MusTIC: Research and Innovation Group on Music, Technology, Interactivity, and Creativity

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Abstract. *MusTIC is a research and innovation group concerned in conceiving and developing products and experiences that have an impact on music, education, visual and performing arts, and entertainment. In particular, we have been working with tools, methods, and concepts from physical computing, interaction design, and signal processing to build new interfaces for artistic expression, to develop tools for rapid prototyping, and to improve education through robotics and gamification.*

1 Introduction

In 1997, the "Centro de Informática" at Federal University of Pernambuco, in Recife, Brazil, started to develop research activities on computer music. This effort was led by Geber Ramalho, after returning from his Ph.D. in Paris 6, under the supervision of Jean-Gabriel Ganascia and François Pachet. In 1999, a 60-hour annual course on computer music for both graduate and undergraduate students had started to be offered. During the next 13 years, this research work led to 3 Ph.D. thesis and 12 MSc dissertations.

All these previous activities on computer music set the basis for the creation of MusTIC research group in 2011 when Giordano Cabral arrived. The group, whose name is an agglutination of Music, Technology, Interactivity, and Creativity, widened the scope of the research from music to other related domains. It also incorporated other researchers and practitioners from different domains that as mechatronics, electronics, graphic expression, dance, lutherie, and others.

Since then, 4 Ph.D. thesis and 16 MSc dissertations have been presented. Beyond academic research, MusTIC has a strong orientation to innovation. Indeed, MusTIC prioritizes works that can potentially lead to concrete results for the society and works in which the technology is the means for creating new artistic, educational, or entertainment experiences. This orientation pushed the group to be involved in dozens of shows, exhibitions, or interactive installations. All this put MusTIC among the most active Brazilian research and innovation groups in art, technology, and interactivity.

2 Work Axes

Currently, the group has defined five leading research and innovation axes to guide the efforts of the students, researchers, practitioners, and professors.

2.1 Digital Musical Instruments

New artifacts are changing the way we interact with machines, and this is particularly important for the musical domain. They open a wide range of possibilities in the creation of Digital Musical Instruments (DMIs), artifacts with inputs (interface controllers) and outputs (sound synthesis modules) that connect according to a mapping strategy [1]. Contrary to acoustic instruments, which impose physical constraints on their design and fabrication, the design of DMIs has more freedom. Paradoxically, this advantage is a problem, since there is no established method or tool to guide the DMI designer or luthier. In this research line, we focus on developing prototyping tools, methods for DMI evaluation, existing technology evaluation, news sensors, and interfaces.

2.2 Sound and Music Analysis

Digital music provided the tools to a revolution in the understanding of sound and music. We are particularly interested in extracting information that even a human with a well-trained ear cannot do, or at least express. By music analysis, we mean the discovery of patterns in data represented in musical form. For example, MIDI/MusicXML files, music scores, tablatures, and MIDI/OSC events captured in live performances. We performed a wide range of researches in this field, from functional harmonic analysis to the discovery of microtiming and microdynamics patterns, from modeling rhythm and variation to the visualization of common harmonic paths by composers. By sound analysis, we mean the extraction of information directly from raw data, such as WAV/MP3 files or microphone audio streams. It involves the development of new technology to create games, the automatic detection of dangerous sounds (like gunshots and explosions) for public security, and music information retrieval (MIR) applications (such as automatic chord recognition). One of the main results of this research is our contribution to projects at the MusiGames Studio and the Audio Alerta initiative.

2.3 Automatic Accompaniment Systems

"Music improvisation and accompaniment systems" are systems that can automatically generate melodic lines, rhythmic patterns and chord voicing chaining in a particular musical style. In our research, we employ different AI techniques (e.g., Hidden Markov Models, Neural Networks, Case-based Reasoning, Multi-agent Systems) to successfully create applications that can work as rehearsal partners or teachers in the styles of jazz, *bossa nova* and other Brazilian genres. This line of research is strongly related to “sound and music analysis”, since their results may feed accompaniment systems with patterns and rules that can be used to generate music.

2.4 Creativity Support Systems

Creativity as an asset is becoming critically important as enterprises, and individuals become more dependent on innovation to be competitive. Creativity Support Systems (CSSs) are processes or artifacts that improve productivity and empower users in creative processes. We are searching for new tools and systems that gives possibilities for the emergent roles in new system production and improves professional routine of creative tasks. Usually, CSSs are focused on the generation and orientation of new ideas (something like brainstorming techniques), but we take a broader view that incorporates the prevention of lock-in in the decision making and the design of user interfaces that do not constrain one’s creative path. It includes, but is not limited to, development of prototyping and experimentation tools, evaluation of processes, development of new sensors and interfaces. We are also particularly interested in the use of artificial intelligence to generate creative systems, a field starting to emerge by the name of computational creativity.

