construção de nosso artefato.

2.1. A Música como discurso

A natureza discursiva da música é abordada por Sloboda (1997) e Serafine (1988) e aqui tomamos o cuidado de não igualar música como linguagem e sim observar estruturas semelhantes entre as duas manifestações. A natureza da música não permite o surgimento de signos, uma vez que as articulações entre os sons não implicam em apenas uma interpretação ou intenção. No entanto, podemos considerar a música, metaforicamente, como um tipo de linguagem, já que possui uma estrutura com intencionalidade que visa algum tipo de comunicação. Mesmo que esta comunicação seja feita de forma mais aberta que a comunicação verbal em relação à sua interpretação, isto nos basta para nossas considerações sobre a educação musical. A música então pode ser considerada como um tipo de discurso.

Swanwick (1979) defende a natureza discursiva da música e chama a atenção para o papel que a educação musical deve assumir. Ele considera que a educação musical tem por objetivo capacitar o estudante para se expressar através deste discurso e também para ser capaz de reconhecer as diferentes formas de se expressar de outros participantes de discursos musicais, em sua época ou em outros tempos.

Swanwick (1979) também destaca dois tipos de manifestações sonoras: o material sonoro e o elemento musical. *Material sonoro* é qualquer som que pode ser percebido, mas não é intencional e não tem um caráter relacional. Por exemplo, o som de chuva, o som de um copo que cai, uma nota musical (altura definida) tocada aleatoriamente (como quando o instrumentista afina seu instrumento). Já o *elemento musical* é um *material sonoro* que, devido à intenção de seu executor adquire um caráter relacional e se transforma em elemento a favor do discurso musical.

Ao considerar a música como um tipo de discurso, podemos então usar a conceito de letramento proposto por Soares (2004): “*letramento é um processo que visa a tornar o sujeito cada vez mais capaz de se expressar naquela linguagem e compreender bem o discurso elaborado pelos outros*”. Com base no que foi apresentado, partimos então de

uma premissa: *a educação musical deve apoiar o letramento dos estudantes no discurso musical.*

2.2. A diminuição das barreiras técnicas para a produção do discurso musical

Educadores como Orff (Frazee & Kreuter, 1997) buscavam facilitar a produção do som utilizando instrumentos como o metalofone e o xilofone, que possibilitam a geração do som sem muito esforço técnico. Adicionalmente, o xilofone, por ser construído com barras que podem ser retiradas, possibilita ser configurado para que sejam evitados determinados erros por parte do estudante num dado exercício: por exemplo, é possível retirar barras deixando apenas o subconjunto específico de notas com as quais ele vai trabalhar em sala de aula. Evita-se assim, problemas com questões de execução técnica, como notas excedentes que podem induzir o estudante ao erro. Consideramos então nossa primeira conjectura: *a diminuição das barreiras técnicas na produção sonora apoia o letramento no discurso musical.*

2.3. O caráter social da educação

Vygotsky (1989) defendia que a interação social apoia a educação. Desta forma, a aprendizagem não seria facilitada apenas pela mediação docente, mas também pela colaboração entre os estudantes. A aprendizagem seria então uma consequência cultural, decorrente do contato do sujeito com outros sujeitos que também manipulam e experimentam os objetos de estudo. Baseando-se nesta característica da educação formulada por Vygotsky, chegamos à nossa segunda conjectura: *a colaboração apoia o letramento no discurso musical.*

2.4. A relação entre o corpo e a aprendizagem

Autores como Dalcroze (1921) e Orff (Frazee & Kreuter, 1997) também defendiam o uso do corpo e do movimento através de gestos como intermediadores do processo de conhecimento musical, dando suporte ao entendimento e à assimilação do discurso musical. Atividades de aprendizagem que privilegiam tanto os aspectos intelectuais e corporais têm um maior impacto na percepção e na aprendizagem dos indivíduos envolvidos no processo. Apoiados por estes autores, nossa terceira conjectura diz que: *o uso do corpo e de seus gestos apoia o letramento no discurso musical.*

Após apresentar nosso entendimento de como as pessoas se relacionam com o discurso musical, abordaremos a seguir as possibilidades de construção de artefatos computacionais diante dos avanços tecnológicos da computação nos últimos anos.

3. Música e Computação Ubíqua

A relação entre a música e a computação ubíqua é relativamente recente e vem sendo investigada há mais de uma década. “*Música ubíqua é, na prática, música (ou atividades musicais) suportada(s) por conceitos e tecnologias da computação ubíqua*” (Pimenta et al., 2015) A pesquisa em Ubimus é caracterizada por diferentes áreas de atuação e investigação incluindo “*a computação sonora e musical, as interfaces humano-computador, os estudos sobre criatividade e a educação musical, possuindo um forte apelo social e comunitário em suas práticas*” (Keller et al., 2019). Tais pesquisas contemplam a participação em contextos musicais artísticos (Keller & Capasso, 2006) e educacionais (Lima, Keller & Flores, 2018; Keller & de Lima, 2018 ; Miletto et al., 2011)

tanto de sujeitos já familiarizados com técnicas musicais como músicos profissionais ou experts, como também de leigos.

Alguns conceitos importantes são apresentados nas pesquisas de ubimus como a criatividade musical cotidiana e as práticas criativas cognitivo ecológicas. Segundo Keller et al (2013) a criatividade musical cotidiana seria uma forma específica de criatividade cotidiana ou little-c creativity (Richards, 2007) e seria “*decorrente dos processos e dos produtos criativos sonoros que ocorrem no dia-a-dia de músicos e leigos fora dos ambientes específicos projetados para o fazer musical.*” Já as práticas criativas cognitivo ecológicas são o resultado da interação entre sujeitos, com seus processos cognitivos, e os recursos materiais presentes no ambiente onde se encontram (Keller & Lazzarini, 2017).

Keller e Barreiro (2018) também chamam a atenção para a existência de duas forças de atração predominantes nas pesquisas em Ubimus: os estudos sobre a criatividade (musical) cotidiana e as novas formas do fazer musical.

A primeira força de atração está nas práticas criativas cotidianas onde existem questões que surgem em relação ao perfil dos usuários e aos desdobramentos que esses diferentes perfis impõem ao design das interações presentes nos sistemas de ubimus desenvolvidos. Usuários leigos em relação ao conhecimento e habilidade musical impõem demandas diferentes em relação a usuários experientes. Desta forma podem ser desenvolvidos diferentes tipos de sistemas para atender perfis específicos de usuários. Contudo problemas poderiam surgir quando ocorrer a mesclagem entre os dois perfis de usuários em uma mesma atividade musical e tal situação ainda precisa ser investigada e avaliada. Uma possível solução para este problema estaria na criação de estratégias de transferência de conhecimento entre os participantes leigos e experts através de pistas gestuais com movimentos corporais (Keller, Aliel & Siva, 2018). Outra possibilidade de solução do mesmo problema seria a transferência de conhecimento implícito dos participantes apoiada pela linguagem verbal evitando-se o uso de termos técnicos específicos musicais. Esta última abordagem pode também levar a inclusão de pistas semânticas em eco-sistemas de ubimus tendo como exemplo a ferramenta Playsound.space (Stolfi et al, 2018).

A segunda força de atração estaria nas novas formas de se fazer música e possui três aspectos distintos:

- 1- A mudança entre as fronteiras das interações entre compositores, audiência e performers durante a execução musical.
- 2- O impacto potencial da ubimus no desenvolvimento humano e no bem estar de seus usuários.
- 3- A influência das técnicas da computação ubíqua no desenvolvimento da ubimus.

Após investigar os diferentes trabalhos de ubimus e conhecer alguns conceitos importantes desta área de pesquisa algumas reflexões emergem. Para este autor a ubimus potencializa uma grande mudança nas relações entre os sujeitos que produzem sons com instrumentos sonoros e estes instrumentos. Desde a invenção dos primeiros instrumentos sonoros como flautas de ossos, ou tambores escavados em troncos ou no chão, o ser humano sempre teve de se adequar às características acústicas de seu ambiente e principalmente às características físicas do instrumento escolhido para intervir no ambiente. Era preciso criar um instrumento para traduzir as intenções sonoras do sujeito em vibrações sonoras que alteravam o ambiente, seja pela vibração de cordas, membranas

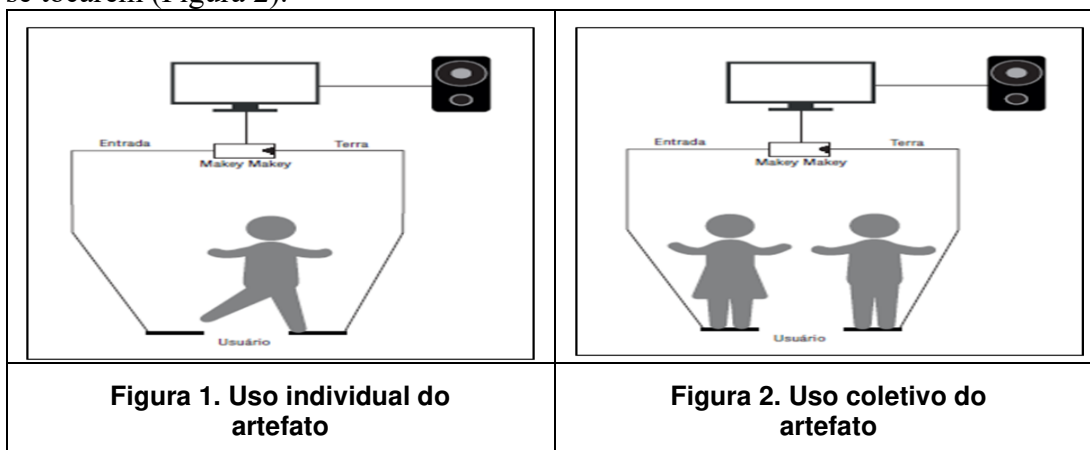
ou colunas de ar. Com o passar do tempo as técnicas de produção de instrumentos foram se desenvolvendo mas algumas características mecânica-acústicas dos instrumentos não eram possíveis de modificar. Por exemplo seria impossível construir um cavaquinho que soasse como um contra-baixo e alcançasse as mesmas notas. A produção de som e a técnica de execução sonora dos instrumentos acústicos está presa à suas características físicas (como forma e materiais constituintes) pois são estas que interagem fisicamente com o ambiente para produzir som. As consequências ergonômicas e de postura são inúmeras e o ser humano sempre foi dependente da característica física do instrumento sonoro para poder aprender como usar o seu corpo para acionar o instrumento. O corpo do ser humano se molda então ao corpo do instrumento. A ubimus apresenta um novo paradigma de interação entre o corpo do usuário e o instrumento sonoro e também em relação às formas de colaboração entre os usuários. Com a miniaturização da computação e seu consequente espalhamento pelo ambiente não só é possível criar sons digitais, que não mais dependem das características físicas dos instrumentos para serem produzidos pois estão virtualizados em receitas de código binário, como também é possível partir das características do corpo humano e seu funcionamento para criar técnicas de movimentos que são traduzidas em sons. Agora podemos moldar o instrumento sonoro digital às características do corpo do usuário invertendo as relações ergonômicas entre instrumentista e instrumento e também moldar o artefato ao ambiente onde as atividades ocorrem.

4. Tapetes Musicais Inteligentes

O artefato desenvolvido, denominado Tapetes Musicais Inteligentes (Santos, 2015), é composto por um conjunto hardware e software.

4.1. O hardware

Composto por tapetes de borracha, fios elétricos, uma placa USB (Makey Makey), um computador (laptop) e caixas de som. O Makey Makey (2020) detecta quando circuitos elétricos são fechados e emite comandos para o computador emulando o acionamento de teclas e movimentos do mouse. Os fios são conectados aos tapetes, permitindo que os usuários fechem os contatos e disparem os comandos para o software no computador. Os comandos feitos pela placa podem ser acionados por uma pessoa, pisando em ambos os contatos de entrada e de terra simultaneamente (Figura 1), ou pode ser feito por duas pessoas, uma pisando em um contato de terra e outra pisando no contato de entrada, ao se tocarem (Figura 2).



4.2. O software

O Soundplant é proprietário, mas tem uma versão gratuita que foi usada na pesquisa. Este software endereça diferentes amostras de áudio (em formatos como wav, aiff, mp3) para as teclas do computador e, quando a tecla é acionada, ele dispara o som em questão. O Makey Makey pode então acionar o software Soundplant, e sons de amostras de áudio escolhidas pelo usuário são disparados no computador e são escutados por meio da caixa de som. Uma limitação presente nesta versão do artefato é o fato de o usuário enquanto está produzindo os sons não poder alterar o volume das amostras sonoras disponíveis. Desta forma questões musicais referentes à dinâmica ainda não podem ser exploradas nesta versão do TMI e podem ser investigadas em pesquisas futuras.

4.3. Aspectos metodológicos e epistemológicos da pesquisa

A produção de conhecimento sobre o desenvolvimento de artefatos é o objetivo das Ciências do Artificial (Simon, 1969), que deve ser realizada de forma diferente das Ciências Naturais e das Ciências Sociais. Uma vez que este trabalho investiga um artefato que não é próprio da natureza, mas criado pelo homem, compreendemos que esta pesquisa está no contexto das Ciências do Artificial, conforme detalhamos nesta seção.

4.3.1. Metodologia-epistemologia

O conhecimento técnico que é gerado ao longo da construção de um artefato é diferente do conhecimento científico gerado por uma pesquisa. A fim de realizarmos uma pesquisa que gere conhecimento científico no desenvolvimento de nosso artefato, adotamos a abordagem epistemológica-metodológica Design Science Research - DSR (Figura 5). Esta abordagem, que está apoiada nas Ciências do Artificial, tem duplo objetivo de: (1) desenvolver um artefato para resolver um problema prático num contexto específico e (2) gerar novos conhecimentos técnicos e científicos (Dresch et al., 2015). Numa pesquisa realizada com a abordagem DSR, o desenvolvimento do artefato apoia o avanço da teoria sobre o comportamento dos usuários, que, por sua vez, apoia o desenvolvimento do artefato. Isso ocorre num processo iterativo em que ambos se refinam mutuamente. Em DSR, é utilizado o pensamento abduutivo típico do trabalho projetual, em que são identificadas alternativas e selecionadas soluções, diferentemente do pensamento indutivo, dedutivo e hipotético-dedutivo.

Nesta pesquisa desenvolvemos um artefato didático-musical (os tapetes), para resolver um problema real (dependência no aprendizado da técnica de um instrumento para o aluno poder ter entendimento de conceitos musicais), num contexto sócio-técnico (a Educação básica). Concomitantemente, durante o desenvolvimento do artefato, investigamos as conjecturas teóricas sobre ensino de música (seções 2.2 a 2.4) neste novo contexto em que se utiliza um artefato apoiado pela tecnologia computacional ubíqua. Assim, nesta pesquisa estão envolvidos o artefato, seu desenvolvimento e os usos e relações dos participantes com este artefato.

4.3.2. Produção de dados

Utilizou-se o método de pesquisa estudo de caso seguindo uma abordagem qualitativa com posição epistemológica interpretativista (Pimentel et al., 2017) tipicamente utilizada nas Ciências Sociais: esta tem como objetivo extrair valores e conhecimentos sobre o

comportamento das pessoas em um determinado contexto através da interação do pesquisador com os participantes da pesquisa. A técnica de produção de dados foi feita com questionário e grupo focal para os alunos, entrevistas com os professores e observação direta do pesquisador. O estudo de caso foi feito com 2 turmas de 7º ano de escolas municipais do Rio de Janeiro, totalizando 75 alunos. Foram desenvolvidas 4 atividades educacionais para apoiar a investigação da aceitação e do uso do artefato nas aulas de música e também algumas conjecturas levantadas por nosso grupo de pesquisa sobre como as pessoas aprendem música. As mesmas atividades foram realizadas nas duas escolas em oficinas pedagógicas e duraram aproximadamente 3 meses no ano de 2014.

Segundo Candau (1999), as oficinas pedagógicas são uma atividade formativa que é realizada em espaços e grupos com um caráter interativo e dialético. Para esta autora, os trabalhos de formação de conhecimento nas oficinas pedagógicas acontecem em um ambiente com as seguintes características:

[...] espaço de construção coletiva de um saber, de análise da realidade, de confrontação e intercâmbio de experiências, de exercício concreto dos direitos humanos. A atividade, a participação, a socialização da palavra, a vivência de situações concretas através de sociodramas, a análise de acontecimentos [...] são elementos presentes na dinâmica das oficinas (Candau, 1999, p. 23).

As perguntas do grupo focal foram: O que você achou das atividades feitas com o equipamento? Você teve alguma dificuldade para usar o equipamento? O que você aprendeu nas atividades? Você gostaria de fazer outra aula com o equipamento?

As entrevistas com os professores foram semi-estruturada com tópicos definidos sobre os quais conversamos livremente. Foi utilizado o Método de Explicitação do Discurso Subjacente (Nicolaci-da-Costa, 2007) para a análise e interpretação dos dados obtidos no grupo focal e nas entrevistas com os professores das turmas.

4.3.3. Avaliação do artefato

Fizemos três avaliações com o artefato: a aceitação do artefato pelos usuários, a avaliação das conjecturas trazidas de nosso quadro teórico sobre a educação musical com o uso do artefato e se nosso problema de pesquisa foi resolvido.

Para avaliar a aceitação do artefato usamos um modelo estendido de aceitação de tecnologia o UTAUT2 (Venkateshet et al., 2012) e consideramos que o artefato Tapetes Musicais Inteligentes deveria satisfazer os seguintes constructos: *ter boa performance* (possibilitar explorar adequadamente o discurso musical), *baixo esforço de uso* (ser fácil de usar), *promover motivação hedônica* (ser divertido de usar), *ter intenção de uso* (os alunos gostariam de usar o artefato em outras aulas) e *baixo preço*. Não consideramos *Hábito* como um constructo relevante para a adoção do artefato aqui proposto, já que este é um artefato inédito. Sobre o constructo *Influência Social*, consideramos que existe uma certa pressão da sociedade, dos pais e dos alunos, para que a escola faça uso das tecnologias computacionais na educação e, neste sentido, o fato de estarmos projetando um artefato computacional ubíquo qualquer já corroboraria para a intenção de uso; por isso, este constructo também não foi investigado no estudo com o artefato projetado, embora influencie positivamente a sua adoção. O modelo também tem um constructo *Condições facilitadoras* que diz respeito à operacionalidade e montagem do artefato e este constructo foi avaliado na entrevista com os professores. Tais constructos nortearam

as questões presentes no questionário e nas perguntas do grupo focal e entrevistas com os professores das turmas.

Esta pesquisa foi aprovada pelo comitê de ética da Universidade Federal do Estado do Rio de Janeiro - Número do Parecer: 893.135. Data da Relatoria: 26/11/2014.

5. Resultados

Apresentamos aqui os relatos dos estudantes de forma a dialogar com nossas três conjecturas teóricas e com os constructos do modelo de aceitação de tecnologia UTAUT2. A análise de todas essas informações nos permite avaliar se nosso artefato resolveu o problema de pesquisa. Também apresento ao final desta seção os resultados mais relevantes do questionário apresentado aos estudantes.

5.1. A diminuição das barreiras técnicas apoia o letramento musical

Os estudantes acharam que o artefato possibilitou uma fácil produção de som e eles puderam dar atenção ao discurso musical: *“Tive só de esperar o momento certo de bater. Tinha vezes que eu tinha dificuldade, mas depois eu fui pegando”*. Na entrevista com o professor desta turma, perguntei o que ele achou da facilidade que os estudantes tiveram para usar o artefato, e o professor considerou que a dificuldade para tocar pelo artefato se equivale a aprender um instrumento qualquer: *“Acho que eles tiveram as dificuldades normais de se aprender um instrumento novo. Eles têm aquela trava no começo e depois vão desenvolvendo com mais facilidade”*. No entanto, os estudantes apresentaram uma opinião diferente, consideraram o artefato mais fácil de tocar do que os instrumentos musicais tradicionais: *“Eu gostei porque é um instrumento tecnológico e mais fácil de tocar. Antes para aprender um instrumento é meio difícil, você tem que treinar. Eu gostei de participar de um experimento desses”*; *“Eu achei legal porque eu achei mais fácil de tocar e mais fácil de aprender. É mais fácil de prestar atenção porque os outros, os instrumentos tradicionais, a gente demora muito para aprender”*. Uma vez que a maioria dos estudantes tem instrumentos musicais tradicionais em suas casas (conforme resultado obtido por meio de questionário), as opiniões destes estudantes estão embasadas em experiências, o que nos oferece indícios para afirmar que os estudantes, de fato, consideraram que o artefato possibilitou produzir som mais facilmente do que com instrumentos tradicionais.

5.2. A colaboração apoia o letramento musical

Alguns estudantes destacaram a interação que estabeleceram com seus colegas: *“Eu gostei muito porque é bem ... interagi muito.”*; *“Eu achei bem interessante (...) Ainda mais que a gente trabalha em conjunto e o som fica bem melhor. Não tem uma pessoa trabalhando sozinha. Em vez de ficar decorando, a gente já tem o ritmo e aí fica mais interessante”*. Estas declarações identificam o caráter social na construção do discurso musical.

Na entrevista com o professor de uma das turmas, ele enfatizou a importância da colaboração entre os estudantes para a aprendizagem: *“Eu vi os estudantes colaborando bastante! Você pode aproveitar mais de uma criança para fazer o som. (...) O grande lance é que um estudante depende de outro estudante para fazer o som. Se um tiver mais habilidade e o outro menos habilidade, pode avançar um pouco no começo, mas também entra a questão de que um ajuda o outro a se desenvolver”*.

5.3. O uso do corpo apoia o letramento musical

O uso do corpo foi bem exercitado nas atividades, os estudantes usaram gestos para se expressar, e muitos correlacionaram os gestos com o aprendizado: *“Eu aprendi os ritmos com movimentos do corpo”*; *“Eu aprendi coordenação motora, a marcar o tempo, antes eu não tocava certo no tempo. O professor mesmo reclamava que a gente acelerava o ritmo aí foi acostumando e melhorando”*; *“Eu aprendi a coordenação motora e o tempo de cada nota (gestos de bater palmas). A sincronização é esperar o momento certo de bater”*.

5.4. Aceitação do artefato

Em relação à *expectativa de performance*, as atividades com o artefato possibilitaram uma vasta gama de experiências de aprendizagem entre os estudantes e o conteúdo das aulas. Alguns estudantes ressaltaram o que tinham aprendido nas atividades: *“Eu aprendi os acordes, o tempo que são usados. Sei lá ... eu aprendi a tocar os instrumentos sem ter de usar os de verdade”*. Em relação ao *esforço de uso*, alunos afirmaram que *“No início eu me atrapalhei com o ritmo, mas depois acertei”*; *“No início minha coordenação não era boa e eu acelerava o ritmo. Depois melhorou”*. Mesmo tendo dificuldades iniciais, os estudantes não se sentiram intimidados em explorar o artefato: *“Eu tive um pouco de dificuldade, mas não foi aquela dificuldade que pode dizer ... ah... foi muito difícil”*.

Em relação a *motivação hedônica*: *“Para mim é um instrumento novo que eu gostei, muito muito muito!!”*; *“No primeiro momento eu achei que não ia dar certo. Eu, fazer música com as mãos!! (risos) aí depois eu fui vendo que é bem divertido e legal e a gente aprende. No início fiquei com medo de levar choque”*.