2.5 Educational Systems

This point is a transversal axis of our research. Automatic accompaniment systems, rapid prototyping tools, new digital music instruments, they have all been used as learning tools. For some of them, however, education is the primary concern. For example, Daccord programs which teach how to play guitar, keyboard, and percussion, as well as robotics teaching experiments in partnership with RoboLivre. Our research in this field is, then, twofold: to create tools which enhance learning capabilities using innovative pedagogical approaches, and to develop metrics to evaluate them. One of the results of this research branch is the well-established company Daccord Music Software.

3 Illustrative Projects

In this section, we present illustrative projects developed by the members of MusTIC.

3.1 Previous Works

The same group, which became the MusTIC, performed some significant works. For example, the many systems headed by Giordano Cabral under the brand ”Daccord.” The first of these works, Daccord Guitar, was a full-featured accompaniment system, which led to a particular way of learning to play musical instruments, which brought lots of research problems: automatic synchronization, processing of lyrics and tablatures, intelligent calculation of chord positions and chord position paths, etc. The system was later supplemented by a Chord Dictionary, educational tools for guitar, keyboard, and drums. image: Daccord Violao

Figure 1: Daccord Guitar, um software educacional de acompanhamento automática

Daccord Guitar started being developed in 1999 and became the initial product of the startup Daccord Music Software, still active today. The company continued to work in partnership with the scientific community and developed almost 70 music programs and music games, also generating four spin-offs, specializing on audio processing for security, educational technology, music games, and middleware for mobile devices.

This branch of works evolved into researches about automatic generation of rhythm, such as in the Cyber Joao (for guitar, by Marcio Dahia) and the CinBalada (for percussion, by Paulo Pereira and later Pablo Azevedo). On the other hand, Ernesto Trajano, Raphael Holanda, Didimo Junior, and Ricardo Scholz continued exploring the data structures of harmony and rhythm, performing analysis of microtiming, microdynamics, and functional harmony.

All these works were complemented by MSC researches on audio processing (Henrique Leão), harmony prediction (Sidney Cunha), collaborative music creation (Joao Paulo Rolim), and music visualization (Jarbas Jacome).

Figure 2: ViMus’ Pseudo Fractal

The ViMus [1], for example, is an interactive system for embedded real-time visual processing. Interactive because both the artist and the audience can interact with the work. Real-time because the processing is done at the time that the result is being displayed. Moreover, integrated audiovisual and audio processing because that can be used to change the video, for example.

3.2 Audio Encoding and Sharing

Just before the boom of streaming services, Marcio Dahia performed extensive research about audio encoding, lead-

[1] https://jarbasjacome.wordpress.com/vimus/

ing to a new paradigm of music file-sharing based on layers. This way, services could download different resolutions according to their needs. This research was developed in the context of Canto Livre, an open-source music streaming platform, ordered by the Ministry of Culture, based on creative commons.

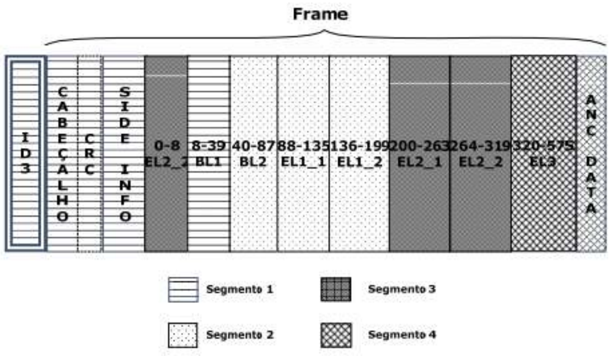

Figure 3: MP3 audio segmentation by perceptive significance

Members involved: Marcio Dahia, Geber Ramalho, Giordano Cabral, Silvio Meira

3.3 tAMARINO

tAMARINO [2] is a visual approach to rapid prototyping in physical computing. It proposes a unique and intuitive visual environment toolkit to accelerate physical computing prototypes both in the software and hardware fields.

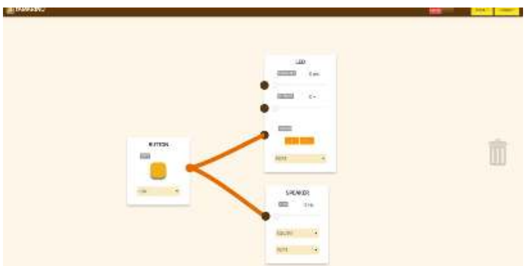

Figure 4: Screenshot of tAMARINO's GUI

The evaluation reveals tAMARINO' success to straightforward, agile development – even on first-time prototyping – further lowering the time-to-market. This first version is designed for Arduino microcontrollers but is extendable to many other boards.