O único constructo que não teve um bom desempenho nas investigações foi a *Condição facilitadora*. Nosso artefato é um protótipo e necessita de melhoras nos aspectos de montagem para que um leigo em informática possa montá-lo para as atividades de forma simples e rápida. Nas entrevistas os professores revelaram que gostaram das atividades e do artefato sendo usado pelos estudantes, mas não se sentiam aptos a montá-lo sozinhos. Desta forma ficam para investigações futuras outras formas de montagem do artefato para facilitar o uso por professores com conhecimentos básicos de computação.

Em relação ao baixo custo: todos os materiais envolvidos na construção do TMI são baratos e de fácil acesso no mercado: fios ethernet, papel alumínio, fita isolante, tapetes EVA, fita crepe. O custo do Makey Makey é R\$ 250,00 (US\$ 50,00) e o soundplant é um software com versão gratuita. O custo de um par de tapetes prontos para conectar ao Makey Makey é de aproximadamente: R\$ 25,00. Estes números estão perfeitamente condizentes com a realidade das escolas.

5.5. Dados dos questionários

Foram feitas perguntas em um questionário que foi apresentado aos alunos depois da última atividade da oficina. A parte inicial do questionário continha perguntas sobre o perfil dos alunos e a segunda parte continha perguntas sobre as atividades e o uso do artefato. Enquanto alguns alunos respondiam o questionário outros eram entrevistados no grupo focal para diminuir o tempo do processo de levantamento dos dados e assim não prejudicar o andamento das agendas escolares e planejamento dos professores de outras disciplinas. As perguntas da segunda parte do questionário apresentavam como

alternativas de respostas uma escala de likert com 5 valores abordando questões como dificuldade, prazer e satisfação em relação às atividades e ao uso do artefato.

Na *Escola 1* 75% dos alunos tinham 12 anos e o restante 13 anos, sendo 54% de gênero masculino. Nesta escola 68% dos alunos tinham algum instrumento musical em casa e 61% aprendem música exclusivamente na escola. Já na *Escola 2*, 46% tinham 13 anos e o restante 12 anos de idade além de 46% serem do gênero feminino. 69% dos alunos desta escola não possuem instrumentos musicais em suas casas e 77% aprendem música exclusivamente na escola.

Em relação às atividades com o uso do artefato na *Escola 1* 60% dos alunos acharam fácil e 10% difícil. Na *Escola 2* 85% acharam fácil e ninguém achou difícil. Em relação ao prazer em se usar o artefato nas atividades foram feitas duas perguntas sobre se era agradável e se era divertido. *Escola 1* teve 71% de alunos que acharam agradável e 10% desagradável. Outros 71% acharam divertida e 10% chata. Na *Escola 2* 69% dos alunos acharam agradável e 8% desagradável e 69% acharam divertido e 15% chata. Em relação à intenção de se usar novamente o artefato na *Escola 1* 75% alegou que sim e 25% que não. Na *Escola 2* obtivemos 85% para o sim e 8% para o não. Estas informações apoiam as análises sobre os constructos do UTAUT *Expectativa de performance*, *Motivação hedônica*, *Intenção de uso* indicando que a experiência de uso do artefato foi fácil de ser executada, prazerosa e deixou na maioria dos participantes a vontade de usar o artefato novamente. Estes dados ao serem triangulados com os dados produzidos no grupo focal e entrevistas com os professores indicam que o artefato tem potencial de aceitação pelos estudantes e seus professores.

6. Conclusão

Nosso problema de pesquisa está diretamente relacionado à nossa primeira conjectura sobre a diminuição das barreiras técnicas na produção sonora apoiar o letramento musical. Como em nossa avaliação dos resultados constatamos que houve diminuição das barreiras técnicas para a produção sonora e os estudantes conseguiam, sem demasiado esforço construir seu discurso musical consideramos que nosso problema foi resolvido. No entanto faz-se necessária uma maior investigação do artefato em outros contextos além do ensino fundamental 2 e das escolas públicas para termos maior confiabilidade nas tendências aqui apresentadas.

Em relação à aceitação do TMI pelos estudantes observamos que o artefato tem potencial de aceitação e seu uso em diferentes contextos e com diferentes perfis de usuários pode servir de base para investigações futuras. Destacamos que o artefato proposto não tem o objetivo de substituir os instrumentos musicais tradicionais, e sim ser apresentado como alternativa para aumentar as opções de ferramentas à disposição da construção do discurso musical pelos estudantes na escola.

O artefato também incentiva a colaboração entre estudantes e o uso dos seus corpos e seus gestos na construção do discurso musical. Da mesma forma que moldamos o artefato ao corpo do usuário este artefato também pode se moldar as características do ambiente onde a atividade ocorre, por exemplo a sala de aula. Tal fato também cria desdobramentos na forma de colaboração entre usuários de sistemas musicais computacionais ubíquos como no caso dos TMI (Santos, 2015). As possíveis configurações físicas de disposição do artefato na sala de aula possibilitam o livre movimento dos usuários e a observação dos gestos de outros participantes, incrementando

as interações e as formulações de suas hipóteses sobre a construção do discurso musical. Uma vez que a produção de som no artefato não demanda tanto esforço cognitivo os usuários podem direcionar sua atenção para o ambiente onde se encontram e trocar informações com outros usuários, sejam verbais ou gestuais. Sendo assim o TMI pode apoiar investigações nas pesquisas de ubimus nos contextos de criatividade musical cotidiana e também possibilita investigações nas formas de interação dos usuários com o artefato e entre si apoiando também pesquisas na área da colaboração e design de interação.

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Can Pipe-and-Filters architecture help creativity in Music?

Rômulo Vieira¹, Flávio Luiz Schiavoni¹

¹ Arts Lab in Interfaces, Computers, and Everything Else - ALICE
Federal University of São João del-Rei - UFSJ
São João del-Rei - MG - Brazil

***Abstract.** Ubiquitous Music is an emerging field of study that addresses how human agents can use computing, in the most diverse ways, to create music, an activity that is characterized by pragmatic and epistemic actions, restricted by natural and social means. In addition, this area of expertise seeks to create tools that support creativity. Thus, this paper discusses how the Pipe-and-Filters architecture, common in software development, can help in creativity and music creation, either by being present in applications that exploit this, or by the logical way in which it is structured.*

1. Introduction

A striking feature of Ubiquitous Music is that all agents in a music performance must be able to influence sound results [Keller et al. 2010]. It includes the audience's members, normally lay-musicians, taking part of the performance and the creative process of music making. It should also be noted that this technique helps in making music a social activity, without pre-defined roles, placing experts and novices side by side [Schiavoni and Costalonga 2015].

The inclusion of everyone in the creative process of music is certainly a task that can bring several challenges to be executed. Among its challenges are: assisting creativity, facilitating laypeople-musician interaction and interaction on fixed and portable devices. There are also ethical dilemmas, such as participation, inclusion, human development and sustainability involved in the decision of taking people as part of a musical presentation [Keller 2017].

To define and understand what creativity is has motivated researchers over the time. Although he was not the first to explore the subject, J. P. Guilford, then president of the American Psychological Association, is considered a pioneer in this type of research. Later, new researchers such as Margaret Boden, Ronald Beghetto, James Kaufmann and Cecília Salles added new topics to the discussion [Beghetto and Kaufman 2007].

Boden [Boden 1991] defines creativity as “*the ability to come up with ideas or artefacts that are new, surprising and valuable*”. She also attributes the characteristic as a natural condition of human beings, as well as thinking, perception and self-criticism. From there, she divides creativity into two fields: **Psychological creativity** (P-creativity) and **Historical creativity** (H-creativity). The first term is defined as a surprising, valuable and unprecedented idea for the person, even if it is a concept already known. As for H-creativity, it is defined as something new in human history [Boden 1991].

Within these two concepts, three other new forms of creativity emerge: **exploratory**, **transformational** and **combinational**. The first one involves making unknown combinations of familiar ideas. These new combinations can be generated deliberately or not, but in all cases creating this combination requires a rich reserve of

knowledge. The most common examples are poetic images, collages in paintings and analogies. The second way involves the transformation of already structured concepts of thought. They are usually from social group and religion, being occasionally affected by other cultures. But in both cases, they are there, they are not originated by an individual mind. Finally, the combinational structure, as the name implies, involves the combination of already familiar thoughts, again influenced by culture and social group [Boden 1991].

Beghetto and Kaufman [Beghetto and Kaufman 2007] define creativity as “*the ability to produce innovative (that is, original, unexpected), high quality and appropriate work*”. The authors further divide this field into four parts: **eminent creativity** (Big-c), which requires specialized knowledge and aims at creating professional products such as works of art or scientific theories; **professional creativity** (pro-c), which also requires specialized knowledge but whose result of the creative process does not have the same impact as eminent creativity; **everyday creativity** (little-c), which uses day-to-day experiences to generate creative products, and **personal creativity** (mini-c), characterized by internal, subjective and emotional aspects but which does not necessarily aim at artistic products.

With regard to music creation, Bennett [Bennett 1976] divides the creative process into five stages and an independent final part of revision. The stages are: **germinal idea**, **sketch**, **first draft**, **elaboration and refinement** and **final draft copying**. The independent internship is the review of all the process (Figure 1).

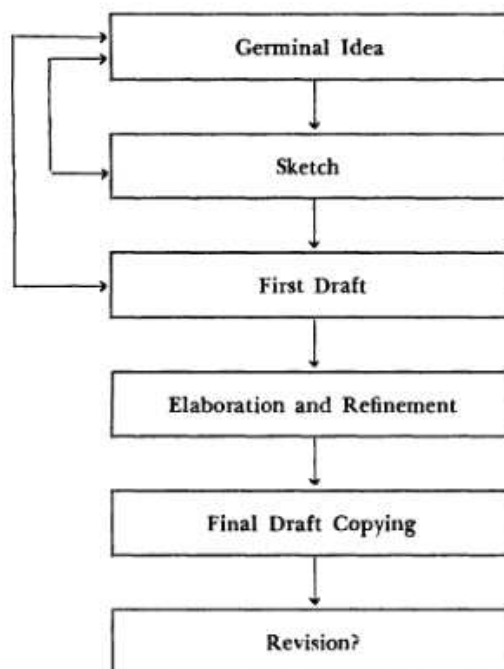


Figure 1. Creative flow elaborated by Bennett [Bennett 1976].

In this way, the process is triggered by a twin idea that expands to a first sample of the composition. At this point, Bennett suggests that a review of the initial idea already sets up a new draft, modifying the first idea. The material is then elaborated and improved, leading to the final composition. Once the work is finished, further revisions can be made.

A point worth mentioning in the model is that backtracking is considered part of the creative process [Bennett 1976].

Keller and others [Keller et al. 2014], after reviewing eight models of creativity in music production, identified three points of relationship with the dimensions of creativity, namely: **materials**, **procedures** and **context**. From this, they identified flaws in the methods of application in music, such as domain restriction and lack of material and social reasoning. Thus, they emphasize that the availability of resources interferes with the creative process.

A common option to face these challenges is to use computer and technologies to integrate people in creative tasks. It is also known that the computer has long been considered an extremely attractive tool for creating, manipulating and analyzing sounds. Its precision and potential for automation make it a useful platform for expression and experimentation. However, it is a fact only to the extent of what we are able to express to the computer to do and how to do it. In view of this reality, the most diverse environments appear to help in the creation and execution of music, including those aimed at lay people, both in the field of music and in the field of computing.

Maybe it is possible to identify a common architecture of these systems, called Pipe-and-Filters, presented in Section 2. In this section we present several examples of how this system architecture can be used to create complex applications combining simple parts of code, from the Unix Shell to sound processing.

At the end, in Sections 3 and 4, we present some discussion about how programming environments, in particular Mosaicode, can help the creativity and the creation of ubiquitous music and what were the conclusions and experiences resulting from this work.

2. The Pipe-and-Filters architecture

According to IEEE, software architecture is defined as a fundamental organization of a system and its components and the relationship between itself and the environment that guide its design and evolution. In short, architecture is about how is the interaction between components and not how they are implemented [Maier et al. 2001].

Nowadays, applications are becoming larger, more integrated with other applications and uses to use a wide variety of technologies. It is in this context that the software architecture is very important. A good architecture works to guarantee the quality of the software product, as well as its reliability and usability. In addition, it serves as a means of communication between the entire stakeholder, represents the initial decisions of the project, is the basis for detailing a work and can be a unit for reuse, which means that your model can be transferable between systems [Bijlsma et al. 2011, Agostini et al. 2019].

There are different types of software architectures, such as: Data Abstraction and Object-Oriented Organization, Event-based, Implicit Invocation, Layered Systems and Pipe-and-Filters. The Pipe-and-Filters architecture, focus of this paper, is a division of a complex task into several sub tasks, implemented by a software component called filters. Filters have multiple inlets and outlets connected to pipes, but never know the characteristics of adjacent filters. The pipeline, on the other hand, is responsible for performing the communication between two software components and acting as data buffers between the adjacent filters. The logical functioning of this model can be seen in Figure 2

[Bijlsma et al. 2011, Avgeriou and Zdun 2005].

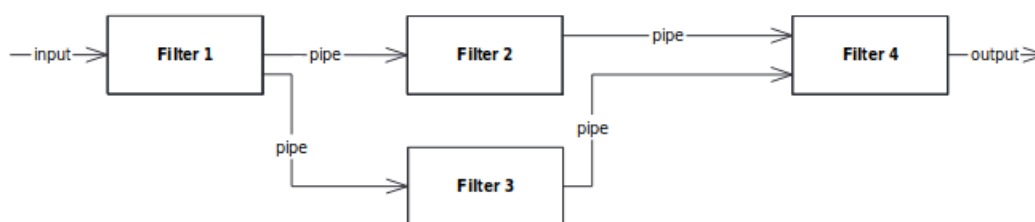


Figure 2. Pipe-and-Filters example [Bijlsma et al. 2011].

The pipe connector is considered to be a key part of the data flow transfer. Because of this, flexibility at the moment of connection is one of the main characteristics of this architecture, as it allows customized assemblies for each specific problem. With regard to data transfer, the flow is constant [Medvidovic and Taylor 2010, Bass et al. 2003].

This type of pattern is very popular and, because of that, adopted in several systems, mainly to manipulate different sets of data in different ways. The use of this model is advisable when little contextual information needs to be kept between the components and the filters are not able to maintain their states. They can still be an alternative to other architectures or work together with them. More directly, they are widely adopted in compilers and the UNIX shell, sound processing and sound programming.

2.1. The UNIX Shell

Created in the 1970s, for minicomputers and mainframes, the UNIX system has become increasingly popular and has moved to workstations and personal computers, going well beyond the use of it by academics or specialists. During that period, he also received several nomenclatures for variations, such as Ultrix, Xenix and Linux [Newham 1998].

In general, the shell is any interface that receives commands or text scripts from the user and converts them in instructions understandable to the operating system. Users typically interact with a Unix shell using a terminal emulator, however, direct operation via a serial hardware connection, or computer network session is common for server systems. The shell, in turn, provides basic commands, such as chaining, command substitution, control structure and conditional testing. These commands, also known as tools, do everything from counting the number of lines in a file, sending electronic mail, to displaying a calendar for any desired year [Newham 1998, Salus 1994].

Another advantage of UNIX shell is that it allows effective connection of simultaneous commands. This connection precisely follows the Pipe-and-Filters architecture. Therefore, it allows the output of one command to be directly connected to the standard input of a second command [Salus 1994, Rosen et al. 2007].

Here, filter terminology refers to any program that can receive input data and then perform some action on that input and send it to the output to be connected in another filter. More clearly, a filter is a desirable change that can occur in the communication between two programs in a pipeline. This makes shell programming extremely useful, providing a variety of tools for programmers and system administrators.

2.2. Pipe-and-Filters in sound processing

The spread of this architecture, or at least its main concept, was so vast that it also reached the field of sound processing. Take the famous Moog synthesizer (Figure 3) as an example. Created in 1964, this instrument was initially monophonic, with a reduced synthesis capacity, providing easy operation by the user, whether he is a musician or not. This feature of the instrument is analogous to the pipeline, where data is sent from a source to another [Trocco and Pinch 2004].

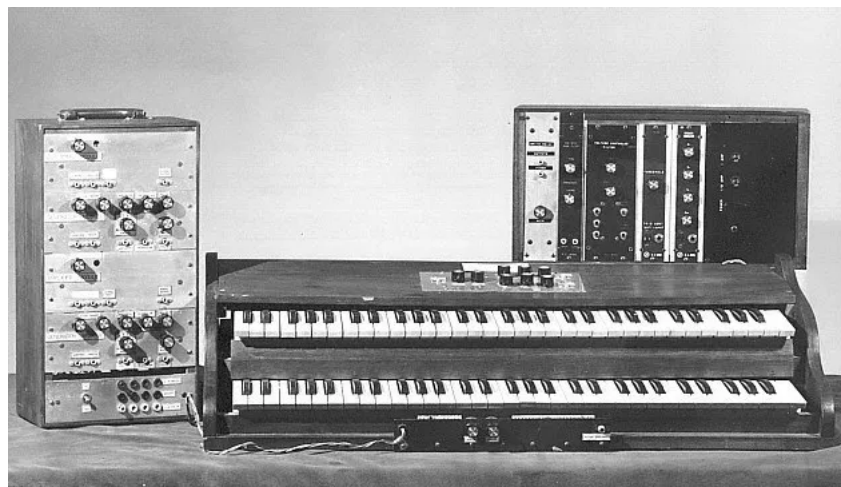


Figure 3. Early version of the Moog Modular [Trocco and Pinch 2004].

Another outstanding feature of this synthesizer is its constitution by separate modules and with specific functions, such as generating an envelope, oscillating the frequency of a note and applying a reverb to the sound. These functions are analogous to filters, capable of applying modifications to the data transmitted by the pipes, in this case, the cables physically connecting different unities. In this way, infinite possibilities have emerged with regard to the creation of sounds and music [Trocco and Pinch 2004].

In sound processing, Pipe-and-Filters architecture is not limited to synthesizers and it is present in several other situations. Effects pedals and pedalboards (Figure 4) for electric guitars work in the same way, that is, audio data generated by the resonance of the strings flows through cables until they reach the pedals. Then, data goes through an electrical circuit that changes the sound of the instrument. After transformation, data is sent to another pedal via another cable until it reaches the amplifier. Each transmission is carried out through a pipeline and each change in sound by a filter [Roberts 2019, Hunter 2013].

When concerning audio in studios and concerts, the same idea is present. A lot of sound sources, like microphones and instruments are connected by pipes, in this case, audio cables. The data is the audio signal and several different devices, like direct boxes, compressors, equalizers, and noise gates, act like filters changing the audio signal. The mixer receives all the pipes and connect them in a complex system, allowing inserts, effects and other filters to be connected. Sometimes, a patch bay is present to simplify the addition or removing of a new component. As an example of the pipes and filters architecture, in this system a audio processing unit is included in the mesh and does not know what is after or before it in the audio chain.



Figure 4. Pedalboard, a set of guitar pedals [Roberts 2019].

2.3. Pipe-and-Filters to music programming

Part of the musical creation can be done based on this architecture, especially using environments or languages of music programming. Even though it is not so explicit, Pipe-and-Filters is present in audio programming languages and environments, such as Pure Data, FAUST, SuperCollider, ChucK, and Mosaicode, for instance. For laymen, both in music and in programming, the advantage is that they can create something from the interconnection, combination and alteration of components, as well as their parameters.

Pure Data (Figure 5) is a graphical interface for real-time programming of audio and video. Its functionality is directed at an interaction similar to manipulating objects in the real environment, moving and connecting them in order to generate new combinations. For this, the language uses the interconnection of boxes that contain some command, forming a flow of information. At this point that it correlates with the Pipe-and-Filter, since the output from one control box will serve as an input to another box, and yet, the data undergoes some change by a filter. Pure Data can be found in several applications, like Reactable, a musical interface aimed at creating collaborative music, RJDJ app and the Networked Resources for Collaborative Improvisation (NRCI) library [Puckette 1998, Puckette 2011].

Functional AUdio Stream, popularly known as **FAUST**, is a high-level language, focused on digital signal processing, with special support for real-time audio applications and plugins on various software platforms, including mobile systems. Among its advantages are: easy creation and reading of command blocks, support for Graphical User Interface (GUI) and generation of C++ code from the created blocks [Michon and Smith 2011, Michon et al. 2019]. Its function is to describe a signal processor, which applies a mathematical equation to the input signals to produce output signals.

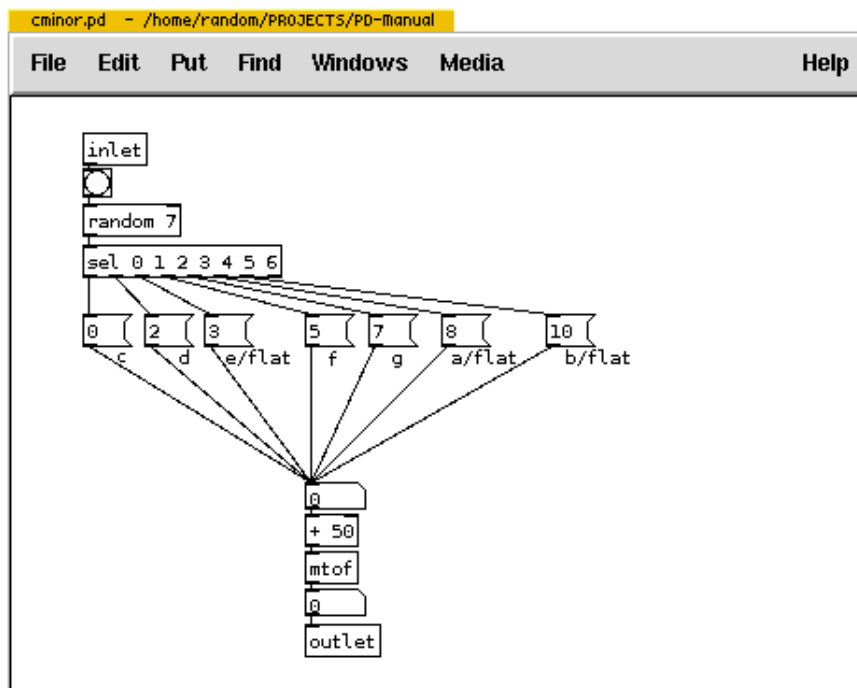


Figure 5. Pure Data interface.

The functional programming approach provides a natural framework for signal processing. Digital signals are modeled as discrete functions of time and signal processors as second order functions that operate on them. It can generate code to the most diverse plugin architecture, including formats such as LADSPA, MAX/MSP and VST, in addition to mobile applications for Android and iOS [Smith 2011, Letz et al. 2010].

SuperCollider is an object-oriented language, with a focus on algorithmic composition and audio synthesis, requiring the least possible effort. Its main characteristic is to transform musical concepts into functions or methods, creating music from the manipulation of these elements through blocks, as well [Wilson et al. 2011]. Among its main qualities are dynamism and brevity. The dynamism allows the user to create structures that generate events in a nested way. Patches can be built dynamically and parameterized not only by floating point numbers, but also by other unit generator graphics. The patch can also be built algorithmically in real time [McCartney 1998]. Since SuperCollider is a Object-oriented programming language, it can be an example of the combination of two architectures, Object-Oriented as a programming paradigm and Pipes-and-Filters as the flow of audio data.