Members involved: Ricardo Brazileiro, Geber Ramalho, Abel Filho, João Paulo Cerquinho

3.4 Sketchument

DMI creation still requires a strong technical background. Based on the importance of prototyping in the process of designing things, Sketchument [3] is an environment devoted to helping non-technical users to quickly prototype DMIs, using multiple input modes and allowing the integration to other useful technologies [2].

[2]https://vimeo.com/65594452
[3]https://vimeo.com/49199339

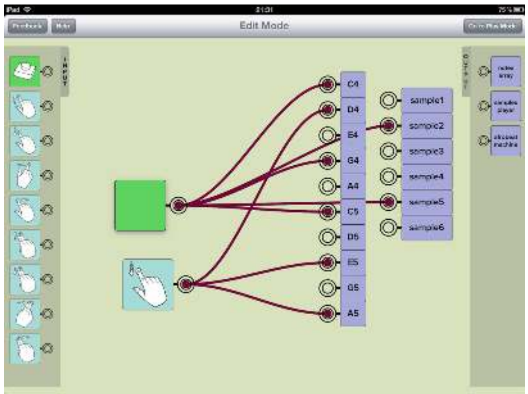

Figure 5: Sketchument on the iPad screen

From low-fi paper prototype to functional ones, passing through movies, questionnaires, interviews, Sketchument has been developed following the same prototyping philosophy we intend to propose to its users. The cyclic process of design-implementing-evaluating has produced valuable feedback from potential users, that have been very useful to back design choices and to push modifications.

Members involved: Filipe Calegario, Giordano Cabral, Geber Ramalho

3.5 LiVES

LiVES (LiVES Video Editing System) [4] development began in late 2002. The author was inspired to start creating a new video editing application after purchasing a new photo camera. In addition to taking photos, the camera was able to record small clips of video; however, for technological reasons, the video clips were limited to a duration of just ten seconds. As well as the limitation in duration, the clips were recorded without audio because of a lack of microphone on the camera.

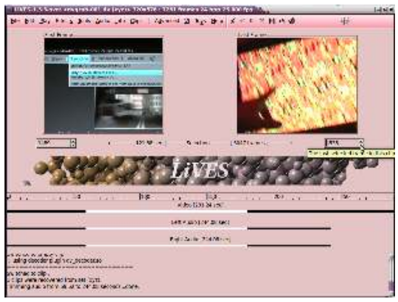

Figure 6: Screenshot of LiVES's GUI

The author decided that a means to increase the usefulness of the camera would be to use a program to join together several of these ten-second segments of video, and to add in some audio – perhaps music or commentary. Finally, he hoped to be able to encode the finished result. However, there was a problem – the author was committed to using only Linux, and at that time, none of the applications available for that operating system could import the

[4]http://lives-video.com/

camera's format. On the other hand, the author was able to use a different program to play the video clips on Linux, although not to edit them. Since the player program was able to output the frames as a sequence of images, the author had the idea of making a simple editor to play the images in sequence and to edit the images, then to add sound, and then to encode. Thus LiVES was born.

Members involved: Gabriel Finch (Salsaman), Giordano Cabral

3.6 Illusio

Illusio [5] is a new Digital Musical Instrument [3]. It is based on an augmented multi-touch interface that combines a traditional multi-touch surface and a device similar to a guitar pedal.

Figure 7: Illusio Multitouch Interface

Illusio allows users to perform by drawing and by associating the sketches with live loops. These loops are manipulated based on a concept called hierarchical live looping, which extends traditional live looping through the use of a musical tree, in which any music operation applied to a given node affects all its children nodes.

Members involved: Jerônimo Barbosa, Filipe Calegario, Geber Ramalho, Giordano Cabral, Veronica Teichrieb

3.7 Sensor Integration on Music

This project used a multisensor integration approach to evaluate gesture interface technologies, in particular, the Leap Motion, to capture gesture nuances in order to improve DMIs' expressivity and meet professional musicians demands obtained in previous research. We found that we were able to capture the nuances and meet latency guidelines from the literature, however instability with the Leap Motion "downward" setup caused system instability when both hands were inside the sensor's FOV.

Members involved: Eduardo Santos, Geber Ramalho

3.8 Meta Learning to Create Audio Classifiers

The group started working with audio processing and analysis in 1999, but it became significant research axes when Giordano Cabral came back from his Ph.D., in Music Information Retrieval for Interactive Systems. Some of the works deserve to be acknowledged, such as that of Dalton Francisco, dealing with search in a space of audio features and ML classifier parameters, that of Sidney Cunha, dealing with the enhancement of chord recognition (and transcription) methods, and that of José Menezes, about the use of multi-objective evolutionary computing methods to improve automatic feature extraction, such as in systems like the EDS.

This research led to innovations, such as those from a startup called Audio Alerta. Audio Alerta systems use audio analysis for public security. For example, one of the products attaches four microphones to monitoring cameras, and process the incoming audio to detect, classify and localize gunshot, explosions, and other alarming sounds.

Figure 8: One of Audio Alerta products

Members involved: Márcio Dahia, Dalton Francisco, Jose Menezes, Giordano Cabral

3.9 Audio API to Video Games

Another innovative use of MIR and audio analysis capabilities was the creation of the MusiGames Audio API. Created jointly with the startup MusiGames, it was a set of functions to automatically extract musical content from both audio files and the incoming audio to create new game experiences. For example, the API allowed the creation of games using the microphone of mobile phones as input, or the microphone of video game consoles. The API also permitted to convert a song into a game level automatically or to manipulate music the music content freely. An overall of 23 game titles was released using this API functionalities.

Figure 9: Some game titles which used the Audio API

[5] https://vimeo.com/25641586

Members involved: Giordano Cabral, Marcio Dahia, Roberto Cassio Jr

3.10 Brazyle and the Flow Machines Project

One of the significant scientific contributions of the group was its collaboration with SONY Computer Science Lab in Paris and the Flow Records in the context of the Flow Machines Project. Flow Machines are a state-of-the-art set of artificial intelligence tools to help compose and arrange music. The Brazilian counterpart inside the project was called Brazyle.

Members involved: Giordano Cabral.

Figure 10: the Brazyle project

3.11 Catalog to Makers

The CatalogToMakers [6] is a collaborative catalog of electronics components. Its main goal is to help enthusiasts of some areas of the physical computing to develop their prototypes that best way possible, centralizing the information about the components in a unique place and reducing the time of all creative process.

Figure 11: Screenshot of Catalog to Makers' GUI

Members involved: Michael Lopes, Filipe Calegario, Giordano Cabral

3.12 Vio.LED

Vio.LED [7] aims to identify usability guidelines on systems that benefit from IoT technology to improve efficiency in the musical instruments learning the process, mainly the acoustic guitar, and support novice musicians.

Within this project, the first step was the creation of a musical instrument containing LED light that can show music notes, chords, and scales. So, a user can learn faster how to play particular songs. The second one was the automatic synchronization of music from streaming services to representations of this music (lyrics, chords, melody) from textual websites.

Figure 12: Vio.LED prototype

The research has, then, multiple facets — first, the development of music information retrieval techniques to integrate many music sources. Second, the development of hardware (augmented musical instruments). Third, the use of HCI and Design research tools to identify the usability guidelines to improve the software.

Members involved: Eduardo Santos, Giordano Cabral, Geber Ramalho

3.13 Cubmusic

CubeMusic [8] is an intelligent cube that works in conjunction with a smartphone/tablet app with Android operating system. Was developed with the Human-Computer Interaction discipline team offered at CIn-UFPE, through the initiative and idealization of the master's degree student in joining music to the challenge of building physical and digital toys.

Figure 13: Cubmusic Prototype

Members involved: Rute Maxsuelly, Giordano Cabral.

3.14 Technological resources and teaching strategies

The research is about strategies to bring the "female audience" closer to the technology area. Some approaches are maker culture, robotics, and game development.

Members involved: Mychelline Souto Cunha, Giordano Cabral.

[6] https://catalogtomakers.com.br/
[7] https://www.youtube.com/watch?v=qGpVHnzdWBg
[8] https://github.com/Rute123/CubeMusic

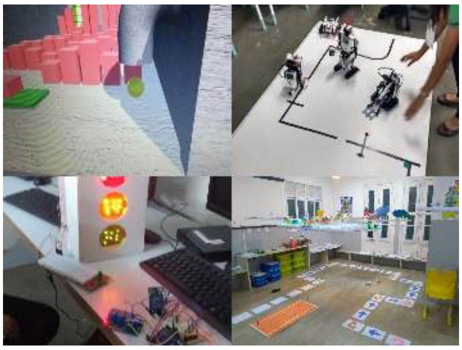

Figure 14: Game, Robotics, Maker Projects and Programming for Children

3.15 Bridge between Extended Reality and Music Interaction

It is a collaborative research between MusTIC and Voxar Lab to explore an Extended Reality interaction (Virtual and Augmented Reality). Principal working on the definition of a Natural Language to Human-Machine Interaction with a many of gesture contexts (like to body, hand, head, wand).