Another language focused on live coding, composition and performance in real time is **ChucK**. Its objective is to be proactive and interactive to the user, however, this causes some restrictions, such as less absolute performance. In addition, ChucK presents a highly visible and centralized view of logical time (via keyword) that reconciles logical time with real time. Another highlight is the ability to edit the code while the program is running [Wang 2008, Wang and Cook 2003]. ChucK natively supports multiple simultaneous and dynamic control rates and the ability to add, remove and modify code on-the-fly, and its application ranges from algorithmic composition to sound synthesis,

recording and visual effects display. As a whole, ChucK allows the programmer to write code quickly and easily to synchronize and communicate with input devices. It can be a good tool for easy use or the rapid prototype of new controllers, or for writing network code or synchronization. This programming language has been used in performances by the Princeton Laptop Orchestra (PLOrk) and for developing the musical applications [Wang 2008, Dean 2009].

Mosaiccode is an open-source programming environment, created by a group of researchers at the Federal University of São João del-Rei, Brazil. Focused on a visual environment, this tool is used for development of systems common to digital art and music in web browsers, extending its use to mobile devices [Schiavoni and Goncalves 2017, Schiavoni et al. 2018a, Schiavoni et al. 2018b]. The similarity with the other techniques is in the fact that it also uses blocks and connections to create a complex code, inspired in the Pipe-and-Filters architecture. A block represents a single unity of code in the system and it can have static and dynamic properties. The dynamic properties is represented by an input port. The output processing is represented by an output port. These ports define the programming data flow and can be connected like presented in Figure 6 [Schiavoni and Goncalves 2017, Schiavoni et al. 2017].

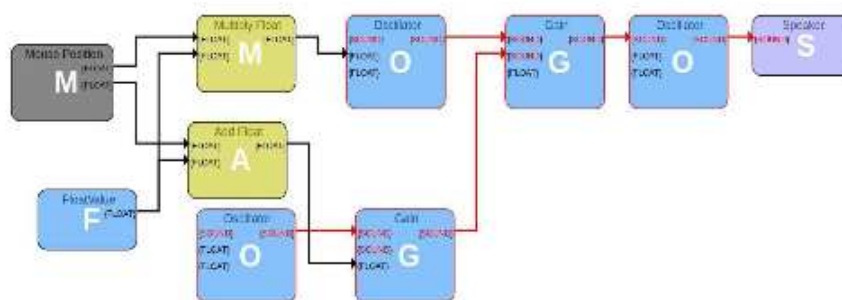


Figure 6. Block interconnection in Mosaiccode.

However, Mosaiccode is not an environment for interpreting code, but for generating it from the combination of blocks created by the user. A code generated in the tool is shown in Figure 7.

3. Discussion

To try to ensure the participation of lay-programmers and lay-musicians in creative process, we propose to use the Pipes-and-Filters architecture in this process. Thus, the creation of a complex music, piece or instrument can be done combining a set of simple objects, the Filters. In this case, we are understanding it in a general way, and it does not matter if one can use guitar pedals, Moog devices, SuperCollider code or Pure Data objects.

Each Filter has a internal configuration, just like the parameters passed to a shell command, the parameters passed to a code function or the knobs and buttons present in a studio compressor, a Moog box or in a guitar pedal. Sometimes we can have a single data type and a single pipe type, like in Unix shell, or different pipes with different data type,

```
view-source:file:///tmp/javascript/webaudio-1491278886.62/webaudio.html
17 var block_20 = context.createOscillator();
18 var block_20_o0 = null;
19 var block_20_i1 = function(value){
20   block_20.frequency.value = value;
21 };
22 var block_20_i2 = function(value){
23   oscillator = '';
24   if (value < 1) oscillator = 'square';
25   if (value == 1) oscillator = 'sine';
26   if (value == 2) oscillator = 'sawtooth';
27   if (value > 2) oscillator = 'triangle';
28   block_20.type = oscillator;
29 };
30
31 // block_60 = Mouse
32 var block_60_o0 = [];
33 var block_60_o1 = [];
34
35 // block_66 = Multiply Float
36 var block_66_arg1 = 0;
37 var block_66_arg2 = 0;
38 var block_66_o0 = [];
```

Figure 7. Example of JavaScript source code of a webaudio application generated by Mosaicode.

like in Pure Data and Mosaicode. The creativity task here is to combine a set of Filters to create an art piece.

A good point to start thinking about creativity and Pipes-and-Filters is that the creation of a complex program in this architecture is based on the combination of a set of less complex filters. Thus, the basic idea is to reuse components that are already known, combining them and using their predefined feature to compose a new idea.

Using the concepts presented by Boden, the Pipe-and-Filter architecture can be used in the three forms of creativity, starting with the **exploratory** form. Exploratory creativity involves making unprecedented combinations of familiar ideas. This model can be highly explored in a Pipe-and-Filters system where the familiar ideas are the Filters and the possibility to combine them is the main form of programming. In this context, music creation tools redefine the use of this architecture, assigning its concepts to a completely different field.

In **transformational** creativity, Pipe-and-Filter is no longer just a hidden part of the software, to appear graphically to the user, allowing one to create and manipulate the system inputs, encapsulate them in pipes and modify them through filters, just like in Mosaicode and Pure Data. Thus, they are still able to create a new parameter, since the application provides a code from the block interconnections.

In the **combinational** structure, the concept of combining different ideas is much broader than in the previous ones. For those who are only initiated in computing, they have already encountered this form of command in their field of action and now they are faced with the technique for creating music. For those who are musicians, the application of filters to input signals occurs on guitars, synthesizers and other electro-acoustic instruments. For those who are laymen in both subjects, they have certainly come across equipment that needed a correct fit to work, especially since this is a recurring activity for children, such as assembling puzzles or Lego pieces. Thus, common ideas are used to create music as well.

The division of creativity forms, presented by Beghetto and Kaufman [Beghetto and Kaufman 2007] can be useful to understand how Pipes-and-Filters can help

creativity and also gives a clue about teaching and learning based on this architecture. Maybe it is possible to understand that the main difference between an agent that can be considered a Big-c and an agent classified as mini-c is the knowledge about how to create a product. In a Pipe-and-Filters system, this knowledge can be understood as how many filters do you know and how deep do you know their features. Certainly, a Pure Data user that knows hundreds objects should not be classified as more creative user than a user that knows a few, but certainly it is possible to classify them as a more expert user and a less expert based on it. Thus, it is possible to define a learning process dividing it in learning several filters and how to combine them.

The creative process presented by Bennett [Bennett 1976], divided into five main stages can also be helped by a Pipe-and-Filters architecture and concept. In this case, the refinement stage and the sketch can be done adding, reordering and removing filters, keeping the main idea and infrastructure and changing components of the final product. Also, it is possible to reuse parts of the systems in other works and to divide the creative process in several tasks, just like in Pipe-and-Filters architecture.

As for the programming languages that use this architecture to create code and consequently music, some peculiar characteristics to each type emerge. Pure Data, for example, has a similar approach to the real world of audio stomp boxes, where the connection of elements in a given order will result in a new value, in addition to being aimed at real-time collaboration between networks and live coding. FAUST, in turn, is marked by not describing a sound or a group of sounds, but rather a signal processor, often in the form of a plugin or standalone application. SuperCollider is characterized by the generation of audio synthesis and algorithmic composition in real time through functions and methods. ChucK is also focused on audio synthesis, composition and performance, but it presents the differential of privileging flexibility over performance. Finally, Mosaiccode can be defined as a visual programming language and a domain-based language, which allows the user to develop systems using two-dimensional notation and interaction with code through graphics, in addition to developing systems within a well-defined scope.

4. Conclusion

This paper proposes to analyze how Pipe-and-Filters can help in the creation of Ubiquitous Music by people without musical or technological knowledge. Applications built from this architecture, or with a similar operating logic, were presented, such as Moog synthesizers and guitar pedals, beyond that which assist in musical composition, such as Mosaiccode, Pure Data and FAUST.

Among the creative processes, this structure of sending and manipulating data correlates with exploratory, transformational and combinational types. In short, it is a technique that supports the tools used to generate some type of art and also composes the creative method to perform this task.

The various forms of creativity focused on music are also taken into consideration and, once again, Pipe-and-Filters can help so that more and more people can express themselves through music, in a simple, playful and graphic (or sometimes textual) way.

To understand how creativity can be related to the combination of simple filters to create a complex system is an interdisciplinary field of study and has an important

role in education, social and technological integration, the exploration of the most diverse techniques helps in the growth of Ubiquitous Music, making it sustainable and accessible to the most diverse people, from the most diverse social classes.

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Experiments on technology-assisted free improvisational practices with an ensemble of saxophone

Miguel Clemente¹, Manuel Falleiros², Tiago Tavares³, José Fornari⁴

¹ Department of Music / IA / University of Campinas (UNICAMP) - Brazil

² CIDDIC / COCEN / University of Campinas (UNICAMP) - Brazil

³ FEEC / University of Campinas (UNICAMP) - Brazil

⁴ NICS / COCEN / University of Campinas (UNICAMP) - Brazil

miguelclementesaxo@gmail.com, mfall@unicamp.br,
tavares@dca.fee.unicamp.br, fornari@unicamp.br

Abstract: *Free Improvisation (FI) has been increasingly used as a tool for musical education because it provides an exploratory environment that facilitates learning motor skills, appreciating sonorities, and interacting with others. In this work, we take a step further in this paradigm by using Ubiquitous Computing (UC) technology to facilitate FI by providing active feedback to the musicians about their performance. We call this approach TAFI (Technology-Assisted Free Improvisation). Experiments in FI sessions with a saxophone ensemble indicate that TAFI fostered creativity and participation both in in-person and in remote (network-connected) FI sessions.*

1. Introduction

Free Improvisation (FI) is a musical practice that emerged in Europe as part of an artistic movement especially strong in Britain, during the 1970s [Canonne, 2016]. Some researchers such as Canonne (2016), Costa (2015) and Falleiros (2012) support the idea that FI comes from a merge of European contemporary formal music and North American Free Jazz. Since then FI has established itself in our culture, for some even as a contemporary way of life, in consonance with our social behavior and individual state of mind¹.

FI is not a "style" or compositional trend. Instead, FI aims to be an experimental, empirical and generally collective musical practice that avoids submitting or become subordinate to any specific aesthetic musical tendency, even if it inevitably converges and dialogues with many of the contemporary musical practices and genres. One important aspect to understand FI is that it is not a geographically constricted manifestation. There are FI musicians spread all over the world. Together they compound a diversified and active worldwide FI panorama [Clemente et al, 2019]

¹ Although FI is a term that tights together the common practice of many improvisers, it is also a term that has currently been criticized precisely for its broad range of meanings. As such, other terms more specific have been gradually more frequently used, such as "Transstilistic", by Sarath (2010), "Hyperimprovisation", by Falleiros (2013) and "Generative improvisation", by Savouret (2010).

Two features that are important for any musician to pay attention while being part of a FI session are Listening and Performing. Together, they draw the musician into a type of "readiness state". This is achieved by attentively listening to all improvisers while keeping a conscious action of performing, in order to accurately play their "sound image" (the set of all musical possibilities that each musician has, even before start playing). In this situation, there is no difference between thinking and playing [Falleiros, 2012]. In this type of musical manifestation, the FI performance advances based on the compromise of what can and what cannot be done by each musician. This happens through a continuous decision-making process, in which each musician attempts to explore their own instrument's methods and sounds thus acquiring new musical methods and possibilities of sonorities based on what they intuitively learned. An FI session can resemble a type of soundscape, that is, a landscape of possible musical organized sounds, because its sonority is ecologically composed by the whole performing group. This soundscape emerges from an evolving musical prosody, which is simultaneously self-similar and novelty-seeking. This creation is collaborative, distributed and therefore utmosly anonymous [Falleiros 2012, p.16-30].

The interpretive activity of FI comes from its typically spontaneous execution, in which the musical material is exposed in collaboratively, leading to an aesthetics that explores different motivational forms new improvisation results. This makes FI a potential educational tool that may allow the foraging of musical cooperation and space sharing among students of music, which in turn fits into the interests of music education. These educational strategies are applied within musical groups such as the one presented by Edward Sarath, which teaches traditional music theory through the use of improvisation [Sarath, 2010]. The use of FI practice for musical education can come along with suggestions for musical exercises addressed by all in the group performing the FI session, as the ones presented in this paper, which are done with a saxophone ensemble of music students. In order to make it possible, we used three important guidelines to the FI performance [Matthews, 2012: 22-26]: 1) The creative process is more important than the musical outcome. 2) All participants must interact with the whole group so to promote the development of a collective musical identity. 3) Sound is the media that allows the entire creative process.

Based on these principles, we performed 4 experiments with FI. The first one is a baseline conventional FI session, without any resource of Information and Communication Technologies (ICT). This was done in order to compare its results with the other 3 experiments, that use ICT. The second experiment is a FI session uses a video game as ICT resource. This experiment derived from a previous research² that used a commercial video-game, developed by Atari Company, called "Adventure"³. The third experiment is a FI with UC (Ubiquitous Computing). This one uses a free app, called MobMuPlat⁴ that allows to run a real time computer model programmed in Pd (Pure Data⁵) in most types of smartphones (Android or iOS). This patch (as a computer model is called in Pd) was specially designed for this experiment. This one promotes the monitoring of melodic variations in loudness and pitch, performed locally for each musician in the FI group. They were asked to run this patch in his or her own

² CNPq research group: dgp.cnpq.br/dgp/espelhogrupo/5225053539670789.

³ "Adventure" was the game of the year in 1979, for Atari 2600 platform. It is considered to be the first video game of action and adventure.

⁴ MobMuPlat (Mobile Music Platform) <http://danieliglesia.com/mobmuplat/>

⁵ <https://puredata.info>

smartphone while playing in the FI session. The fourth experiment uses the same patch from the experiment 3, but here monitoring the melodic variation of each musician in an FI remotely performed, where each participant is in a different location and all FI group is interacting through an audio conference call, making it a truly acousmatic distributed FI performance. As further detailed, these experiments were organized in such order to describe the technological path from FI without any ICT assistance till a FI deeply dependant of ICT and even UC.

All experiments were applied to a group students of saxophone, from a saxophone ensemble of ELM⁶, at the University of Campinas (UNICAMP). This ensemble currently has up to 16 saxophone players in many levels of expertise (musicians with 2 to 4 years of training). These students already had some basic contact with FI foundations throughout 5 workshops that took place in 2019, where they also answered surveys about their musical experiences and opinions after participating in the FI performances. The questions were about their understanding and impressions after each FI session, such as: How comfortable they felt during improvisation; How pleasant was the group sonority; How much they perceive their musicality improving; How was their perception of group's timing and tuning during improvisation; and so forth. The answers were ranked by each participant in a discrete scale ranging from 1 to 5, where 1 was always related to a pessimist or negative impression (e.g. no results, nothing changed, not interesting, not pleasant, etc), and 5 was related to a very positive or pleasant assessment (e.g. useful, meaningful, important, interesting, educating, intriguing, pleasant, etc.) [Clemente et al, 2020]. This work is part of a doctoral research in which the use of FI is studied as a strategy for music education, specially to improve musicality, here defined as the musician's ability of perceiving, appreciating and making music [Honing, 2018]. Musicality improvement is measured by the observation of his or her active listening, rhythmic synchronization, loudness and pitch perception and domain, as well as the acquisition and control of new technical skills in the musical instrument. In this article we present an extension of it, with the use of technology-assisted FI with UC resources. The goal here is to help FI to expand its use and effects for music education, specially in the development of musicality. This is here called TAFI (Technology-Assisted Free Improvisation), that uses UC resources nowadays easily available through the smartphones that almost everybody nowadays owns. With it we developed a simple computer model to monitor 2 fundamental aspects of FI melodic variation. Many other strategies can and hopefully will be further implemented and tested for this subject. The UC resource for FI are centered in the experiments 3 and 4, where the before mentioned customized Pd patch was developed and used to measure in real time the variation of pitch (notes played) and loudness (their perceived intensity) of each musician's in the FI session.

2. FI as a music education resource for the development of musicality

Musicality is one of those elusive aesthetic terms referring to a musical quality found in a performer or a particular performance that is easy to perceive but hard to define. It is directly related to expressiveness in musical performance, a subject broadly studied by many, such as [Fabian, 2014]. Here we define musicality as the ability of a

⁶ *Escola Livre de Música* is part of CIDDIC (Center for Integration, Documentation and Cultural Diffusion), one of the interdisciplinary centers and nuclei of COCEN (Coordination of Centers and Nuclei) of UNICAMP, the school aims to function as a laboratory for experimental musical pedagogies.

musician to consciously control and deliver an expressive performance. Expressiveness is achieved by the manipulation of microstructural elements (meaning borderline perceptual) of a musical performance, such as subtle variations of timing, loudness and even pitch. In that sense, practices such as FI, that explore intuitive musical interaction can help the development of musicality.

According to Sarath (2010) the set of performance possibilities of each FI instrumentalist weaves the musical creation taking place within the group. In this way, each musician finds new paradigms that lead to the acquisition of methods to explore sonorities by encouraging creativity, thus improving the musician's musicality. Each performer who participates in a FI group starts from interacting with his or her own previous experience. That is to say that FI becomes a learning model through improvisation after stylization, which is given by the musician's background. The contribution of each one comes from personal and musical own experience, developed throughout an entire lifespan, which may have been built in many ways, such as, by what the musician heard before, places lived or visited, predilect (or repulsive) musical genres and styles, relationships, performances through which the one's musical aesthetic was expressed and aimed to be translated into sounds [Sarath 2010, p. 32-53].

Chefa Alonso (2007) lists some principles to follow as pedagogical strategy for music education during FI where emphasis is given to the interpersonal musical relationship based on equality and bound. Simply by how the instrument is explored during a FI session, extended techniques are learned by all group members, such as how to solve everyday performatic problems by activities carried out through and during the FI. Alonso also emphasizes that in many occasions creative or improvisational activities should come along with traditional musical academic curricula. In the context of Latin America, the application of FI as part of pedagogical tools are mostly centered in the figure of a famous brazilian (born in German) teacher, composer and musicologist, Hans-Joachin Koellreutter (1997), who used improvisational practices in his compositional and educational work. According to Brito (2003), improvisational activities proposed by Koellreutter also enhanced aspects of organization, coexistence, collaboration among equals, as well as the contact with contemporary musical practices. Brito points out that improvisation should be understood as an important pedagogical tool that accompanies the entire music educational process by giving to the educators opportunities for observing and analysing what trends and bounds students establish with the sound materials to which they have been exposed and are producing [Bruto 2003, p.152]. Carlos Kater (2017) studies the use of FI practice as a musical teaching tool for sound explorations and experiences where open and spontaneous exposure to musical potentially risky situations are welcome and even encouraged. For Kater, in such musical moments, teachers can progressively contemplate and propose for students recreational activities with greater degree of inaccuracy and indeterminacy, which invite the students to position, interact and take decisions [Kater 2017, p.158]. Rogério Costa (2016, p.84), a well known brazilian author on FI subject, points out that this practice has been seen as a pedagogical strategy that can be used to provide the building of knowledge and skills such as listening and the understanding the fundamental aspects of musical composition as FI sets them into action thought the musician's perception of mind and body integration where sound information flows as dynamic musical events that occur during FI musical practice.

Recent research conducted by Brietzke (2018) sought to investigate the implementation of improvisational game models for the collective musical initiation of

cello students. This study was applied in three different institutions in São Paulo, Brazil, obtaining enticing results through the use of FI. The results revealed that students felt comfortable with FI practices, in addition of having better recognized structures of musical narratives during the activities. There was also greater and better integration between classmates as well as deeper understanding and consequent approximation of student to contemporary musical narratives. The educators involved in this research reported the development of creativity in the students and the improvement of their teaching-learning processes, although they also pointed out the importance of previously contextualize the FI proposals, linking it with the traditional model of teaching music. In a previous research on the first contact of students with FI, carried out in 2019 by one of the authors of this work (to be published in his ongoing doctoral project) the results show that students engaged in FI practices perceived and reported improvements in their musicality. Through answers from a survey filled out by the participants, they mentioned the musical improvements they perceived in themselves and in the whole group after participating of FI sessions. The improvements were specially perceived when they played pieces from the traditional musical repertoire, such as improvements in the group's tuning and timing. They also indicated improvements in both the individual and group sound quality, probably due to the fact that FI made them more attentive, leading to be more sensitive, connected and relying more in the individual and grouping musical convergence.

3. FI with ICT

As far as we know there are few studies that have dealt with or analysed the pedagogic implications of FI practice in formal music training. This is even more conspicuous on the study of FI aided by resources of Information and Communication Technologies (ICT). However, in the last 20 years or so, ICT have become more ubiquitous among society, in any field of expertise, including music education. With the commercial use of internet, started in the 1990s, wide spread publication of digital books, use of desktops, laptops, tablets and the most ubiquitous gadget of all, smartphones, pedagogical changes have been occurring both in the way students learn and teachers produce and present their educational material, in which students have become active members of the learning process, many times seeking information online while the teacher presents them, which can also make the education process more flexible and even fun. In order to ICT resources to become truly effective in nurturing and supporting creative improvisational performances they must also become integral parts of the normal, everyday lifestyle of musicians, immersed in the 'cultural ecology' of their habitats, which seems to be the case of smartphones. Cultural ecology is here understood as the dynamics of people's interactions with and within their environments (Dillon, 2008).

Vesisenaho et al (2017) conducted a study done in Finland for the facilitation of creativity in musical improvisations practiced through ICT. This study showed that FI seemed to effectively reduce the underutilized creative resources in schools, universities, workplaces and many other everyday places. This study follows a conceptual framework where musical improvisation seems to be the creative result of certain ecological cultural interactions in learning environments. This study contributed proving that creative improvisation interactions could be facilitated by ICT, where improvisational development ideas were also presented. The purpose of this study was

to review current practices and integrate them into an appropriate conceptual framework outlining a research and development agenda for future innovative work in the FI (Vesisenaho et al, 2017).

There is also framework known as TPACK (Technology, Pedagogy and Content Knowledge), proposed by Shulman (1986). This is an extension of a previous framework, known as PCK (Pedagogical, Content and Knowledge). Shulman pondered on the fields of expertise that the contemporary pedagogical process need to simultaneously address in order to be truly effective. The PCK framework only acknowledges the merge of pedagogy with content (the scientific knowledge of the teacher on the subject being taught). In this sense, content knowledge refers to "what to teach" and pedagogical knowledge refers to "how to teach". This way, the lema: "pedagogical knowledge of the content" expands the original "pedagogical knowledge" on how to teach, while also inferring that the teacher should know more than just the knowledge of his or her area of expertise, for the effective creation of knowledge in the students. TPACK aggregates "technology to the merge of skills that a teacher nowadays needs to possess. It aims to intersect technology, pedagogy and knowledge, thus becoming a practical framework on how to teach what is supposed to be taught. This can be used in creative practices such as FI, by letting students to interact by using current ICT resources of UC, such as the pedagogical use of smartphones running freely available apps, as the one here presented.

4. Experiments with FI performances

Here is described 2 sessions of experiments on FI elaborated with the students at the ELM saxophone ensemble. The first session has 2 experiments and took place in 2019. The first experiment involved only a traditional session of FI without any ICT resource. The second experiment used ICT but no UC resources. The second session occurred in the begin of 2020 and is also comprised of 2 experiments; both using UC. The first one (experiment 3) used UC local and experiment 4, used UC remote, as further explained. Each FI session lasted about 45 minutes. The participants had different levels of instrumental expertise. All of them already had some previous experience with creative pedagogy (a pedagogical envisioning focussed on acquiring knowledge through playful and creative activities) through the use of FI, from previous encounters in a pilot study carried out in 2019. All experiments were applied in the facilities of ELM / CIDDIC / UNICAMP.

The first experiment was called "Takete-Maluma". It was initially developed by one the author of this paper, Manuel Falleiros, for a graduate-level course in music, based on the improvised musical "signatures" system presented by Alexandros Markeas⁷. This was an activity without any type of ICT. Here, the emphasis was on the musical expressivity where the group of students, all used to play only by interpreting a graphical score, was asked to interpret the figures. This activity aimed to explore the symbolism, as referred in a research carried out by Wolfgang Kohler⁸, known as the "bouba/kiki effect", was adapted for this context by Manuel Falleiros that promotes a free mapping between sounds and graphic shapes. In this experiment two figures were

⁷ Professor of generative improvisation (to know more: <https://revues.mshparisnord.fr/filigiane/index.php?id=395>) at the Paris Conservatoire (CNSMD). http://www.alexandros-markeas.net/html_fr/improvisations/classe-improvisation-generative.php

⁸ Available at: <<https://www.bbc.com/portuguese/geral-39685606>>. Access: Nov. 22 of 2019.

presented, one very pointy and another fairly rounded. The participants were asked to name these two figures. They were asked to freely interpret both figures by referring to them either by “takete” (most linked its name to the pointy one) or “maluma” (mostly linked this name to the rounded one). The students were then asked to create a collective sound texture that best represented the qualities of each figure. Next, a challenge was proposed. Two contrasting sound textures were presented and the students were asked to play their instruments, starting from one and slowly transforming it into something similar to the other one, removing distinctive sound qualities from the previous one and emphasizing the qualities of the next. Usually the resulting sound texture for takete is composed of distant intervals rhythmically separated and with short articulations. For "maluma", the sound texture is normally composed of a smaller scope of acoustic tensions profused of long, well-connected notes.

The second experiment was based on a performance called "Game-Game" developed and released in 2015 by the research group "Contemporary Improvisation, Creative Processes and Musical Cognition" at Unicamp. This performance used the video game "Adventure" as a substitute for a score, exploring the limits of musical writing. In this performance, the participants received a sheet with a two-column table, in the first column are figures with the characters of the game, and the second column, empty, must be filled with musical parameters (for example, scales, long notes, low notes, frullato etc.).

Each one of these parameters was then related with a character of the video game (chosen by the FI group before each performance and changed for each presentation). As part of the performance, it was mandatory that, at the end of it, each musician tear down its own music score in front of the audience, as a form of making it ephemeral and also protesting against the limits imposed by the traditional music notation. Each time a video game character appeared in the screen, a particular musical parameter attributed to it should be performed by each musician in the FI group. The screen was divided into 4 equal parts (quadrants), each one also indicating an specific musical parameter. The position of the characters in the screen also indicated the selection of a quadrant and consequently the playing of its corresponding parameter. Since each character also had attributed a specific musical parameter, both had to be performed together (character and quadrant). Practice proved that this arrangement made this sort of FI game both highly challenging and enjoyable for the performers, as unexpected and even contradictory combinations wouldn't eventually happen during performance. In a pedagogical adaptation of this game, the goal was that the person in control of the game (and for this reason wouldn't be playing together with the rest of the FI group) would be unaware of the musical parameters chosen by the group. Before each FI game, this person would be asked to momentarily leave the room while the group decided which musical parameters would be related to the characters and quadrants. The goal assigned to this person was to discover, while listening to the FI, as many related parameters as possible, before the game ended. This procedure can also be applied in musical classrooms with larger number of students, by divided it into 2 groups, one that plays and another that seeks the parameters. The experiment carried out with the saxophone orchestra aimed to bring an innovative educational proposal that combined musical performance with visual interaction and audacity education. Despite it was created as a purely performing proposal, this activity proved to be a meaningful and useful pedagogical tool for musical perception and creative development.

The third experiment used a simple computer model programmed in Pd (Pure Data); a patch specially developed for this paper, that runs in smartphones as an app. This one is here called TAFI (Technology-Assisted Free Improvisation) and run in most smartphones (Android or iOS) inside a free app MobMuPlat. TAFI collects audio from the smartphone's microphone and measures in real time the dynamic variation of loudness and pitch. Each participant of the FI group where TAFI was tested was asked to download the app and run the referred patch in his or her own smartphone, during the FI session. This turns each smartphone into a real time measurement tool of the variation of each melodic improvisational line from each musician, by measuring its melodic line. The fourth experiment also used TAFI but in a remote fashion. Instead of having the whole FI group gathered together in the same room, this experiment had each participant remotely displaced, away from each other. The musical interaction between them was mediated by a freely available ICT resource that enables audio conference calls (in this experiment we used Skype). Audio only conference call between participants was mandatory in order to make sure that the FI interaction would occur only by means of sound, thus promoting a truly acousmatic experience (without any visual reference from others during the FI group). Each musician was asked to be in a place with good internet reception (to guarantee a fair quality for the network) and preferably in a soundproofed place where he or she wouldn't be disturbed during the FI (such as alone inside of a car). In order to hear the sound of others while playing together through the network, each musician was asked to play wearing headphones. TAFI was also used here to measure in real time the dynamic variations in loudness and pitch of each musician's improvisation. The aesthetical results were provided by the participants of this remote FI group, through an open discussion on their impressions and contrasts about the effects and potentials of local versus remote approach. The idea behind the use of this measurement of melodic variation is to help each musician to have a better and deeper understanding of the musical quality of their improvisations through an impersonal and dynamic feedback given by an algorithm. For now, this patch only measures the dynamic variation of loudness and pitch, however there are a myriad of possibilities to be measured and tested, which can and hopefully will be developed in more complex measurements, in further experiments, as discussed later. The next section describes the development and usage of TAFI.

5. A patch for the dynamic measurement of melodic variance

PureData (Pd) is a visual computer language created by Miller Puckette in the 1990s, developed to allow the creation of dynamic real time computer models (called "patches") for the analysis, processing and synthesis of data, such as control (e.g. MIDI) and audio. Each patch is dynamically interpreted and run continuously, even while the patch is being built or modified (also allowing its use in live coding performances). Pd was specially designed for computer music applications and sound art performances. As mentioned before, recently, the free app MobMuPlat provided a simple yet powerful framework that allows Pd patches to run inside a smartphone and to have access to many of its embedded sensors (e.g. cameras, microphone, GPS, gyroscope, accelerometers, etc.). This opens up the possibilities offered by Pd to explore capabilities in a ubiquitous computing fashion through smartphones. TAFI is a simple patch that aims to help the development of FI for music education by means of UC. The figure below shows its GUI.

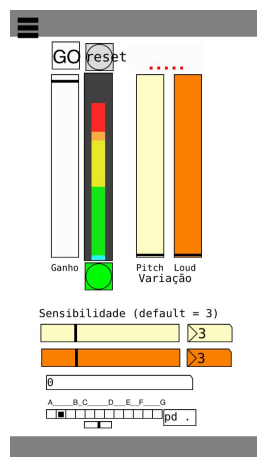


Figure 1. TAFI⁹ (technology-assisted free improvisation) Pd (Pure Data) patch frontend GUI (graphical user interface), as seen in the smartphone screen, via MobMuPlat (Mobile Music Platform).

At its top left there is a toggle button labeled "GO" that starts the patch monitoring process. Below that, there is a white slider that allows the user to dynamically control the microphone's smartphone gain. The player has to set its level before starting the monitoring process, leaving it just above the threshold to capture the sound of his or her musical instrument without capturing the sound of others. As the gain slider is adjusted by the player, in its right side there is a black slider that shows the actual sound intensity captured by the microphone. This level is divided in 3 colors: green for low level, yellow for middle level and red for high level. Notes will be detected by the patch only within yellow and red levels, where red level will also capture notes from other musicians (so each musician is required to tackle the gain to keep its level in the yellow range). When a note is captured, the green bang button under the black level slider will switch colors, from green to yellow. This means that notes are being captured and analysed by the patch, in terms of pitch variance, (whose cumulative histogram is depicted in the yellow vertical slider, at right) and loudness variance (whose cumulative histogram is depicted in the orange vertical slider, at far right).

If few (or even one single note) is being played but in different loudness, the vertical yellow column indicator will slowly go upwards. If many different notes are played but with similar loudness, the vertical orange column will slowly raise. Once its maximum value is reached, the orange dots on the top of these two vertical sliders will turn into the word "FIM" meaning that the analysis process is over and the musician should stop playing. The idea here is that the player whose improvisation vary the most finishes the FI session first, till having only one last musician improvising (the one that varied its improvisation the least). The horizontal yellow and orange sliders at the bottom allow the player to set the sensibility of each corresponding melodic parameter. The default value is 3, but it can go from 1 to 9. Above the default level, the cumulative variance pace (shown by the vertical sliders) is faster, and vice versa. This was done for several reasons. Initially because sounds generated by saxophones tend to present less attack than percussive tonal instruments, such as the guitar or the piano (where the patch

⁹ link for download

https://drive.google.com/drive/folders/1qES65pxyMg_LXLUUDwgkp0DzwbY7NrDZ?usp=sharing

was initially developed and tested). This makes the cumulative loudness variance for saxophone to be slower than the one for piano, turning the whole improvisation session analysis session slower in sax (when using the default setting value). Besides that, varying these sensibilities can let the FI group focussing in different musical nuances. It can change the FI session duration, or make the musician to focus more in one of these melodic aspects. Under these horizontal sliders the white number box shows the overall cumulative melodic variance (given by the product of loudness and pitch variances). Its value ranges from 0 to 1 million. Finally, at the bottom of the screen, there is a small horizontal radio button that shows the pitch of the notes being captured, in letter notation. Below that there is a tiny horizontal slider showing the dynamic fine tuning of each detected note (where the middle range of this slider represents the correct tuning, at the standard A = 440 Hz).

As said before, this is a simple patch whose development aims to state the principle and to demonstrate the possibilities of using UC resources provided by smartphones in creating and using dynamic computer models for the improvement of musicality through the educational use of FI. TAFI was used in the 2 experiments of the second session, as previously mentioned, respectively for local and remote FI. The results of both experiments are described, compared and discussed in the next section.

6. Discussion and conclusion

As seen, this article presented 4 experiments with FI for the development of musicality in students of music. They were organized in a timeline that followed the increase of ICT resources used in each experiment. The first one had as FI resource static images of different graphic shapes. The students were asked to translate these shapes into sounds were they freely associated each one of them with melodic phrases. It was observed there how consensual is the translation of shapes into melodies among students. This experiment showed the synesthetic relation between image and sound which is produced by the mind and constantly used in arts. The second experiment went one step further, using as FI resource animated images. A video game was then introduced. This simple ICT was used as a general and local media for the students to explore simultaneous musical interactions with the game characters and their locations in the screen. Here the FI group was divided in two subgroups, one that transmits (play) and another that receives (listen). The first subgroup had previously arranged, in secrecy, specific musical patterns for each game character and position. The second subgroup had then to listen to the improvisation of the player subgroup while the game was running and, without knowing the improvisational rules previously arranged, had to decode the message, which means, to find out the improvisational rules arranged by the players just by listening to the performance. This explores the concept of information flow explicit category, where music is the media that information is communicated and eventually decoded, even without having semantic content. Here it's also seen how a distributed compositional process such as FI departs from an "storytelling" aesthetic communication style and approaches a "gamification" one, given by the distributed and cooperative flow of creativity and culture. The next experiment show this tendency even stronger. In the third experiment, the app here introduced by the acronym TAFI was distributed for all students, to be played in their own smartphones while they were participating in the FI session. As said before, TAFI measures melodic variation in real time. When started, the variation is accumulated until it reaches a maximum where the

process stops. In this scenario the students naturally treated the FI session as a game¹⁰. Most of the musicians seem to have enjoyed this experience. Some of them offered suggestions for improvements such as using other improvisational rules like measuring the proximity of the notes with a tonal center, or wearing microphones connected to the smartphone and placing it inside the saxophones so the audio leaking would be minimized. However, all students said that had forgotten about the music interaction and focussed only on "winning the game" which meant to finish the process first by varying the melody the most. This can be musically beneficial as it invites each student to try out new melodies, which would mean to generate more variation, however this also dampens musical interaction and replaces it with a form of musical competition. For that reason a simple change in a newer version of TAFI can solve this situation, just by not stopping the cumulative process when a maximum is reached. The fourth experiment also used TAFI but in a remote way. For that, each student was in a different location and all played together through audio conferencing software¹¹. For reasons that seem to be related to information security, these type of apps do not let to record audio while they are in use. For this reason each musician had to use its own smartphone to run TAFI and another computer (or other small device) to run the audio conferencing software (which in theory shouldn't be necessary). This remote interaction lessened a few notches the open competition flourished in the third experiment and promoted more interaction through music once that sound was the only mean of communication to create the informational flow of the remote FI. The opinions here were divided. Some prefer the local FI sessions as this type offers a multimodal experience where humans senses other than hearing are in action and interaction. Few prefer or seem to see a point in having remote interactions as they tunnel the information flow through only one channel (the hearing), which in theory could with continuous practice, eventually make this mind processing enhanced and thus equipping these musician with a better auditory processing for music. Some participants refer to that as lacking the same liveness of human interaction, as it frequently happen in courses of distance education, It is still too early to settle this matter as new and better experiments should be designed, proposed and further explored.

The first session, having been done more than one year previously to the second session, already showed improvements in the musicality of the participants of these FI sessions. Both individual and group sonority improved, according to the students and the teachers who coordinated the FI sessions. The second session using TAFI is still too recent to have offered a solid feedback on the possibilities of improvement of musicality. They shared the same ludic and intuitive atmosphere of the previous session, where the group enjoyed participating and exploring new musical possibilities. TAFI also offers the possibility for each student to make sound experiments in which the melodic variability is not evaluated by another human being, always prone to judge based on personal values, but by an algorithm devoid of personal judgment and thereby providing an evaluation free from human bias thus allowing unusual melodies to flourish. We hope that further developments on this subject may offer more and better tools to nurture, improve and deliver musicality among musicians by means of FI practice assisted by UC.

¹⁰ A video of this session can be watched in the following link: <https://youtu.be/VUOWfZIQZtl>

¹¹ Skype (www.skype.com)

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Comprovação e Interação Leigo-Músico nas Práticas Criativas Cognitivo-Ecológicas: *The Maxwell Demon*

Luzilei Aliel¹, Damián Keller²,

¹ Departamento de Música (CMU) Escola de Comunicação e Artes - Universidade de São Paulo. Professor Luciano Gualberto, 374 - Butantã - São Paulo - SP

² Centro Amazônico de Pesquisa Musical (NAP) - Universidade Federal do Acre, Brasil
BR 364, Km 04 - Rio Branco - AC

{luzaliel@usp.br, dkeller@ccrma.stanford.edu}

Abstract. *We discuss the contributions of a ubimus-oriented artistic project - Maxwell's Demon (The Maxwell Demon) - highlighting the specific challenges of lay-musician interaction. Using the MoMuPlat environment, we implemented the TMD sound-synthesis tool for portable and fixed devices. Five musicians and three lay people of both sexes participated in the study, targeting improvisational group activities based on simple verbal instructions. Through interviews with participants, on-site observations and analysis of audio and video recordings, we obtained results that indicate advantages and limitations of the knowledge-transfer strategies applied during the activities. The items covered include, on the one hand, problems in the activity-preparation stage; the generation of new materials was encouraged but the reuse of sound resources was low. On the other hand, the participants' body movements served to expand their creative engagement; the layman-musician interaction was effective in establishing a common mechanism for participants with and without specific training. Overall, these results indicate that it is necessary to develop design strategies focused on making the knowledge explicit or supporting the transfer of tacit knowledge necessary to achieve creative group results.*

Resumo. *Discutimos as contribuições de um projeto artístico realizado dentro do contexto da pesquisa ubimus - o Demônio de Maxwell (The Maxwell Demon) - dando destaque para os desafios específicos da interação leigo-músico. Inicialmente, foi implementada a ferramenta de síntese sonora TMD para dispositivos portáteis e fixos, utilizando o ambiente MoMuPlat. Participaram na experiência cinco músicos e três leigos, de ambos sexos, realizando atividades grupais improvisatórias a partir de instruções verbais simples. Com base em entrevistas com os participantes, além de observações no local e da análise de gravações de áudio e vídeo, obtivemos resultados que indicam vantagens e limitações das estratégias de transferência de conhecimentos aplicadas no estudo. Os itens abordados incluem, por um lado, os problemas encontrados durante o estágio de preparação da atividade; a geração de novos materiais foi incentivada mas o reaproveitamento dos recursos sonoros*

foi baixo. Por outro lado, os movimentos corporais dos participantes serviram para ampliar o engajamento criativo; a interação leigo-músico foi efetiva para estabelecer um mecanismo comum entre os participantes com e sem treinamento específico. Esses resultados sugerem que para atingir resultados criativos grupais, é necessário desenvolver estratégias de design focadas na explicitação ou na transferência do conhecimento tácito.

1. Introdução

Desde a publicação do primeiro volume sobre pesquisa musical ubíqua (ubimus) [Keller et al. 2014], várias novas perspectivas ampliaram a paleta de possibilidades para ações artísticas nesse segmento. Uma tendência promissora envolve a incorporação de estratégias de improvisação para promover a exploração de recursos sonoros. Essa abordagem orientada para a prática da pesquisa musical já estava presente em vários projetos de ubimus, mas ganhou uma base conceitual e metodológica específica através da incorporação de estruturas ecológicas. No entanto, a questão de como o pensamento ecológico afeta as práticas criativas sob perspectivas ubíquas ainda é relevante. Abordamos essa questão por meio de uma discussão de várias propostas dentro da prática criativa baseada em ecologia, fornecendo exemplos práticos do design e implementação de projetos artísticos usando recursos sonoros acústicos e computacionais.

Um aspecto da pesquisa ubimus que recebeu mais atenção nos últimos anos envolve a implementação de apoio ao envolvimento criativo de músicos e participantes que não possuem treinamento técnico. Essa é uma questão particularmente problemática, porque a maioria das pesquisas existentes sobre interação musical se limita a músicos profissionais e, em alguns casos, concentra-se no artista virtuoso como o modelo ideal para o design de interação [Wessel e Wright 2002]. A ênfase indevida no entendimento do virtuosismo baseado em gênero e uma interpretação culturalmente tendenciosa da expressão levantaram sérias barreiras à inclusão de participantes não treinados na produção musical. Em vez de adotar gêneros preconcebidos, ao mesmo tempo em que adapta o design às necessidades de um nicho específico de músicos, as abordagens do ubimus têm se esforçado para evitar um foco restrito nas propostas anteriores de interação musical e destacaram a necessidade de permitir que os participantes façam suas próprias escolhas de quando e como implantar recursos para atingir seus objetivos criativos. Sendo até o conceito de objetivo criativo foi questionado. Quando aplicada a atividades artísticas e educacionais, a visão utilitária da interação como solução para problemas mostrou sérias limitações [Lima et al. 2012]. É por isso que os métodos ubimus abordam os aspectos exploratórios da criação musical criativa e as demandas dos mecanismos de transferência de conhecimento em atividades que envolvem participantes treinados e não treinados. Essa área de pesquisa foi denominada interação ubimus leigo-músico.

Neste artigo, apresentamos um estudo de caso, discutimos os resultados e suas implicações na pesquisa ubimus, focando nos mecanismos de transferência de conhecimento e apoio a leigos e músicos durante atividades artísticas que envolvem improvisação. A primeira parte do artigo discute modelos teóricos para apoiar aspectos da interação ubimus, de uma perspectiva cognitivo-ecológica [Aliel et al., 2018; Ferraz e Keller, 2014; Keller e Lazzarini, 2017]. Na segunda parte, descrevemos um projeto

artístico que emprega estratégias de transferência de conhecimento envolvendo leigos e músicos, com o objetivo de ampliar o potencial de inclusão do público no contexto de atividades musicais improvisatórias.

2. Comprovação: Planos de diretrizes e planos de contingências aplicados à interação leigo-músico

A prática da comprovação é uma estratégia artística emergente que engloba composição e improvisação musical. O termo comprovação não tem uma definição consensual e suas origens remontam às propostas improvisatórias dos anos sessenta - incluindo grupos artísticos como a *Orchestra Scratch* ou o conjunto *Musica Elettronica Viva* [Cardew, 1969; Curran e Teitelbaum, 1989]. As abordagens comprovisatórias atuais estão documentadas em Hannan (2006), Dudas (2010), Fujak (2011), Bhagwati (2013), Aliel (2017) e têm impulsionado encontros em torno das representações interativas nas partituras musicais.¹ Fujak (2011) afirma que a comprovação deve ser compreendida como uma metáfora da vida. Ele argumenta que em atividades envolvendo seres vivos, alguns cenários podem ser parcialmente planejados. No entanto, os eventos produzidos por fatores não controlados podem impactar as condições iniciais e os comportamentos dos agentes. Com base na metáfora da comprovação como processo biológico formulada por Fujak, Aliel (2017) propõe duas vertentes metodológicas: os planos de diretrizes e os planos de contingência. *Planos* são formas de projetar relacionamentos entre recursos, abrangendo aspectos materiais e cognitivos. Do ponto de vista ecológico, as unidades de interação são definidas como *eventos* (ver Keller, 2000; Keller e Capasso, 2006). Quando os recursos são disponibilizados, materializam-se tanto as ações planejadas quanto os comportamentos imprevisíveis.

Os *planos de diretrizes* incluem regras, ações previstas, algoritmos e recursos obtidos por meio de métodos assíncronos (geralmente vinculados à atividade de pré-composição). Os *planos de contingência* destacam a imprevisibilidade, as eventualidades, as estratégias caóticas (determinísticas) e aleatórias (abrangendo fatores ambientais e estratégias computacionais) de organização sonora, incluindo o erro humano. As contingências podem desencadear transformações significativas nas diretrizes pré-estabelecidas. Portanto, os planos de contingência abrangem métodos e recursos que são mutáveis e que podem ser disponibilizados durante a improvisação. Nas práticas cognitivo-ecológicas, esse aspecto é abordado através do conceito de *Gelassenheit* [Aliel et al., 2018].

As diretrizes e os planos de contingência oferecem oportunidades para nivelar o acesso aos processos criativos, evitando noções preconcebidas de prioridade de um plano sobre o outro (ver discussões críticas sobre a aplicação de métodos composicionais hierárquicos e centralizados em Bhagwati, 2013; Keller, 2000; Lewis, 2000). Dependendo das necessidades musicais e sociais dos agentes envolvidos, ambas as estratégias podem sofrer transformações. Essa flexibilidade tende a dar mais peso aos planos de contingência. Um dos desafios do design ubimus aplicado à comprovação é

¹ TENOR: International Conference on Technologies for Music Notation and Representation.

fornecer diretrizes que contemplem tanto os recursos persistentes quanto os recursos voláteis [Keller, 2014], deixando espaço para a exploração do potencial criativo das contingências.

3. Paradoxos como estratégias alternativas ao enfoque acústico-instrumental

Etimologicamente, o termo paradigma tem origem no termo grego *paradeigma*: algo que serve de exemplo a ser seguido. Frequentemente, os paradigmas são estabelecidos como dogmas que podem ser transmitidos por razões políticas ou que podem ser copiados para aumentar a coesão social. O paradigma acústico-instrumental (cf. discussões críticas em Bown et al., 2009; Keller, 2000; Keller et al., 2014) constitui um conjunto de conceitos normativos com forte impacto nas práticas criativas musicais atuais. Provavelmente originado no século dezenove nos países centrais da Europa e da América do Norte, esse processo normativo abrange a invenção do gênio (cf. revisão crítica em Weisberg, 1993) e coloca a performance de instrumentos acústicos como o modelo ideal a ser atingido em todas as práticas criativas [Wessel e Wright, 2002]. Segundo esse enfoque, as habilidades geniais e incomuns de alguns, descritas como virtuosismo, permitiriam alcançar objetivos musicais que estão além das possibilidades musicais da maioria. Portanto, é estabelecida uma hierarquia social, centrada nos objetivos da prática instrumental, relegando a a casos periféricos as manifestações musicais que não se enquadram nesse tipo de prática, e minimizando seu peso político, cultural e estético (Messina e Aliel, 2018]. Outro aspecto a ser destacado é a relação entre a organização social e a estruturação do espaço. O paradigma acústico-instrumental adota o palco italiano como um formato privilegiado para a atividade artística (cf. Trueman, 2007). Esse formato determina uma hierarquia rígida, separando o público dos artistas-criadores (ver análises críticas em Keller, 2000 e Lewis, 2000).

A etimologia do termo *paradoxo* tem origem grega no *paradoxon*, também encontrada no latim arcaico como *paradoxum*. A palavra é composta do prefixo *para-*, que significa "contrário a", "alterado" ou "oposto a", juntamente com o sufixo nominal *-doxa*, que significa "opinião". Nas práticas criativas, Messina e Aliel (2019) conceituam os *paradoxos acústico-instrumentais* como simulação, estabelecendo uma estratégia contrária ao paradigma acústico-instrumental do simulacro. Os autores utilizam uma adaptação das notas de Baudrillard (1994) sobre os dois conceitos: o simulacro e a simulação. Para Baudrillard (1994, p. 44), os simulacros são cópias que representam elementos que nunca existiram ou que atualmente não têm equivalentes na realidade. No contexto do paradigma acústico-instrumental, o simulacro sugere uma unidade perfeita e singular. Um bom exemplo é a figura do "gênio", um ser que atua em um nível superior à realidade material e às possibilidades humanas. Em contraste com essa visão idealista da prática musical, Messina e Aliel (2019) apontam que a simulação é a imitação de uma operação ou de um processo existente no mundo material. O paradoxo acústico-instrumental alinha-se ao conceito de simulação, explorando aspectos miméticos, situados e corporizados, visando práticas artísticas fortemente vinculadas aos recursos materiais locais. Nessa estratégia embasada no enfoque cognitivo-ecológico, são considerados os processos de adaptação dos agentes às condições locais do ambiente, estimulando a exploração das possibilidades criativas

através do reaproveitamento dos recursos materiais. A utilização de paradoxos tenderia a ampliar a oferta de referências estéticas permitindo que cada agente encontre sua própria abordagem criativa.

Como estratégia exploratória, as práticas cognitivo-ecológicas permitem a incorporação de elementos *Gelassenheiten* no processo criativo [Aliel et al., 2018]. No entanto, como promover estratégias que aumentem as chances de gerar materiais artísticos significativos? A questão é complexa porque afasta as práticas criativas da tradição acústico-instrumental. A associação entre instrumentos acústicos e estruturas musicais derivadas do uso desses instrumentos torna a experiência mais familiar para os músicos. Os paradoxos colocam o processo de tomada de decisões fora do paradigma acústico-instrumental, impulsionando um contexto atípico de possibilidades e forçando a adaptação dos comportamentos a novos cenários. Assim, os agentes (sejam eles leigos ou músicos) podem introduzir concepções divergentes das práticas musicais preexistentes.

Ao utilizar os paradoxos como estratégia criativa, não estamos propondo que a interação entre leigos e músicos seja apenas uma "simulação da prática artística". O uso da simulação aqui serve para promover ações que podem ser entendidas por ambos os grupos e que podem ser projetadas musicalmente a nível macro (se estiverem dadas as condições necessárias). Por exemplo, podemos gerar regras que organizam os parâmetros musicais ("toque utilizando baquetas somente no interior do piano", ou "use somente os objetos no lado esquerdo da sala para produzir sons", ou "use apenas sons do corpo"). Neste caso, as diretrizes se aplicam aos dois grupos. Todos os envolvidos têm acesso aos conhecimentos necessários para realizar essas propostas e portanto as restrições não estão vinculadas ao conhecimento técnico, à utilização de sistemas simbólicos do domínio específico ou à complexidade das ações requeridas para atingir resultados sonoros satisfatórios. A partir dessas diretrizes, o plano de contingências pode ter maior ou menor impacto nas trocas (alguns indivíduos usam raspagens nas cordas, outros produzem ostinatos, ou usam objetos cotidianos, sons vocais ou percussão corporal). Ao propor "use somente os objetos no lado esquerdo da sala para produzir sons" incluímos uma diretriz restrita que permite uma ampla gama de potencialidades para músico ou leigos. As possibilidades de interpretação da frase serão condizentes com os conhecimentos específicos de cada agente. Entretanto, podem haver trocas de conhecimentos por vias miméticas ou verbais.

Uma contribuição importante da presente proposta é a construção de representações que ultrapassem os limites do paradigma acústico-instrumental, permitindo a socialização dos recursos materiais e fomentando a diversificação das interações entre leigos e músicos. Tanto no plano das diretrizes quanto no plano das contingências existem aspectos potencialmente positivos e negativos para o suporte às práticas criativas (ver tabelas 1 e 2). O conceito de paradoxo constitui uma tentativa de nivelamento de informações para viabilizar a troca de conhecimentos. Ou seja, o paradoxo acústico-instrumental prevê diretrizes gerais que podem ser compreendidas por todos, músicos e leigos, e servem para embasar decisões conjuntas. A abordagem empurra a discussão dentro do campo da comprovação de modo efetivo já que, ao criarmos diretrizes rígidas aplicamos princípios composicionais, sendo que os aspectos

contingenciais ficam a critério dos agentes, fomentando uma maior volatilidade nos recursos e potenciando os elementos *gelassenheit*.

Tabela 1: Planos de diretrizes nas atividades comprovacionais.

Estratégias	Características	Impacto Leigo-Músico	Exemplos
Recursos notacionais fixos	Alta complexidade; Exigem domínio de leitura e escrita musical.	Menor interação; Baixa acessibilidade para o grupo leigo.	Uso de notação musical tradicional.
Aquisição de conhecimentos do domínio específico	Exigem alto investimento para aprendizagem e treinamento técnico.	Menor interação; Menor fluxo de informações; Maior tempo para a transferência de conhecimentos.	Aprendizagem de leitura ou solfejo de partitura tradicional; Desenvolvimento técnico específico em performance baseado no paradigma acústico-instrumental.
Metáforas para a ação criativa	Persistência e sustentabilidade : as metáforas para a ação criativa permitem que o material e os procedimentos sejam compartilhados, revisitados, analisados e	Maior interação; Menor demanda de tempo para a reapresentação de material sonoro; Suporte para trocas longitudinais.	Técnicas de suporte verbal, gestual, gráfico, procedimental, sonoro, audiovisual.

	documentados.		
Organização formal	Permite aplicar procedimentos teleológicos detalhados na estruturação da obra.	Menor demanda de esforço organizacional.	Estruturas hierárquicas: ABA, ABBA, AABB. Adoção de padrões idiomáticos de improvisação (cifra, escalas, padrões rítmicos, clichés improvisacionais)

Tabela 2. Planos de contingências nas atividades improvisacionais.

Estratégias	Características	Impacto Leigo-Músico	Exemplos
Recursos notacionais adaptativos	Redução do tempo de aprendizagem; Menor exigência de conhecimentos do domínio específico na leitura e escrita; Elementos <i>gelassenheit</i> .	Maior interação; Maior troca de conhecimentos; Aumento do potencial criativo.	Práticas que ficam entre a improvisação livre e a comprovação envolvendo formas abertas de notação (<i>soundpainting</i> , <i>intuitive musik</i>)
Recursos materiais locais	Forte relação entre os processos criativos e os materiais disponíveis nos locais de realização das atividades musicais.	Menor tempo para adquirir conhecimentos; Abertura a contingências; Redução de hierarquias na interação social.	Marcação temporal; Marcação espacial; Marcação procedimental-gráfica.
Improvisação livre	Alta volatilidade: os recursos	Pode impulsionar a geração de novos	Improvisação livre instrumental;

	sonoros são raramente revisitados ou analisados.	conhecimentos, mas prevalecem os elementos contingenciais; Os resultados dependem fortemente da aplicação do conhecimento tácito dos participantes dos participantes.	Improvisação livre com recursos sonoros disponíveis na internet; <i>Live coding;</i> <i>Live patching.</i>
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4. The Maxwell Demon: Suporte para leigos em atividades criativas profissionais

Nesta seção apresentamos os procedimentos para gerar planos de diretrizes e de contingências em ações criativas embasadas no enfoque ecológico, a partir da análise do estudo de caso *The Maxwell Demon (TMD)*. O projeto TMD é uma comprovação inspirada no experimento realizado por James Clerk Maxwell em 1871. O Demônio de Maxwell representa uma criatura imaginária destinada a contrariar a segunda lei da termodinâmica (isto é, a tendência à entropia de todos os sistemas). No experimento de Maxwell encontramos uma caixa com dois compartimentos. A divisória tem uma porta que pode ser aberta e fechada pelo Demônio de Maxwell. O demônio abre a porta para permitir que apenas as moléculas mais rápidas fluam para um lado da câmara. Somente as moléculas mais lentas circulam para o outro lado, aumentando gradualmente o nível de energia de um lado (e reduzindo a entropia), enquanto no outro compartimento a temperatura diminui (representando um nível mais alto de entropia). Aliel e coautores (2015) utilizam o Demônio de Maxwell como uma metáfora artística focada no som, representando um ser imaginário - através de um algoritmo estocástico - que busca controlar o resultado sonoro para aumentar ou reduzir o nível de entropia do resultado musical.

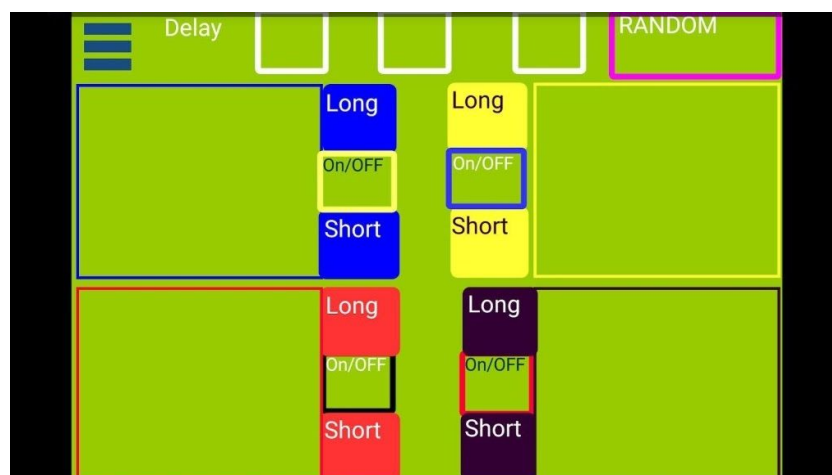


Figura 1. Interface do patch móvel *The Maxwell Demon*.

Materiais e equipamentos. Foi desenvolvida uma ferramenta: 1) capaz de produzir sons facilmente manipuláveis; 2) acessível a todos os agentes (através da implantação em plataformas móveis baseadas em sistemas Android e iOS). Todos os participantes (músicos e não-músicos) receberam um telefone celular com um *patch* (algoritmo em linguagem visual) construído em *Pure Data* (PD) (Puckette, 1997) e adaptado para o ambiente *MobMuPlat* (Iglesia, 2016). A tela principal do sistema possui quatro controladores de osciladores de síntese aditiva. Mais quatro osciladores baseados na síntese FM também foram implementados, com parâmetros de controle para modificar frequência, duração e processamento de áudio (*delay*). Os geradores de parâmetros aleatórios podem ser ligados e desligados ao tocar na tela do telefone. As frequências variam de 220 Hertz a 1320 Hertz. O aumento da frequência está associado a gestos da esquerda para a direita. Ao lado de cada retângulo estão três interruptores de osciladores (botões liga/desliga) e dois controladores de envelope (*ADSR*). Um com períodos curtos de ataque, decaimento, sustentação e repouso e outro com durações mais longas. O botão esquerdo na parte superior da tela controla um gerador estocástico de frequências. Os três botões restantes controlam o processamento de *delay* aplicado ao material sonoro. Da esquerda para a direita, têm valores fixos de atraso de 150 ms, 300 ms e 750 ms.

Com características semelhantes aos algoritmos usados em dispositivos portáteis, foi implementado um patch PD para execução em dispositivos estacionários (figura 1). A ferramenta emprega a síntese por modulação de amplitude (AM), utilizando quatro osciladores. Cada oscilador recebe três parâmetros que modificam a amplitude. Os osciladores são controlados por um processo estocástico, gerando frequências entre 50 Hz e 2000 Hz. Um controlador de envelope (ADSR) define os parâmetros de ataque, decaimento, sustentação e repouso. O envelope também pode ser gerado a partir de parâmetros aleatórios, produzindo uma variedade de perfis de ataque, decaimento e sustentação. Todas as fontes sonoras são processadas via filtros de passa-alta, *delay* e reverberação. Os parâmetros de atraso variam aleatoriamente entre 0 e 5000 ms.

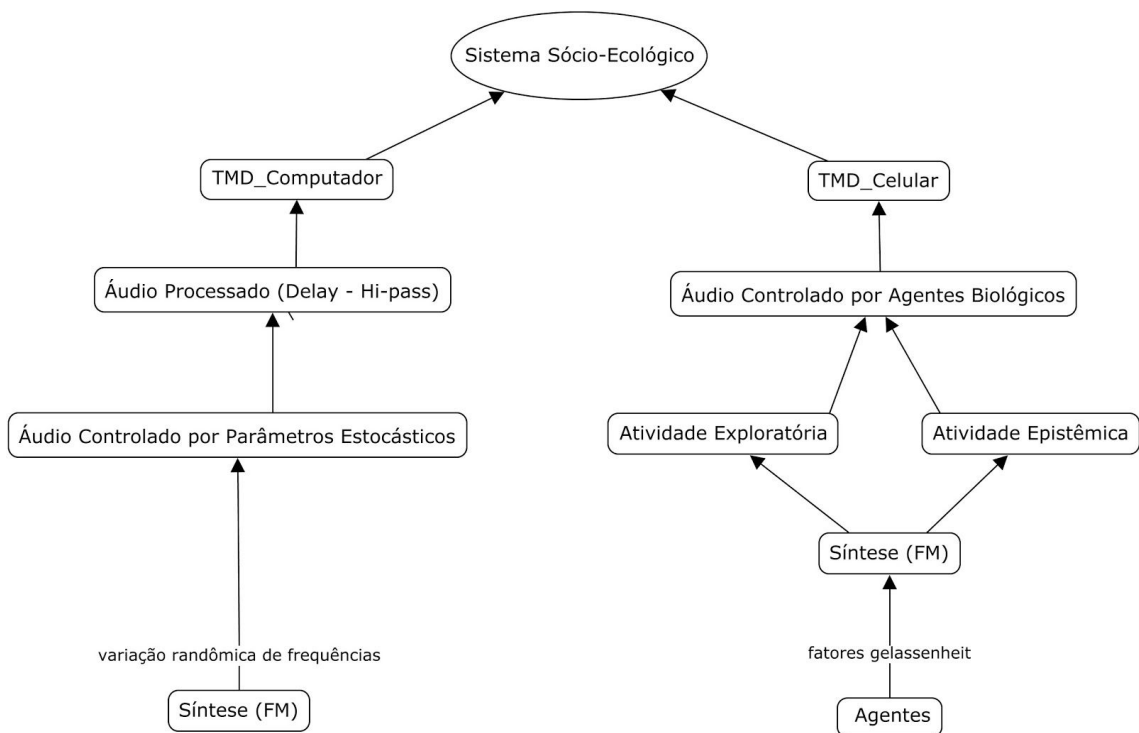


Figura 2. Procedimentos implementados em Pure Data para o projeto *The Maxwell Demon*.

4.1 Métodos

Durante o desenvolvimento do projeto *The Maxwell Demon (TMD)* foram realizadas performances com o objetivo de coletar informações sobre os comportamentos dos agentes, os recursos sonoros e o suporte tecnológico. TMD fusiona as técnicas de síntese sonora com formas de organização baseadas em dinâmicas sociais (ver também *sócio-síntese* - Burtner et al., 2012).

Local das sessões. O experimento foi realizado em um estúdio de pequeno porte, de aproximadamente 10 x 7 metros. O ambiente tem tratamento acústico e possui diversos instrumentos musicais tradicionais, como piano e afins. O estúdio fica localizado no departamento de música da Universidade de São Paulo.

Perfil dos participantes. Cinco músicos e três participantes sem treinamento em música participaram nas sessões. Todos tinham educação superior. Os participantes leigos estavam familiarizados com conceitos musicais básicos. Três eram mulheres (idades: 25, 32 e 35 anos). Com treinamento e experiência musical de 10 e 30 anos, os músicos eram quatro homens (idades: 26, 34, 38 e 58 anos) e uma mulher (idade: 22 anos).

Procedimentos. A performance foi orientada pela definição de *cenários* (Sibertin-Blanc et al., 2011). Nessa abordagem um cenário representa uma improvisação livre com dispositivos portáteis, de sete minutos de duração. As únicas orientações dadas aos agentes foram "percorra o espaço e use telefones celulares para produzir sons". Ao tocar do primeiro sino, o computador inicia os parâmetros predefinidos e seleciona o número de osciladores, alturas, dinâmicas, durações e a magnitude do *delay*. A sessão conclui ao

tocar o segundo sino.

Avaliação. Os dados foram coletados por meio de entrevistas com os participantes, via observações no local e através da análise de gravações de áudio e vídeo realizadas durante as sessões. O objetivo foi avaliar as interações entre os agentes e a forma como os recursos foram utilizados, incluindo: 1. estado inicial das *entidades*, 2. a dinâmica do processo criativo (os fatores internos), 3. o impacto dos fatores externos nos processos e nos produtos criativos. A avaliação dos cenários foi realizada com base nos indicadores derivados da atividade musical, incluindo o estado final das entidades.

4.2. Resultados

Preparação. Vários fatores dificultaram a manutenção e o suporte tecnológico aplicado na execução da proposta. Os participantes escolhidos tinham dispositivos móveis configurados com diversas versões de sistemas operacionais. Várias tentativas foram feitas para ajustar o desempenho do software implementado em PD. Parte dos voluntários não puderam participar porque os sistemas instalados em seus dispositivos não tinham suporte para executar o aplicativo TMD. Houveram também conflitos entre aplicativos previamente instalados e *MobMuPlat*. Como a ferramenta *MobMuPlat* é implementada em Java, ela depende das versões atualizadas dessa linguagem, porém algumas ferramentas não funcionam corretamente devido à incompatibilidade entre as versões.

Contingências. Os agentes exploraram vários recursos materiais, envolvendo diversas formas de interação. Os sons gerados pelos algoritmos geralmente estiveram vinculados a novas ações dos agentes. Grande parte do material produzido nas sessões de TMD raramente era reutilizada, impulsionando a originalidade dos produtos criativos mas reduzindo sua relevância. Portanto, as interações e comportamentos que levaram à descoberta de novos recursos sonoros podem ser interpretados como fontes de contingências. Isso indica a necessidade de implementação de mecanismos específicos para lidar com esse aspecto do suporte à criatividade.

Impacto da experiência musical prévia. Materiais coletados em estudos anteriores indicam que a geração, manutenção e exclusão de materiais sonoros de improviso, geralmente ocorrem a partir de estratégias imitativas [Mannis, 2014] ou de atividades exploratórias e epistêmicas [Keller et al., 2010]. Apesar das disparidades nos níveis de conhecimento musical, todos os participantes apresentaram habilidades técnicas similares nas atividades criativas.²

Corporização e formas de interação entre artistas e audiência. A peça TMD dá destaque às ações corporais e aos possíveis significados e simbolismos dos gestos. Ao eliminar o palco italiano, o uso do espaço em TMD contribui para incentivar o engajamento dos agentes leigos. A mobilidade dos participantes - além do baixo nível

² Durante o estudo realizado por Aliel et al. (2015) foram observadas semelhanças nas três sessões, envolvendo intensas interações entre os agentes (algoritmos x agentes, agentes x agentes e agentes x recursos materiais).

dinâmico dos sons gerados nos dispositivos móveis - proporcionou um ambiente rico, motivando constantes mudanças nos focos de atenção. Através do uso de dispositivos móveis, em TMD as massas sonoras migram em tempo real para novas configurações a partir da movimentação dos participantes. Desta feita, TMD contribui para o uso do movimento corporal como estratégia estética.

O paradoxo acústico instrumental em TMD. TMD aplica como premissa o conceito de cenário (Sibertin-Blanc et al., 2011). A diretriz utilizada foi: "percorra o espaço e use telefones celulares para produzir sons". A frase propõe elementos espaciais, exploratórios e abordagens adaptativas envolvendo a utilização do celular para produzir sons, modificando a função primária do equipamento. As atividades de exploração e apropriação do espaço e produção sonora ficam vinculadas às trocas de conhecimentos, seja por imitação entre os participantes ou por geração de novos recursos durante o processo. Dentro desse contexto, as trocas socioecológicas fomentam um nivelamento das diferenças entre os comportamentos dos músicos e dos leigos.

É importante salientar que a partir da aplicação de conhecimentos individuais, os participantes podem explorar novos resultados ou limitar o acesso a recursos por parte dos outros agentes. Em alguns casos, para manter as premissas do paradoxo acústico-instrumental é necessário introduzir novas diretrizes. A introdução de novas diretrizes pode abranger tanto informações verbais quanto a aplicação de novos recursos tecnológicos (como acontece na prática de *live coding*), com o objetivo de retomar o fluxo das trocas permitindo o nivelamento entre as partes. Durante as sessões de TMD, não foi necessária a introdução de novas diretrizes.

5. Considerações finais e desenvolvimentos futuros

Levando em conta que um músico profissional precisa realizar um treinamento longo até alcançar um nível satisfatório de habilidade técnica e expressiva no uso de instrumentos acústicos, existe uma grande disparidade entre a base de conhecimentos de leigos e de músicos. A partir do contexto teórico estabelecido pelas práticas criativas cognitivo-ecológicas, propomos uma abordagem comprovisatória como suporte às interações entre leigos e músicos. Nosso principal objetivo é facilitar as trocas entre os agentes.

Sustentabilidade criativa. No contexto da aplicação de modelos sonoros na composição baseada em recursos tecnológicos, Barreiro e Keller (2010) sugerem que, quando não há regras fixadas a priori, podem ocorrer vários fenômenos emergentes e auto-organizados. Segundo os autores, o resultado sonoro global (a macroestrutura musical) é um produto da interação local entre os agentes - sejam eles improvisadores humanos ou recursos computacionais. Músicos e processos algorítmicos moldam - mas não determinam - as relações macroestruturais dos materiais sonoros. Abordagens ecológicas, modelos bioinspirados e algumas estratégias de sonificação compartilham um terreno com potencial de ampliação das práticas musicais criativas. Parte dessas estratégias dão espaço para as propriedades musicais emergentes.

Dentro de um sistema socioecológico, a aplicação de modelos de síntese ou de processamento sonoro pode envolver processos determinísticos (usualmente descritos como escolhas composicionais) ou estratégias baseadas em contingências (que abrangem atividades exploratórias ou processos improvisatórios). Ao introduzir estratégias ecológicas de síntese e processamento sonoro - aliadas a contextos de improvisação - fomentam-se condições únicas para cada performance (no nível macro) e para cada evento (nos níveis meso e micro).

A introdução de diretrizes fornece uma base de organização para a atividade criativa [Aliel, 2017]. O processo de improvisação não adota regras rígidas. As regras são flexíveis para permitir a convivência com processos de improvisação. Por exemplo, uma regra pode exigir que todos os dispositivos usem recursos estocásticos para produzir som durante um minuto. Apesar de existir um limite para a duração da seção, não há como ter certeza do tempo de ocorrência de cada evento (quando os dispositivos serão acionados, quando eles serão desconectados, se devem ser posicionados juntos ou separados, etc.), nem pode-se prever o resultado sonoro final. A regra se aplica apenas no nível da macro-organização. Nesse contexto a improvisação permanece presente, mas é governada por uma força composicional persistente, aumentando a sustentabilidade e replicabilidade do resultado artístico.

Interação leigo-músico. A complexidade das relações entre a criatividade profissional e a criatividade cotidiana em atividades musicais envolvendo participantes com treinamento formal em música e sujeitos sem treinamento específico são evidenciadas nos estudos da interação leigo-músico (Ferreira et al., 2016; Keller, 2018). As estratégias adotadas no projeto *Demônio de Maxwell* contribuem para a integração da audiência e dos participantes casuais nas práticas ecológicas voltadas para a improvisação. No projeto TMD, a audiência foi integrada como agente do processo criativo através de propostas musicais abertas, da movimentação no espaço e dos recursos sonoros gerados com as ferramentas de síntese disponibilizadas.

Transferência de conhecimentos. Embora a criatividade musical seja tradicionalmente vinculada apenas a resultados sonoros obtidos por músicos profissionais, as abordagens ubimus destacam a relação íntima entre os recursos materiais e os processos cognitivos que conduzem a resultados criativos por parte de leigos (Brown et al., 2014; Lima et al. 2017). No entanto, o compartilhamento do conhecimento tácito ainda é uma das questões pendentes no suporte à criatividade musical. Os métodos acústico-instrumentais empregam sistemas de notação simbólica baseados no conhecimento explícito e na exposição extensiva a práticas instrumentais. As propostas musicais ubíquas aplicam estratégias oportunistas para viabilizar o uso de recursos materiais locais e o uso de conhecimentos extramusical. Portanto, não exigem o desenvolvimento de habilidades focadas exclusivamente na performance musical e podem ampliar o leque de estratégias disponíveis para os participantes leigos. Tendo em vista essas demandas da interação leigo-músico, acreditamos que os resultados obtidos em TMD abrem novas perspectivas para o suporte de atividades musicais ubíquas.

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A Ferramenta SoundSphere no Contexto da Exploração e da Criação Sonora: Um Estudo de Caso de Música Ubíqua dentro da Sala de Aula

Ivan Simurra, Damián Keller, Brendah Freitas, Jeú Ferreira, César Leite, Marlon Teixeira, William Ramon Barbosa Bessa

Núcleo Amazônico de Pesquisa (NAP) – Universidade Federal do Acre (UFAC)
Caixa Postal 500 – 69.915–900 Rio Branco – AC– Brasil

ivan.simurra@ufac.br, dkeller@ccrma.stanford.edu

Abstract. *We report a study involving sound creation, production and mixing with the SoundSphere prototype, done by 32 students at the Federal Institute of Acre. The volunteers were 16 women and 16 men, who used SoundSphere for a period of 45 minutes. The audio materials encompassed synthesized sounds and everyday-sound recordings. Two activities with SoundSphere were proposed: exploration and creation. The results suggest that the participants had a satisfying and fun experience, with a good potential for collaboration. Nevertheless, despite the encouraging aspects of the experience some subjects failed to fulfil their creative goals. We point to possible adjustments in the experimental methods to deal with the issues identified by this ubimus study.*

Resumo. *Trata-se de um estudo envolvendo alunos do Instituto Federal do Acre (IFAC) após a sua interação com a ferramenta de criação, produção e mixagem sonora denominada SoundSphere. No total, as sessões tiveram a participação de 32 voluntários (16 mulheres e 16 homens) por um período de 45 minutos. As amostras sonoras abrangeram sons processados e gravações do cotidiano sonoro. Duas atividades foram propostas: exploração e criação. Os resultados sugerem que os participantes tiveram uma experiência satisfatória e divertida, com bom potencial de colaboração. No entanto, também indicam que eles acharam a atividade instigante sem atingir os objetivos criativos. Apontamos ajustes possíveis nos métodos experimentais em música ubíqua, para enfrentar parte dos problemas identificados nesta pesquisa.*

1. Introdução

Os recentes avanços no suporte da tecnologia da informação desencadearam múltiplas estratégias de auxílio nas atividades criativas [Mitchell et al., 2003]. Todavia, apesar dos avanços tecnológicos, boa parte das técnicas de transferência de conhecimento e informação musical perpetuam a divisão conceitual entre as tecnologias focadas na composição musical instrumental por um lado, e os recursos tecnológicos de processamento digital de sinais e síntese sonora por outro. Acreditamos que tais

distinções entre as especificidades tecnológicas impactam negativamente as atividades artísticas de participantes profissionais e limitam o acesso dos leigos ao fazer musical criativo. Diante deste cenário, parte das iniciativas centradas nas práticas criativas propõem a criação musical fora dos locais e ambientes de produção artística tradicionalmente estabelecidos. Desta feita, evita-se o contexto palco-plateia, no qual o palco representa a parte ativa da produção sonora e musical e a plateia limita-se à recepção passiva de conteúdos musicais. A área de pesquisa que desenvolve estudos nos contextos que acabamos de citar denomina-se música ubíqua ou ubimus [Keller et al., 2014]. A pesquisa ubimus fomenta propostas tecnológicas alternativas para participantes com perfis diversos, com o intuito de desenvolver estratégias de suporte que sejam simultaneamente flexíveis e intuitivas, sem perda da qualidade da experiência musical. Dentro do contexto ubíquo, a criação musical não emerge a partir de concepções e ideias isoladas, individuais. Mais do que isso, música ubíqua assoma-se a partir de interações de múltiplos participantes [Kramann, 2020]. Desde o ponto de vista do público-alvo, objetiva-se o fomento a experiências artísticas que evitem resultados musicais monótonos, maçantes ou não correlacionados. A flexibilidade conceitual das ferramentas ubimus tende a garantir uma maior sustentabilidade [Pereira et al., 2018], através de metáforas para a ação criativa que não demandam conhecimentos do domínio específico. A naturalidade dessas metáforas ajuda a reduzir o período de aprendizado a apenas alguns minutos, permitindo assim o seu uso casual [Keller e Lima, 2018].

Desta maneira, as pesquisas centradas em ubimus fomentam uma maior integração entre músicos e iniciantes, situando os usuários amadores ou leigos como colaboradores congêneres na atividade artística e criativa. No entanto, a *interação leigo-músico ou amador-músico*, descrita por Ferreira et al. (2016) e por Keller e Lazzarini (2017), denota uma potencial dicotomia entre os recursos tecnológicos e computacionais tradicionalmente desenvolvidos para músicos e as estratégias de suporte para a interação por parte de leigos. No primeiro aspecto, as ferramentas especializadas demandam conhecimento técnico aprofundado. No segundo aspecto, relativo à participação casual, as estratégias ubimus visam dar apoio a participantes com pouco ou nenhum treinamento técnico-computacional ou artístico [Keller e Lima, 2016]. Diversos trabalhos discutem os desafios com relação a usuários e os artefatos associados à produção de ubimus. Santos et al (2020) argumenta que artefatos centrados em educação musical implicam cuidados inerentes ao ensino, à produção e à própria execução sonora do material por parte de seus usuários, em especial, leigos. Relativo à questão centrada na tecnicidade associada aos artefatos ubimus, Mandanici (2019) destaca que tais questões suscitam desafios não somente na educação musical quanto na própria criação musical com usuários multivariados que demandam técnicas inclusivas de usuários especiais.

Neste artigo apresentamos os resultados de um estudo realizado a partir da disponibilização da Ecologia SoundSphere ou Esfera do Som [Bessa et al., 2015] em um ambiente educacional, com a participação de estudantes de nível técnico do Instituto Federal do Acre (IFAC). A pesquisa objetiva a inclusão de leigos em atividades criativas musicais. O público-alvo teve pouco acesso a atividades de apreciação artística e praticamente nenhuma experiência prévia em criação musical. Por esse motivo, o estudo centra-se ainda na observação dos aspectos técnicos e práticos do uso da tecnologia musical por parte dos estudantes do IFAC.

Nas próximas seções apresentamos a metáfora para a ação criativa denominada SoundSphere e descrevemos o método utilizado para a coleta e análise dos dados. Discutimos os resultados obtidos e desenvolvemos nossas considerações sobre o potencial de aplicação de ubimus no âmbito educacional. Concluímos o artigo destacando as contribuições e projeções específicas para o design de ferramentas de suporte para a criatividade, indicando possíveis convergências da pesquisa ubimus, e dando destaque para o impacto dos resultados obtidos nos procedimentos a serem aplicados na aferição de resultados criativos por parte de leigos em música.

2. SoundSphere: Metáfora para a Ação Criativa

O projeto SoundSphere iniciou-se em 2015 no Núcleo Amazônico de Pesquisa Musical (NAP),¹ e centra-se em estudos relativos à tecnologia aplicada à música fora dos contextos tradicionais do fazer musical [Bessa et al., 2015]. A ecologia SoundSphere objetiva proporcionar um ambiente de suporte assíncrono e parcialmente conectado,² direcionado a atividades criativas sonoras. A metáfora que fundamenta seu desenvolvimento técnico sugere o posicionamento da pessoa que realiza a atividade criativa no meio de uma esfera, sendo que os eventos sonoros projetam-se na superfície da própria esfera [Keller et al., 2019, p. 7]. A tela do dispositivo representa o painel de mixagem, cuja organização temporal associa-se à latitude da esfera e, portanto, situa-se no eixo horizontal. Ortogonalmente, o eixo vertical corresponde às manipulações e ao processamento das amostras sonoras. Deslocar a visualização do eixo vertical para cima ou para baixo permite o acesso a eventos que serão renderizados simultaneamente. Movimentos ao longo da linha do tempo em direção à esquerda revelam eventos passados enquanto que movimentos à direita dão acesso às projeções futuras de conteúdo sonoro [Keller e Bessa, 2018, p. 1]³. A ferramenta foi estruturada de acordo com protocolos baseados em técnicas e funcionalidades da API Web Audio,⁴ sendo compatível com a maioria dos navegadores de internet [Freitas et al., 2019]. SoundSphere⁵ pode ser descrito como um sequenciador de dados sonoros em grande escala (*massive sound-data sequencer*). Como destacado na seção de introdução, a proposta foca a acessibilidade visando atingir a curva zero de aprendizagem. No presente estudo utilizamos o protótipo SoundSphere como estratégia de apoio a atividades de exploração e de criação sonora no contexto educacional. Na seção seguinte, apresentamos os materiais utilizados nas tarefas realizadas pelos participantes, o método de observação e a dinâmica dos procedimentos para a coleta de dados.

3. Materiais

Nas sessões experimentais utilizaram-se 32 Computadores Dell Inspiron 3277-A10 (Intel Core i3 4GB 1TB), com monitor LED 21,5”, Windows 10, com acesso à internet. Esse modelo dispõe de alto-falantes embutidos. A interação entre os participantes e o

¹ Para mais detalhes, acessar: <https://sites.google.com/site/napmusica/perfil> (Data de acesso: 26/01/2020)

² É importante destacar que apesar de utilizar a plataforma web - e mais especificamente o navegador como ambiente de desenvolvimento - SoundSphere pode ser utilizado sem conexão permanente à internet.

³ A Figura da interface do protótipo SoundSphere, em sua versão estável e utilizada no experimento, pode ser visualizada pelo link: <https://bit.ly/39U8n93>

⁴ <https://www.w3.org/TR/webaudio/>. A ferramenta foi testada com a versão disponibilizada em setembro de 2018.

⁵ SoundSphere pode ser acessado no seguinte endereço eletrônico: <http://soundsphere.com.br/> Data de acesso: 26/01/2020. O protótipo atual utiliza arquivos de áudio PCM, em formato WAVE estéreo, 44,1 kHz, 16 bits.

ambiente de criação artística sonora foi realizada com a ferramenta SoundSphere versão 1.4.10, acessada utilizando o navegador Chrome.75.0.37770.100. Para coletar os dados dos participantes, utilizou-se o Questionário de Desempenho CSI-NAP v. 0,7 e o questionário de Identificação e Perfil Sócio-Econômico ISE-NAP v. 0,5.

3.1. Aferição do Desempenho Criativo

O CSI-NAP é um instrumento que permite coletar dados objetivos a partir de questões subjetivas acerca do desempenho dos participantes durante as atividades criativas [Keller et al., 2011]. O CSI-NAP abrange diversos aspectos da experiência individual e dos produtos utilizados [Freitas et al., 2019]. Os dados são utilizados para avaliar o impacto dos recursos disponíveis na atividade [Freitas et al., 2019, p. 10]. As categorias propostas para o presente estudo são resultado das seguintes perguntas: “O resultado foi bom?”, “O resultado foi original?”, “A atividade foi fácil?”, “Você ficou atento?”, “A atividade foi divertida?”, “A atividade foi produtiva?”, “Foi fácil colaborar?”. Os participantes respondem às questões do instrumento por intermédio de uma escala Likert⁶ de valores entre -2 e 2. A Tabela 01 ilustra a descrição semântica dos valores utilizados na aferição das categorias.

Tabela 01. Tabela com os descritores semânticos associados a cada valor.

Descrição	Valor
Discordo Totalmente	-2
Discordo Parcialmente	-1
Não sei	0
Concordo Parcialmente	1
Concordo Totalmente	2

3.2. Local das Sessões

O Instituto Federal do Acre disponibiliza 2 laboratórios com 40 computadores para as atividades práticas dos alunos do curso Técnico em Informática para Internet. Com carga horária total de 3.150 horas, o curso é frequentado por alunos do ensino médio. As sessões foram realizadas no Laboratório de Informática Básica III. O espaço tem 8 x 12 metros e está equipado com mesas com capacidade de alocar até 5 computadores. São disponibilizadas cadeiras, modelo secretária em tecido. A sala está equipada com um projetor multimídia com suporte para reprodução de áudio e uma lousa interativa. A Figura 1 ilustra a sala utilizada no presente estudo.

⁶ A escala Likert é um procedimento de coleta de dados a partir de respostas psicométricas de voluntários em um questionário. Basicamente, a escala, bipolar, é configurada por meio de itens que às associam as potências de cada questão associada. Para mais detalhes: https://pt.wikipedia.org/wiki/Escala_Likert. Data de acesso: 18/05/2020.



Figura 01. Laboratório do Instituto Federal do Acre no qual foi realizado o experimento.

3.3. Recursos Sonoros

Para o experimento utilizaram-se 76 amostras sonoras, abrangendo sons processados digitalmente (amostras de gravações de sons de instrumentos musicais acústicos processados no aplicativo Audacity) e sons do cotidiano. Para minimizar potenciais efeitos de viés no uso das amostras, os sons foram organizados em dois grupos de 40 amostras para a atividade de exploração e 36 amostras para a atividade de criação. As durações ficaram entre 3 segundos e 13 segundos⁷.

Amostras da atividade de exploração. Nas atividades de exploração sonora foram utilizadas 40 amostras distribuídas em dois grupos: sons processados e sons do cotidiano com as características descritas na Tabela 02.

⁷ As amostras utilizadas fazem parte do material de apoio compartilhado para a disciplina de Tecnologia Musical IV do Curso de Música da Universidade Federal do Acre. Elas foram elaboradas por membros do NAP.

Amostras da atividade de criação. Nas atividades de criação sonora foram utilizadas 36 amostras distribuídas em dois grupos de sons: processados e sons do cotidiano. A Tabela 03 sintetiza os dados relativos às amostras sonoras da atividade de criação⁸.

Tabela 02. Tabela com dados relativos às amostras sonoras na Atividade de Exploração

Tipos de amostras	Quantidade	Duração	Descrição
Sons processados	24	3 a 13 segundos	Amostras obtidas em banheiro, sons de carro, síntese por modelagem física (simulação de corda dedilhada)
Sons cotidianos	16	3 a 13 segundos	Sons do dia a dia: amostras obtidas em banheiro e cozinha

Tabela 03. Tabela com os dados relativos às amostras sonoras na Atividade de Criação

Tipos de amostras	Quantidade	Duração	Descrição
Sons processados	18	6 a 11 segundos	Amostras obtidas em banheiro, sons de carro, síntese por modelagem física (simulação de corda dedilhada)
Sons cotidianos	18	6 a 11 segundos	Sons do dia a dia: amostras obtidas em banheiro e cozinha

4. Perfil dos Sujeitos

Participaram do experimento um total de 32 alunos com faixa etária entre 18 e 22 anos ($19,53 \pm 0,80$), sendo 16 mulheres e 16 homens. Para o experimento contamos com a colaboração voluntária de alunos no curso técnico em informática do Instituto Federal do Acre.

O primeiro aspecto considerado foi o perfil dos participantes. A média de idade dos participantes é de 19,53 anos com um desvio padrão de 0,8 anos. A maioria dos participantes tem ampla experiência no uso de celulares e computadores ($6,97 \pm 3,25$ anos). São poucos os que estudaram música formalmente ($1,74 \pm 0,43$ anos), sendo que quase todos podem ser classificados como leigos.¹⁰ A Tabela 04 ilustra o perfil dos participantes.

Tabela 04. Perfil dos participantes

⁸ Para mais detalhes e acesso às amostras sonoras: <https://doi.org/10.5281/zenodo.3871735>. Data de acesso: 01/06/2020

⁹ A participação foi viabilizada pela gentil disponibilidade do Prof. Dr. Marlon Amaro Coelho Teixeira, que ofereceu todo suporte e apoio para desenvolver o presente experimento.

¹⁰ Aplicamos o critério de um mínimo de dois anos de treinamento musical formal para considerar um participante como estudante de música. Essa classificação é baseada nos dados fornecidos pelos sujeitos na ferramenta ISE-NAP. É possível aplicar um protocolo mais refinado para determinar o nível de treinamento musical. No entanto, dado o foco da pesquisa na inclusão de leigos a declaração dos próprios sujeitos é suficiente.

N	Mulheres	Homens	Idade	Uso de tecnologia	Estudo musical
32	16	16	19,53 ± 0,8	6,97 ± 3,25	1,74 ± 0,43

5. Procedimentos

A primeira etapa do experimento - preparação - focou a escolha do perfil dos participantes, o local de realização e a organização da coleta dos dados. Estabelecemos contato com professores e profissionais do Instituto Federal do Acre (IFAC) que se dispuseram a colaborar cedendo parte do horário de aula.

As sessões experimentais foram realizadas por alunos do terceiro período matutino do curso Técnico em Informática para Internet. O experimento foi organizado em 3 módulos distintos e sequenciais. O experimento iniciou-se com a preparação dos computadores, utilizados na interação Participante-SoundSphere, adicionando as amostras de áudio organizadas em dois bancos de arquivos digitais intitulados *Exploração* e *Criação*¹¹. Em seguida, os participantes foram recepcionados e convidados a ocuparem os computadores. Após a introdução, iniciamos as atividades dos Módulos descritos a seguir. Ao término do experimento, coletamos os dados dos participantes e os armazenamos em um dispositivo de memória portátil.

Fase 1. Apresentação do experimento aos participantes, introduzindo sucintamente aspectos relativos à tecnologia musical e o ambiente SoundSphere. Os experimentadores forneceram instruções sobre as atividades e sobre o preenchimento do questionário Perfil Sócio-Econômico (ISE-NAP v. 0.5). Em linha com o protocolo proposto para aplicar o experimento, iniciamos o Módulo 01 discutindo sucintamente questões introdutórias relativas à tecnologia musical além de destacar os recursos tecnológicos que utilizamos no nosso cotidiano. Discutimos ainda sobre como produzir materiais sonoros, em especial, gravações de fontes sonoras do cotidiano que estão ao alcance de todos os participantes por intermédio do uso de ferramentas portáteis de manipulação sonora, como mixDroid [Radanovitsck et al., 2011]. Com auxílio da central multimídia e da lousa eletrônica acessamos navegador Chrome versão 75.0.37770.100 e acessamos o ISE-NAP para ilustrar os procedimentos de preenchimento do questionário.

Fase 2. SoundSphere foi utilizado na tarefa denominada atividade de exploração. A atividade visa a exploração das possibilidades técnicas e artísticas do protótipo. Nesse módulo, participantes entram em contato com os recursos de carregamento de amostras de áudio, importar as amostras no painel de interação e mixagem além de aplicar algumas técnicas de processamento digital dos materiais sonoros, tais como aplicação de filtros de conteúdo espectral por banda de frequência sonora. Seguidamente, os participantes respondem ao Questionário de Desempenho (CSI-NAP v. 0.7). Acessamos o questionário CSI-NAP para demonstrar o seu preenchimento. Posteriormente, acessamos novamente o protótipo SoundSphere para realizar a atividade de criação.

¹¹ A transferência dos arquivos foi realizada utilizando um pen drive com capacidade de 8 Gb.

Fase 3. Utilização do SoundSphere na tarefa denominada atividade de criação. A tarefa objetiva a utilização da SoundSphere para a realizar e desenvolver um produto criativo sonoro de própria autoria. Neste Módulo, participantes interagem livremente com os materiais, sem restrição conceitual ou artística. Ao concluir a atividade, eles respondem novamente o Questionário de Desempenho (CSI-NAP v. 0.7).

6. Duração das Sessões

A duração do experimento foi de 30 minutos, sendo 13 minutos para a introdução, explanação e instrução do experimento; 5 minutos para o preenchimento do questionário ISE-NAP; 1 minuto para a Atividade de Exploração; 5 min para o preenchimento do questionário CSI-NAP relativo ao Módulo 02; 1 minuto para desenvolver a Atividade de Criação e; 5 minutos para a última etapa do Módulo 03, o preenchimento do questionário CSI-NAP. O experimento iniciou-se no período da manhã. Os 32 participantes responderam ao questionário ISE-NAP, versão 0,5. No Módulo 02, Atividade de Exploração, todos os 32 participantes desenvolveram a atividade e 29 responderam ao questionário. Para o Módulo 03, 5 participantes não preencheram o questionário CSI-NAP apesar de terem realizado as atividades do Módulo 03. A Tabela 05 sintetiza os dados apresentados anteriormente, incluindo a duração de cada uma das atividades.

Tabela 05. Atividades realizadas e número de participantes.

Atividade	N	Duração (mins)
ISE-NAP	32	5
Exploração	29	1
CSI-NAP	23	5
Criação	25	1
CSI-NAP	18	5

7. Resultados

Exploração. Ao analisarmos os resultados da atividade de exploração, dentro do intervalo dos índices de aferição descritos na Tabela 01 (entre os valores -2 e 2), observamos que a menor média de avaliação foi relativa ao critério de relevância do produto ($0,12 \pm 1,51$),¹² seguida pela produtividade da atividade ($0,83 \pm 1,37$) e pela originalidade do produto ($1 \pm 1,02$). Outrossim, a categoria facilidade (inversamente correlacionada ao esforço cognitivo) teve baixo consenso ($1,16 \pm 1,09$). Em contrapartida, a maior média de avaliação nesta atividade foi relativa à categoria

¹² Os dados são apresentados utilizando a média e o desvio padrão das avaliações fornecidas pelos sujeitos.

atenção ($1,45 \pm 0,65$), seguida pelo suporte à colaboração ($1,33 \pm 0,81$) e por último diversão ($1,29 \pm 1,03$) (tabela 6, N = 23).

Criação. Nos resultados da atividade de criação observamos que, diferentemente da atividade de exploração, as maiores médias referem-se à colaboração na atividade ($1,26 \pm 0,65$) e à diversão ($1,26 \pm 0,80$) durante a execução da atividade, seguidas pelo fator atenção ($1,15 \pm 1,01$) e produtividade ($1,00 \pm 1,00$). Em contrapartida, a menor média da atividade refere-se à relevância do produto criativo ($0,52 \pm 1,13$), seguida pela originalidade ($0,89 \pm 0,99$). O item correspondente ao inverso do esforço cognitivo (facilidade) também apresentou escores altamente variáveis ($0,94 \pm 1,07$). A tabela 6 inclui o cálculo da média e do desvio padrão para cada uma das categorias avaliadas por um total de 23 (exploração) e 18 sujeitos (criação).

Tabela 06. Resultados dos fatores criativos (média \pm desvio padrão), para os dois tipos de atividades realizadas: exploração (N = 23) e criação (N = 18).

	Relevância	Originalidade	Facilidade	Atenção	Diversão	Produtividade	Colaboração
Exploração	$0,13 \pm 1,51$	$1,00 \pm 1,02$	$1,17 \pm 1,09$	$1,46 \pm 0,66$	$1,29 \pm 1,16$	$0,83 \pm 1,37$	$1,33 \pm 0,81$
Criação	$0,52 \pm 1,30$	$0,89 \pm 0,99$	$0,94 \pm 1,07$	$1,16 \pm 1,01$	$1,26 \pm 0,80$	$1,00 \pm 1,00$	$1,26 \pm 0,65$

8. Discussão

A principal característica dos resultados obtidos é a alta variabilidade dos escores. Isso se aplica à maioria dos fatores avaliados, colocando alguns itens dentro de uma faixa de respostas completamente aleatórias (como é o caso da aferição da relevância dos produtos criativos). Em contrapartida, parte dos fatores mostram tendências positivas: o nível de atenção e o suporte à colaboração na atividade de exploração; e a diversão e novamente o nível de suporte à colaboração na atividade de criação. Em conjunto, esses três fatores (atenção, diversão e colaboração) indicam que houve engajamento efetivo dos participantes durante as atividades. Porém apesar de uma leve tendência positiva no fator facilidade, não é possível concluir que o nível de esforço cognitivo foi baixo para todos os participantes. Cabe tecer algumas considerações em relação à variabilidade no tipo de engajamento nas atividades e à falta de critérios uniformes na aferição dos próprios resultados criativos por parte dos sujeitos.

Como destacado na Introdução, estudos anteriores apontaram desafios importantes relativos à aferição dos resultados musicais por parte de leigos em música, tanto do ponto de vista da interação com os dispositivos quanto pela própria produção musical. Vemos por um lado que a participação em atividades grupais, com músicos profissionais, é uma modalidade altamente visada pelos amadores. Nossa hipótese é a de que este tipo de colaboração atende as expectativas do que é fazer música construídas a partir da exposição à mídia comercial. Nessa esteira, é esperado que as aferições dos resultados criativos utilizando sons não instrumentais e envolvendo processos de escolha com os quais os participantes não estão familiarizados gerem escores baixos ou aleatórios. O preconceito do que é e do que não é música pode ser um dos fatores mais fortes no julgamento dos resultados sonoros próprios e alheios nas

atividades criativas. Como enfrentar esse empecilho é um dos questionamentos levantados pelo presente estudo.

A falta de alinhamento entre os fatores vinculados ao engajamento (em ordem descendente: atenção, colaboração e diversão) e os fatores voltados para os recursos da atividade (facilidade e produtividade) sugerem que os participantes acharam a atividade instigante porém não conseguiram atingir seus objetivos criativos. Mais uma vez, ideias preconcebidas do que constitui o fazer musical podem explicar esse descompasso. No entanto, também é possível que alguns procedimentos utilizados tenham tido impacto negativo na performance dos sujeitos. Por exemplo, observamos que o grau de atenção dos participantes diminuiu ao longo do experimento. Essa observação é corroborada pela diferença no número de respostas efetivas obtidas na primeira atividade (exploração, N = 23) e na segunda (criação, N = 18). Essa queda de mais de 20% na conclusão da proposta poderia ter diversas causas.

A primeira é a duração dos procedimentos. Se analisamos a diferença entre a duração total das atividades (45 minutos) e o tempo dedicado ao uso do SoundSphere (2 minutos) vemos que a maior parte do tempo foi investida nas instruções, na espera entre as atividades e no preenchimento dos formulários. Sem dúvida, um grupo de adolescentes reagirá negativamente a essa demanda. É necessário estabelecer um protocolo mais rígido que garanta um tempo amplo para a atividade criativa, que seja no mínimo equivalente ao tempo dedicado às outras fases experimentais. A segunda é o objetivo da atividade.

Na atividade de exploração não existe uma exigência de obter resultados criativos. Os sujeitos podem simplesmente explorar diversas opções e concluir sem ter gerado um produto. Já a atividade de criação só se considera satisfatória se o participante fornece um resultado sonoro. Tendo em vista esse quesito, caberia esperar um aumento no nível de esforço cognitivo, representado neste caso em escores mais baixos no fator facilidade e mais altos no fator atenção. O resultado foi o oposto. O único fator que mudou de patamar entre as duas atividades foi a atenção. Mas em lugar de aumentar, teve uma queda drástica de 1,46 para 1,16, e com maior variabilidade entre os sujeitos. Por que os colaboradores perderam interesse ao ter que fazer uma segunda atividade? Um aspecto observado em estudos anteriores é o material sonoro fornecido. Em estudo anterior utilizando a mesma ferramenta SoundSphere (Freitas, 2019), foi utilizado um arcabouço diferente de estímulos sonoros com resultados diferentes sobre o mesmo instrumento CSI-NAP.

No presente estudo houve o cuidado de corrigir dois erros identificados nas experiências ubimus anteriores: a falta de quantidade de material sonoro para permitir escolhas significativas sem exceder a capacidade dos sujeitos de familiarização com os recursos dentro do tempo fornecido; e a repetição dos materiais sonoros em atividades diversas, impactando negativamente no nível de interesse dos agentes. Porém, cabe estender essa pergunta ao tipo de materiais sonoros. Será que mesmo tendo amostras diferentes, a repetição das classes sonoras é percebida como pouco instigante pelos sujeitos? Esses questionamentos poderiam ser abordados solicitando respostas abertas dentro da avaliação dos fatores criativos. Por exemplo, podem ser solicitados três aspectos negativos e três aspectos positivos que não constam como fatores no

formulário. Os comentários dos sujeitos podem complementar as respostas quantitativas obtidas via escala Likert.

Resumindo, os resultados do presente estudo apontam para a necessidade de ajustes nos procedimentos de coleta de dados atentando para as particularidades da criatividade musical cotidiana. Entendemos que há necessidade de lidar com as preconcepções dos leigos quanto ao que constitui processos e produtos musicalmente relevantes. Esses aspectos podem ser estudados em maior profundidade através de observações do impacto da quantidade, qualidade e características do uso de materiais sonoros em relação às aferições das atividades realizadas. A incorporação de técnicas automatizadas de coleta de dados pode ajudar nesse quesito. Também é importante atingir um equilíbrio entre as atividades necessárias para a obtenção de resultados (incluindo treinamento, instruções e fornecimento de informações) e as atividades-alvo da proposta específica, visando a manutenção do interesse dos participantes sem reduzir a capacidade analítica dos procedimentos aplicados. Os próximos passos do projeto SoundSphere apontam nessa direção.

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Materiais de Apoio

Questionário de Desempenho - CSI-NAP v. 0,7

https://docs.google.com/forms/d/e/1FAIpQLSfOMGzhDXdE9pH3NzVguiZU6VeNVYScC_L8KdYP53GpxSj_ZA/viewform

Questionário de Identificação e Perfil Sócio-Econômico - ISE-NAP v. 0,5

<https://docs.google.com/forms/d/e/1FAIpQLSdE26GvRqxzuANIC0BpMCDRy7BRUXt-gXqZUG2lZLgwaVjc2w/viewform>

Amostras Sonoras

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Features Extraction and Segmentation for an Assistive Musical Interface

Higor A. F. Camporez¹, Yasmin M. de Freitas², Jair A. L. Silva¹,
Leandro L. Costalonga³, Helder R. de O. Rocha¹

¹ Departamento de Engenharia Elétrica (DEL) – UFES
Vitória - ES, Brasil

² Departamento de Teoria da Arte e Música (DTAM) – UFES
Vitória - ES, Brasil

³ Departamento de Computação e Eletrônica (DCEL) – UFES
São Mateus - ES, Brasil

{higorcamporez, yasm Marquesf}@gmail.com

{jair.silva, leandro.costalonga, helder.rocha}@ufes.br

Abstract. *Assistive technology can be used to promote accessibility and inclusion for impaired people, including musical activities, for example, through musical interfaces control using eye tracking. Technological advancements, especially the Internet growth, allowed access to a huge digital music database, which can contribute to a new form of music creation, inspired in mashup and concrete music aesthetics. Thus, Music Information Retrieval (MIR) techniques can be applied to find samples that combine themselves. In this paper, we propose the application of some MIR techniques for music segmentation and similarity, aiming at the development of a new form of musical creation and its adoption in an assistive musical interface. The experimental results can be found in [bit.ly/2VVtSmi].*

1. Introduction

According to the last Brazilian demographic census [IBGE 2010], made in 2010, around 45.6 million people declared to have some disability (visual, auditory, motor, or intellectual), where motor disability represents 13.1 million people. Thus, assistive technology (AT) – defined as product adaptation, or specific development, to help impaired people – can provide inclusion for these people [WHO 2001].

Besides promoting accessibility, the AT can also help in impaired people rehabilitation. Thus, the AT is present in musical activities, enabling disabled people to create music, not only for pleasure but also in the rehabilitation process. For example, the instrumental execution can help in motor rehabilitation as well as cognitive improvement, since music activates several areas of the brain [Larsen et al. 2016]. Thus, adaptations in traditional instruments can be done to support the use by disabled people [Louro et al. 2005]. Another example is the musical game GenVirtual [Correa et al. 2007] that uses augmented reality technology for cognitive and motor rehabilitation. Another AT, known as eye tracking, is also present in musical activities [Hornof 2014], and some related works are described in Section 2.

Technological advancements, such as the advent of the Internet, revolutionized the way users can access, create, and disseminate musical content. Nowadays, users can access a huge digital music database, that includes songs, playlists, discographies, etc. The complexity associated with the organization and extraction of information from this enormous online database contributed to the creation of a research field known as music information retrieval (MIR) [Futrelle and Downie 2003]. In addition, the use of technological resources for musical activities also provide the creation of the research area *ubimus* (ubiquitous music) [Keller et al. 2014]. *Ubimus* uses ubiquitous systems of human agents and material resources for musical purposes.

However, today's digital technology is mostly used for communication (many-to-many), entertainment, and pleasure. This can be verified in the *Kutiman ThruYOU*¹ project, in which the Author uses YouTube videos to create new songs, interestingly with no direct relations between them. *Kutiman* mixed slices of videos, made by amateur musicians, to create new songs with a manual search process in the YouTube database. A system to help *Kutiman*'s searches, based on MIR techniques, was created to provide content filtering [Lindenbaum et al. 2010], where experiments using the same database used by *Kutiman* matched on average 60% of his previous choices. In the same way, *Mix The City*² project provides an interactive video clip interface that allows users to compose with slices of video produced by local artists, enabling the users to discover cities through the produced songs and videos. Therefore, non-musicians can create songs, because the available slices of videos have some musical similarities.

This paper describes the assistive musical interface design using eye tracking to control musical samples (segments), showing musical similarity levels between segments to facilitate the use by non-musicians. Thus, we also describe methods about music segmentation and similarities extraction to support the interface. Procedures are proposed for automatic creations and also for users' compositions. The remainder of this paper is organized as follows. Section 2 describes some gaze-controlled musical interfaces. Section 3 presents musical features extraction used to find music similarity and the relationship of the features is described in Section 4. Section 5 illustrates segments concatenation procedures. The experiments and the results are presented in Section 6 and the conclusion remarks are provided in Section 7.

2. Gaze-Controlled Interfaces

The *EyeMusic* [Hornof and Sato 2004] is a musical interface that uses a commercial eye tracker, where the device's coordinates (x,y) are used to create a granular synthesis of click-sounding samples, through the Max/MSP in real-time. The *Oculog* [Kim et al. 2007] is a system created using Pure Data programming language with an eye tracker, where the pupil coordinates (x,y) are mapped in note number and velocity, respectively, to control a tone generator. The *EyeGuitar* [Vickers et al. 2010] is a system based on the *Guitar Hero*³ game style, in which uses eye tracker information as input to play, however, due to the eye tracker limitations, it is only necessary to select the correct string and not the action to hit it together like in the original game.

¹www.thru-you.com

²www.mixthecity.com

³www.guitarhero.com/

The EyeHarp [Vamvakousis and Ramirez 2012] is a gaze-controlled musical interface. The project is divided into three parts: a) the pie menu, b) the step sequencer, and c) the arpeggiator. The interfaces b) and c) are used for rhythmic and harmonic construction in background, whereas a) is used for melodic construction in real-time. Other gaze-controlled interfaces, outside musical context, are pEYEWrite and pEYETop [Huckauf and Urbina 2008]. Where pEYEWrite aims textual writing and pEYETop focuses on computer navigation. However, the design of the interface follows a circle structure, named the pie menu. The authors reported that users had a better performance in pEYEWrite than in the virtual ABCDE keyboard.

Olhar Musical [Camporez et al. 2018] is an gaze-controlled musical interface. The interface has six cells where each one controls an audio sample (segment) by sending MIDI messages to Ableton Live⁴. The interface allows the user to choose to play or pause the audio samples. The use by non-musician is also an objective of the interface, therefore, it shows levels of similarity between the audio segments to help the user to choose the next audio segment.

3. Musical Features Extraction

The system created to help Kutiman’s searches [Lindenbaum et al. 2010] uses the following musical features and measures: a) Beats per Minute; b) Chromagram and Chromatic Scale and c) Cyclic Harmonic Cross-correlation. The attributes and measures extracted from the WAV files are described in this Section. The calculations are defined considering that, two musical segments are the vectors \underline{x}_1 and \underline{x}_2 .

3.1. Beats per Minute

Beats per minute is an important musical feature that describes the rhythm in which the song is played. Thus, generally speaking, BPM can be seen as the number of repetitions found in each minute. DJs often use songs with similar BPM for mixing them, because they are more easily synchronized. In this work, the BPM relationship between two musical segments can be expressed by equation (1) [Lindenbaum et al. 2010], in which the distance that shows their similarity is calculated. Therefore, the BPM distance is defined as:

$$D_{tempo}(\underline{x}_1, \underline{x}_2) = \frac{|tempo(\underline{x}_1) - tempo(\underline{x}_2)|}{\max[tempo(\underline{x}_1), tempo(\underline{x}_2)]}, \quad (1)$$

where $tempo(x)$ represents the BPM extracted from x .

3.2. Chromagram and Chromatic Scale

The feature chromatic scale contains 12 musical notes equally spaced from a semitone [Benward and Saker 2008]. The chromagram, or harmonic pitch class profile, represents a histogram of musical notes that shows the energy distribution across the interval pitch classes [Gómez 2006]. A chromagram can be mathematically expressed by

$$\underline{C}_x(b) = \sum_{m=0}^M |X_{cq}(b + m\beta)|, \quad (2)$$

⁴<https://www.ableton.com/en/live/>

for M the total of octaves, b the chroma bin number, β the number of bins per octave and X_{cq} the frequency domain signal obtained by the Constant Q Transform (CQT) method [Brown 1991] using

$$X_{cq}[k] = \sum_{n=0}^{N(k)-1} w[n, k] \cdot x[n] \cdot e^{-j2\pi n f_k}, \quad (3)$$

where $f_k = 2^{k/\beta} \cdot f_{min}$ is the k^{th} frequency bin, for f_{min} the minimum frequency.

In this work, we considered that $\beta = 12$, f_{min} is approximately 32.7 Hz (C1), $b \in [1, 12]$, \underline{C}_x is a 12-length vector and the chromagram is normalized to values between 0 and 1.

3.3. Cyclic Harmonic Cross-correlation

For most listeners, two notes with several common harmonics sound pleasant [Thompson 2015]. For example, musical notes with intervals between 4 or 7 semitones share several harmonics, which makes them harmonically compatible [Piston and DeVoto 1987]. According to Lindenbaum et al. (2010), one way used to quantify harmonic similarity is based on the cross-relation of pieces' chromagrams. Thus, the normalized cross-correlation [Yoo and Han 2009], that return values between -1 and 1, is define as

$$R_{1,2}(p) = \frac{\sum_l [\underline{C}_{x_1}(l) - \overline{C}_{x_1}]}{\sqrt{\sum_l [\underline{C}_{x_1}(l) - \overline{C}_{x_1}]^2}} \times \frac{\sum_l [\underline{C}_{x_2}(l - p \bmod 12) - \overline{C}_{x_2}]}{\sqrt{\sum_l [\underline{C}_{x_2}(l - p \bmod 12) - \overline{C}_{x_2}]^2}}, \quad (4)$$

for p a cross-correlation, l the vector length and \overline{C}_{x_i} the \underline{C}_x mean value. Following the process described by Lindenbaum et al. (2010), the higher cross-correlation value between $R_{1,2}(0)$, $R_{1,2}(4)$, and $R_{1,2}(7)$ indicates that there are many common harmonics, which reflects a great compatibility. Using the maximum achieved value, the chroma distance is calculated as

$$D_c(\underline{x}_1, \underline{x}_2) = \frac{1}{2} [1 - R_{\max}(\underline{x}_1, \underline{x}_2)], \quad (5)$$

for $R_{\max} = \max [R_{1,2}(0), 0.8R_{1,2}(4), 0.8R_{1,2}(7)]$.

4. Assistive Musical Interface

Increasing our previous work, *Olhar Musical*, we design a new interface inspired in [Huckauf and Urbina 2008] in which presents good results for circle interfaces structure and [Vamvakousis and Ramirez 2012] that uses circles with dots in the center to help the user focus on the circle. As is shown in Figure 1, this is a gaze-controlled musical interface, where there are eight light blue circles (C1, C2, C3, C4, C5, C6, C7, C8) and each one controls a musical sample (segment). For control each light blue circle there are buttons play and pause, as well as the center circle that represents some actions on the segment, where the user can control volume; loops, number of repetitions; preview, to listen through a specific channel out of the performance; and graphics, to see a visual representation of the segment. However, the user can control beats per minute (BPM), master volume, and a button named stop all that pause all segments in execution.

This work is planned for use by non-musician too. Thus, the interface shows similarity levels among the segments through the yellow circle, where the yellow thickness expresses the similarity level. Then, we use the musical features explained in Section 3 to define similarity level between musical segments, where the relationship among the features is shown in Section 5. The use process of the interface is shown in Section 6.

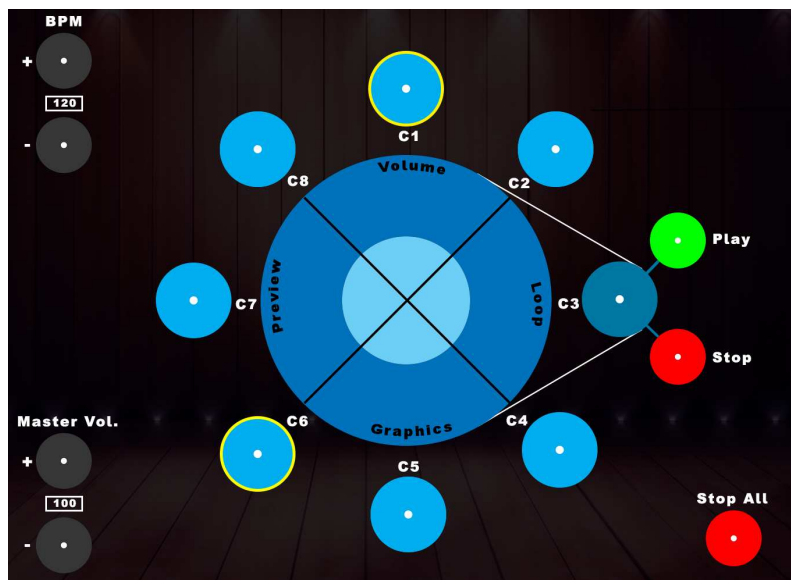


Figure 1. Assistive Musical Interface controlled by eye tracking.

5. Musical Features Relationship

Our interface, cited above, uses a large amount of musical segments that can be cropped from songs databases. Then, find good points for songs segmentation is extremely important for the quality of the segments and their overall “mixability”. Thus, traditional musical structures, i.e. bar, can provide a good segmentation strategy for our interface.

Music bars can be found through the spectral differences in audio samples [Davies and Plumbley 2006]. Developed by the Center for Digital Music (C4DM), the bar detector is implemented in the QM Vamp Plugin Library [Cannam et al. 2014] for Vamp³ audio analysis plugin system. In addition, the calculation of chroma, BPM and RMS were done with Librosa library [McFee et al. 2015].

According to Lindenbaum et al. (2010) the relation between the musical features distances can be defined as

$$D(\underline{x}_1, \underline{x}_2) = \sum_{i \in A} w_i D_i(\underline{x}_1, \underline{x}_2), \quad (6)$$

where A is a group of features and w_i is the weight set for each feature. A default value for w_i can be obtained by $\frac{1}{|A|}$. Figure 2 shows a block diagram of the process employed in the segments quantification, as described in equation (6).

Beginning from the dataset, subsequently, each sound is segmented into bars based on the plugin above-mentioned. Afterward, the features of each segment are extracted,

³<https://www.vamp-plugins.org/>

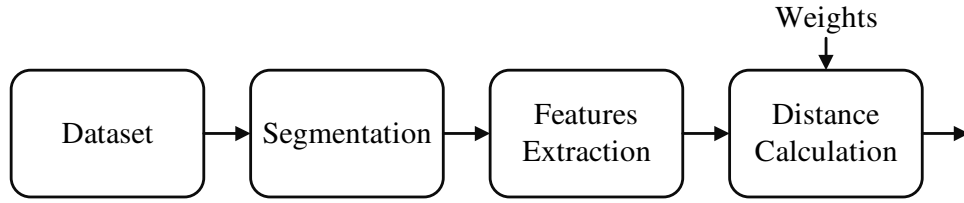


Figure 2. Block diagram of the process used in the segments quantification.

and, finally, a many-to-many relationship is calculated to find similarities between the segments. The relationship can be explained in matrix form, where Figure 3 shows 25 segments relationships. The matrix shows the distances between segments calculate by equation (6), where lower distances (red color) represent high similarities between the segments. The algorithm uses this matrix to show the similarity level on the interface (Figure 1).

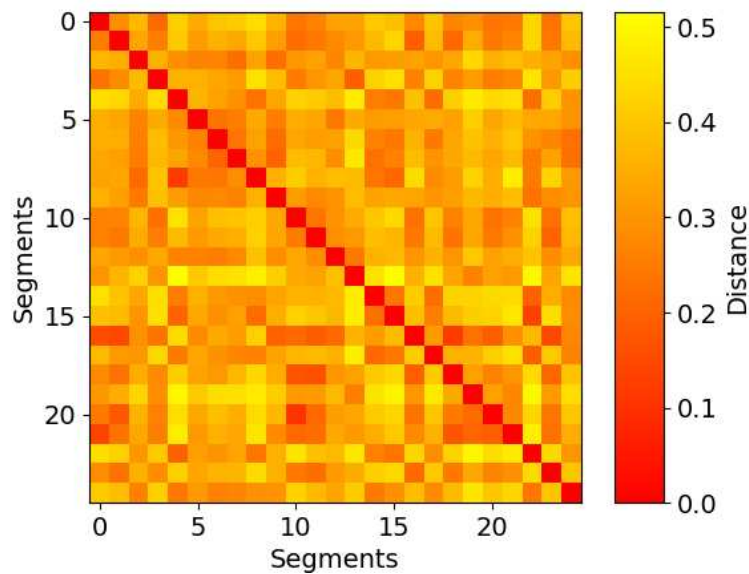


Figure 3. Similarity matrix for 25 segments.

6. Segments Concatenation Procedures

6.1. Automatic Concatenation

Figure 4 shows a flowchart of the proposed segments concatenation process. After the choice of a propellant segment (segment a) the segment closest to it (segment b) is searched. Next, the segment closest to segment b (segment c) is selected and, this process is repeated until complete the quantity of segments. Thus, to segments concatenation, we also employ a crossfade technique with fade in and fade out, according to the following formulas

$$\frac{\sqrt{(1+t)}}{2} \text{ and } \frac{\sqrt{(1-t)}}{2}, \quad (7)$$

respectively, where the intersection area is mapped for $-1 \leq t \leq 1$.

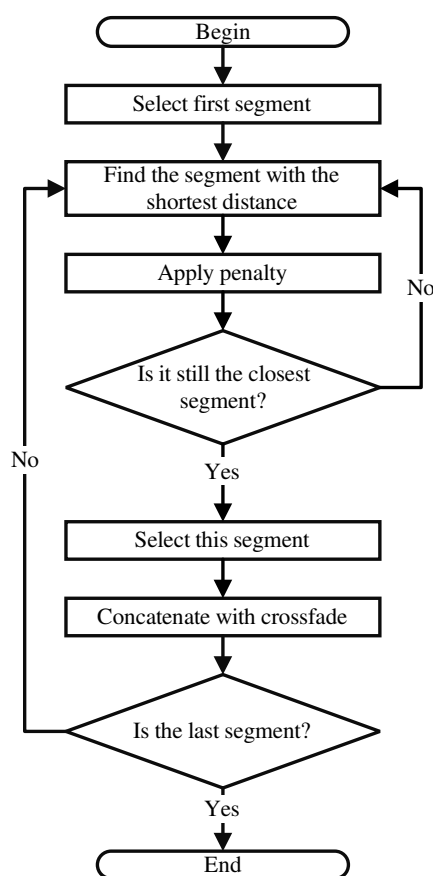


Figura 4. Segments concatenation processes.

In the concatenation process, there is the possibility of loops between segments. For example, the segment closest to a is b and the segment closest to b is a . Thus, the segment choice procedure can get inside a loop between a and b . Therefore, to avoid a local minimum, we defined a penalty for the distance, where the expression is defined as

$$D_{pen} = D \cdot e^{\alpha n}, \quad (8)$$

where n is a number of repetitions and α is a penalty factor.

Figure 5 shows an example of concatenation between two segments with the values of the employed features. The highlighted area shows the intersection where the crossfade was applied.

6.2. Semi-automatic Concatenation

One of the objectives in our assistive musical interface is the use by non-musicians. Thus, we use musical features explained in Section 5 to facilitate users' choices. In the interface, when the user focuses on a cell, the gray window (Figure 6) presents the musical features as well as the relationship (distance) between the last choice and the focused cell.

Figure 7 shows a procedure to use the interface. Initially, the interface shows 8 segments randomly, thus the user can start by choosing a segment, then he/she has options to edit, preview, and control the execution. When the segment is played, the interface

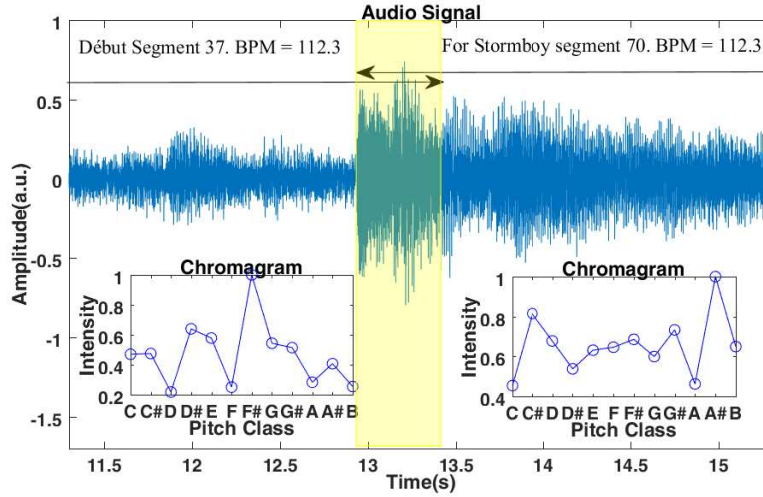


Figure 5. Features of two concatenated segments.

shows 7 new segments similar to the last choice and their similarity levels. Afterward, the user can choose the next and repeat it until finish the performance.

7. Experiments and Results

In this work, a small dataset of instrumental music was chosen for testing. Thus, the 24 songs, shown in Table 1, were chosen from an instrumental Spotify playlist called Peaceful Piano ⁴. The songs were divided into 2623 segments as described in Section 5. Therefore, experiments following the automatic concatenation were done.

Tabela 1. Songs list.

Max Richter - A Catalogue Of Afternoons	Aaron Lansing - Naive Spin
Alexandra Streliski - Changing Winds	Karin Borg - Norrskén
The Daydream Club - One Last Thought	Moux - Chasing Stars
Mélanie Laurent - Début	Oskar Schuster - Maribel
Alexandra Streliski - Plus tôt	Black Elk - Intro
Rhiannon Bannenberg - For Stormboy	Poppy Ackroyd - Strata
Robert Haigh - Portrait with Shadow	Tedósio - The Book of Jen
The Daydream Club - For the Lost Ones	Moux - Gaze
Peter Sandberg - Remove The Complexities	Phildel - Qi
Jean-Michel Blais - igloo - acoustique	Samuel Lindon - Tallis One
Peter Bradley Adams - Interlude For Piano	Bela Nemeth - This Moment
James Heather - Last Minute Change Of Heart	Poppy Ackroyd - Time

7.1. Experiment I: Harmonic Distance Influence

In order to verify the harmonic distance influence in segments combination, tests were done with high weight to this feature, according to

$$D(\underline{x}_1, \underline{x}_2) = 0.8D_c(\underline{x}_1, \underline{x}_2) + 0.2D_{tempo}(\underline{x}_1, \underline{x}_2). \quad (9)$$

⁴<https://open.spotify.com/playlist/37i9dQZF1DX4sWSpwq3LiO>

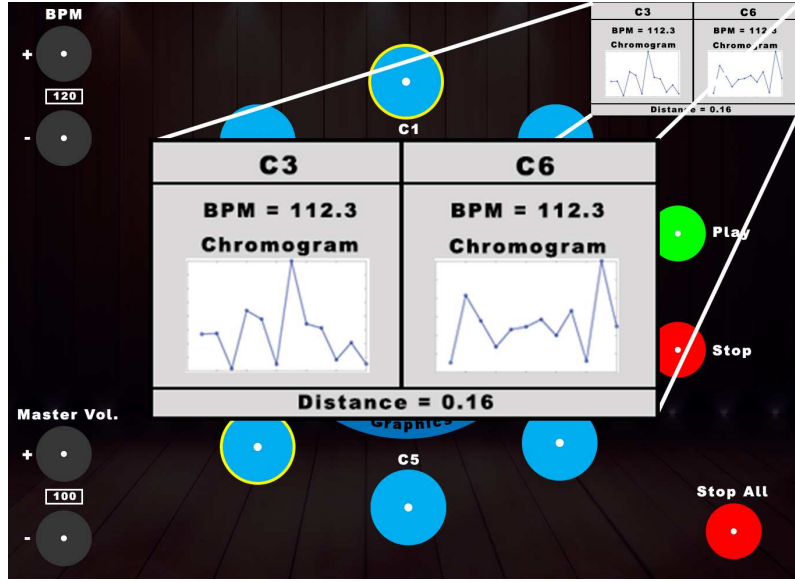


Figure 6. The assistive musical interface showing musical features information.

The test, aiming to demonstrate segments compatibility, has the intention of creating a new experimental song with 20 segments in sequence, following the Figure 4 procedure. In this experiment α was empirically defined as approximately 0.1386, thus, the fifth repetition has its distance doubled. The number of repetitions was counted only among the last 5 chosen segments. The results can be found in [<https://bit.ly/2GDgKcU>].

7.2. Experiment II: Tempo Distance Influence

This experiment aims to observe the influence of the feature tempo distance for compatibility. Thus, tempo distance received high weight adopting the formula

$$D(\underline{x}_1, \underline{x}_2) = 0.2D_c(\underline{x}_1, \underline{x}_2) + 0.8D_{tempo}(\underline{x}_1, \underline{x}_2). \quad (10)$$

As in experiment I, the same test was performed keeping the same concatenation, penalty parameters, and pivot segment. The results generated by the procedure of Figure 4 can be found in [<https://bit.ly/2Gw1XQ9>].

7.3. Experiment III: Balance Between Harmonic and Tempo Distance

In this experiment, the main target is to verify the balance between harmonic and tempo distance. Therefore, the two features were weighted equally, that is, 0.5 for each one. The distance formula was defined as

$$D(\underline{x}_1, \underline{x}_2) = 0.5D_c(\underline{x}_1, \underline{x}_2) + 0.5D_{tempo}(\underline{x}_1, \underline{x}_2). \quad (11)$$

Following the same idea used in experiment I with the same pivot segment, however, using a new distance formulation. The results for the test can be found in [<https://bit.ly/2ZtcGTU>].

Another test was executed aiming to observe the application for user assistance. Thus, from a randomly chosen pivot segment, 15 segments closest to it were listed. Thereafter, the user could create new experimental music by choosing segments from that list.

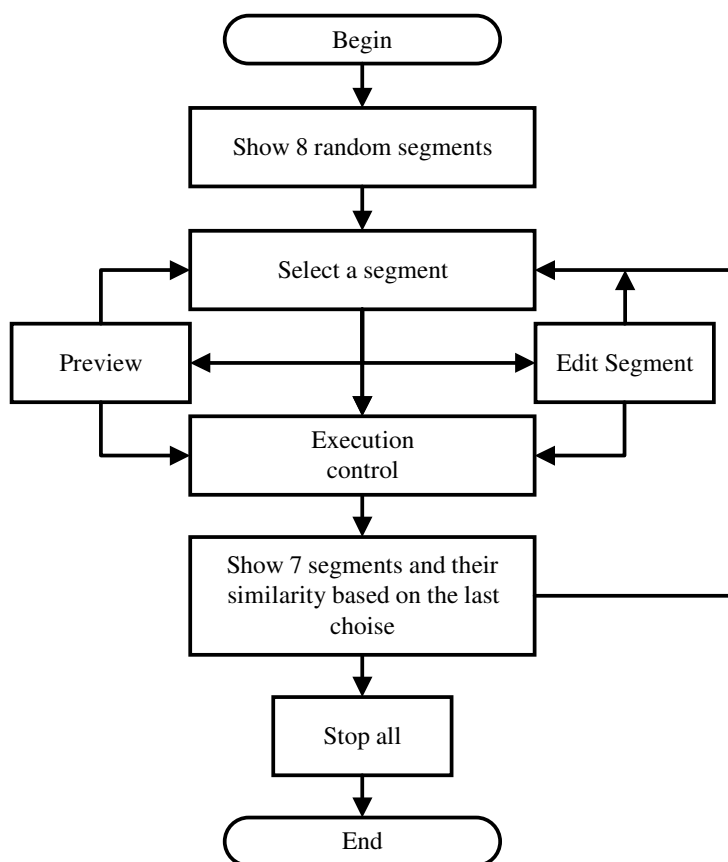


Figura 7. Flowchart with the user's procedure.

In addition, the user can edit segments to improve the music quality. The results of this interesting test can be found in [<https://bit.ly/2VVtSmi>].

8. Conclusion

Music information retrieval techniques were proposed in this paper for music segmentation and extraction of the chroma and beats per minute features, to support an assistive musical interface, aiming the use for non-musicians. A semi-automatic concatenation procedure was proposed for user performance. In addition, an automatic composition procedure, tested on a dataset containing instrumental music, was proposed to evaluate the considered MIR techniques.

The experimental result done by user choices from a list of audio segments is shown in [<https://bit.ly/2VVtSmi>], it demonstrated an aesthetic sound analogous to concrete music and mashup. However, there are many challenges to be addressed in the interface. For example, we observed that segmentation based on bar results in short segments, which reduces the user's time to choose the next segment.

As future works, we suggest the study of segmentation based on more than one bar or musical phrase. We also suggest studies related to musical context, in which a segment is removed from the original music, in order to understand combination possibilities. And finally, application of experimental tests done by people with disabilities.

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***Contracap*s for remote double bass and effects: Creative Semantic Anchoring, Corpus Linguistics and Remote Interaction**

Marcello Messina^{1,2}, Carlos Mario Gómez Mejía¹,

¹Universidade Federal da Paraíba (UFPB)
João Pessoa – PB – Brazil

²Amazon Center for Music Research (NAP)
Rio Branco – AC – Brazil

marcello@ccta.ufpb.br cmgarun1@gmail.com

1. Introduction

Creative semantic anchoring (ACS) is based on the use of verbal indicators in order to facilitate creative processes. Previous research within the g-ubimus, 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*”) [Feichas 2015; Keller e 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.

Now, our proposed piece *Contracap*s takes verbal cues and textual tokens as a starting point in order to initiate a process that transcends notation and redimensions the discursive hegemony of “the score” as an ultimate and nonnegotiable source of musical “truth”. While Keller et al (2010) enumerate “the score” as part of a set of “social paraphernalia” that potentially “breaks down in the context of ubiquitous music” (Keller et al 2010: 320), Nicholas Cook also recognises the disproportionate hegemony of the score in the context of musicological investigations [Cook 2009; cf. also Costa, Brito and Ciacchi 2018].

From a generative point of view, for this piece we plan to collect the score material exclusively in terms of verbal fragments, making use of heterogeneous tools and techniques such as automated text analysis, corpus linguistics and the aleatory trimming of verbal fragments.

2. *Contracap*s

Our piece *Contracap*s¹ is based precisely on the excogitation of non-standard responses to the verbal material generated through the textual analysis. The work is

¹ Preparatory sketches of the piece, all developed as part of a remote collaboration, are available in the following shared folder:

<https://drive.google.com/drive/folders/1liXe4hYcm3wBr0TZlre2P8TaDOdnb59J?usp=sharing>

A prototype of the piece, without electronics, is available at: <https://youtu.be/TMIC3LRwcN0>

based on ongoing research on experimental music and (de)coloniality (cf. Messina et al 2020; Messina, Feichas & Ribeiro, 2019). Importantly, both the feeding of these materials and the instrumental responses to it must happen when the “composer” and the “performer” are not sharing the same physical space.

Interacting via simple mobile apps for text and audio sharing, the two exchange textual descriptions and instrumental reactions to said descriptions. A corpus of aural fragments is thus obtained, that is then reordered, processed and packed into a digital piece for prerecorded fragments and live electronics.

Contracapás (Spanish for “counter-layers”) is thus the product of different layers of interventions on different corpi of heterogeneous materials, namely, text and musical fragments. Among other things, the layers here constitute a practical alternative to simultaneous interaction, in line with the limitations of simultaneous approaches described by Messina et al (2019).

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Lyapunov Time Experiment

Luzilei Aliel ¹,

Daniel Oliveira ¹

{luzaliel@usp.br}

{danisom@gmail.com}

¹ Universidade de São Paulo (USP)

Abstract. *Lyapunov Time (LYT) is a improvisation for solo clarinet and live electronics (Aliel et al. 2019). In this proposal, live electronics will be conducted by cell phones. The play proposes an aesthetic metaphor based on a theory presented by Aleksandr Mikhailovich Lyapunov. According to Lyapunov, some classes of dynamic systems become chaotic in a foreseeable moment. The metaphor of how dynamic systems become chaotic serves as an aesthetic starting point for artistic work. We propose a dynamic system that has guidelines and contingencies (Aliel et. Al, 2019; Aliel, 2017)*

Resumo. *Lyapunov Time (LYT) é uma improvisação para clarinete solo e eletrônica ao vivo (Aliel et al. 2019). Nesta proposta, a eletrônica ao vivo será conduzida por telefones celulares. A peça propõe uma metáfora estética baseada em uma teoria apresentada por Aleksandr Mikhailovich Lyapunov. Segundo Lyapunov, algumas classes de sistemas dinâmicos se tornam caóticas em um momento previsível. A metáfora de como os sistemas dinâmicos se tornam caóticos serve como ponto de partida estético para o trabalho artístico. Propomos um sistema dinâmico que possui diretrizes e contingências (Aliel et. Al, 2019; Aliel, 2017)*

1. Fundamentação Teórica

A peça é uma performance/experimento (composição + improvisação - Aliel, 2017), conduzida contra as propostas de práticas ecologicamente fundamentada em ubimus (Keller; Aliel, 2017). Usamos aplicativos móveis para apresentar o público como participantes da performance. Nesse sentido, dois aspectos principais serão discutidos com o trabalho: a função do aspecto local (place - Keller; Capasso, 2000) e o esforço para expandir as possibilidades do conceito de paradigma acústico-instrumental (Bown et al. (2009), Keller (2000), Keller et al. (2014).

A notação aplicada em Lyapunov Time é do tipo gráfico e é consistente com os trabalhos que visam a improvisação, com base nas práticas ecológicas fundamentadas (Aliel et. Al, 2018). Está notação gráfica foi inspirada em pêndulo de três eixos que em um determinado momento no tempo entra em um estado caótico. Quando este evento ocorre há uma desorganização geral do contexto e nenhum momento a partir deste

ponto será repetido ou semelhante. O experimento pode ser visto em: <https://www.youtube.com/watch?v=ae5XJ4F7MAc>

Nossa abordagem inicial seria desenvolver trabalhos artísticos com um músico profissional e permitir que leigos (agentes não músicos) contribuam para a performance da peça, ou seja, o músico usando clarinete e os demais participantes usando material eletrônico desenvolvido e realizado por telefone celular. Infelizmente devido a pandemia não será possível alocar participantes para a atividade. Desta forma, nós iremos propor uma adaptação ao material e buscar formas de apresentar a peça de forma inicialmente desenvolvida. Entretanto, tentaremos utilizar ferramentas online para buscar uma prática a distância para a peça. Lyapunov Time foi apresentado em vários formatos; no entanto, a versão proposta aqui pode ser vista em: <https://www.youtube.com/watch?v=BEHHLs28i0c&feature=youtu.be&fbclid=IwAR2CGp0JYHgsiMYzVIN2ywGOB9jWrDepSKjM7Dx1ZpWTh2yn5kBLWem2qeo>

2. Recursos Materiais

- Devido à atual pandemia, foram necessárias modificações no planejamento inicial e iremos propor uma realização via performance online ou via vídeo gravado, o que for mais eficaz no momento.

InFracta: Dialogue Processes in a Multi-modal Environment

Thales Roel P. Pessanha¹, Guilherme Zanchetta¹, Thiago Rossi Roque¹, Lucas Bertoloto Pereira¹, Gabrielly Lima de Oliveira¹, Bruna Pinheiro¹, Renata Paulino¹,
Tiago Fernandes Tavares¹,

¹ Institute of Arts - State University of Campinas. Zeferino Vaz University City - Barão Geraldo, Campinas - SP, 13083-970

{thalesroel@hotmail.com, guilhermezanchettac@gmail.com,
thiago.roque07@gmail.com, lucasbertoloto@outlook.com,
limadeoliveira.gaby@gmail.com, bruu.cmp@gmail.com, r186523@dac.unicamp.br,
tiagoft@gmail.com

Abstract. *The InFracta Project uses electronic and computing media, including motion sensing, to create an environment in which gestures are transformed into sound and sound is transformed into real-time image, generating a dialogue between the artistic languages of dance, music and new media. The project emerged from the interaction between undergraduate students of UNICAMP [University of Campinas] interested in the use of new technologies in their artistic processes and the contribution of those to the synergy between different artistic languages. The InFracta Project has support from NICS [Interdisciplinary Center for Sound Studies] and the IA [Arts Institute], both in UNICAMP.*

Resumo. *O Projeto InFracta utiliza meios eletrônicos e computacionais, incluindo sensor de movimento, para criar um ambiente no qual os gestos se transformam em som e o som em imagem em tempo real, gerando um diálogo entre as linguagens artísticas da dança, música e novas mídias. O projeto surgiu da interação entre alunos de graduação da UNICAMP [Universidade de Campinas] interessados no uso das novas tecnologias em seus processos artísticos e na contribuição destas para a sinergia entre diferentes linguagens artísticas. O Projeto InFracta conta com o apoio do NICS [Centro Interdisciplinar de Estudos do Som] e do IA [Instituto de Artes], ambos da UNICAMP.*

Playsound Agora

Ariane Stolfi¹,

¹CFA - Centro de Formação em Artes. - Universidade Federal do Sul da Bahia (UFSB).
S/n Rodovia BR-367 Km 10 Zona Rural, Porto Seguro - BA, 45810-000

{arianestolfi@gmail.com}

Abstract. *Playsound.space is a tool that was developed in 2018 for the practice of free improvisation. At UBIMUS 2018 we present a piece where we use the system to create a soundscape from Oswald de Andrade's anthropophagic manifesto. This time, we propose a participatory performance, where the audience can, through the chat interface offered by the system, propose search terms for the performer. When communicating during the performance by chat, each word typed becomes a link to search the system. The performer who will be connected to the central sound system will choose words from those typed by the audience to create a soundscape in real time.*

Resumo. *Playsound.space é uma ferramenta que foi desenvolvida em 2018 para a prática de improvisação livre. No UBIMUS 2018 apresentamos uma peça onde utilizamos o sistema para criar uma paisagem sonora a partir do manifesto antropofágico de Oswald de Andrade. Desta vez, propomos uma performance participativa, onde a audiência poderá, através da interface de chat oferecida pelo sistema, propor termos de busca para a performer. Ao se comunicar durante a performance pelo chat, cada palavra digitada se converte em um link para busca no sistema. A performer que estará conectada ao sistema de som central escolherá palavras dentre as digitadas pela audiência para criar uma paisagem sonora em tempo real.*


```
67 (  
68 r = Pdef('arp', Pbind('instrument', 'karp',  
69 'freq', Pseq(Scale.minor.ratios * [0.5,1,2,0.75,1.5] * 220, inf),  
70 'digitalPin', Pseq([4,5,6,7], inf),  
71 'amp', 0.5,  
72 'dur', 0.2,  
73 'decaytime', 1,  
74 'delaytime', 6  
75 )).play(quant: 1);  
76 );|
```



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