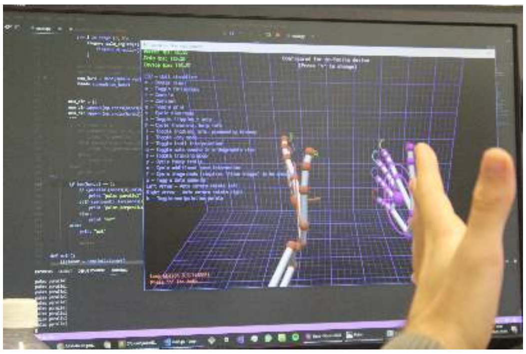

Figure 15: Prototype of Extended Reality and Music Interaction

Members involved: Jader Abreu, Giordano Cabral, Geber Ramalho

3.16 Personality Music

The project aims to understand the relationship of people's personality to their musical preferences using statistical analysis and machine learning techniques. As some of the results, we can mention Popularity x Extraversion, Valence x Openness, Danceability x Extraversion.

Members involved: Delando Júnior, Giordano Cabral

3.17 TumTá and Pisada

TumTá is a wearable Digital Dance and Music Instrument (DDMI) [4] in the form of a pair of insoles to be placed inside the shoes. It detects heel foot stomps and triggers samples from them. It was designed to give new sonic possibilities to the bold foot-stomping dance of Cavalo Marinho, a tradition from the Northeast of Brazil. It was developed as a demand from Helder Vasconcelos, a dancer, musician, and actor formed by this tradition, to explore new sound and dance possibilities in a performance he was devising [9].

Figure 16: Helder Vasconcelos playing/dancing with "TumTá" during his solo performance "FOCO"

It was designed with a handmade pressure sensor from conductive foam and thread that was rugged enough to receive bold stomps. These insoles were connected through wires to a wireless transmitter belt, that did not constrain the dancer's movement.

Pisada is another DDMI designed to fulfill some limitations of TumTá that did not afford the player to change the samples to be triggered during the performance. It consisted of a set of ten big and thin pads to be spread around the stage to change the sound banks. It represented the same functional qualities of a MIDI pedalboard being with a different physical structure that allowed broader foot-pressing gestures, so the performer could press it while dancing.

Figure 17: Some "Pisadas" spread on the floor

Members involved: João Tragtenberg, Helder Vasconcelos, Filipe Calegario, Giordano Cabral, Geber Ramalho.

[9] https://www.youtube.com/watch?v=m4q6iD513pY

3.18 Giromin

Giromin is a wireless wearable free-gesture Digital Dance and Music Instrument [4]. It was made to be worn around the torso and on the upper arm not to impose any movement restrictions. It was designed to allow more expressive gestures in the control of continuous musical parameters on synthesizers (usually done with knobs and sliders). It afforded a precise instrumental control while allowing the performer to dance.

Figure 18: Giromin in action during the performance "Gira" in NIME 2019

It was motivated by research that suggested that the musical community in the Northeast of Brazil [5] saw that it was important for electronic musicians gestures to be perceivable by the audience and later used in the "Gira" performance. Each wearable module is composed of an accelerometer, gyroscope and magnetometer, which could extract movement information without imposing physical restrictions. It used a sensor fusion algorithm to extract orientation data of each limb together with rotation speed and acceleration data.

Members involved: João Tragtenberg, Filipe Calegario, Giordano Cabral, Geber Ramalho

3.19 Pandivá

Pandivá is an exploratory functional prototype which merged the guitar-inspired posture, the way of triggering sounds by tapping a tambourine skin and the way of altering the pitch using a trombone slide [5]. The instrument was called Pandivá (reduction of Portuguese words "*pandeiro de vara*", in English: slide tambourine).

Members involved: Filipe Calegario, Giordano Cabral, Geber Ramalho

3.20 Probatio

This project aims to address the following questions: how can we provide structured and exploratory paths to generate digital musical instruments (DMI) ideas? How can we decrease the time and effort involved in building functional DMI prototypes? To deal with these questions, we

Figure 19: Pandivá Prototype

developed a physical prototyping toolkit for building functional DMI prototypes: Probatio [10], a modular system of blocks and supports to prototype instruments based on specific ways of holding and gestural controls for musical interaction [6, 7]

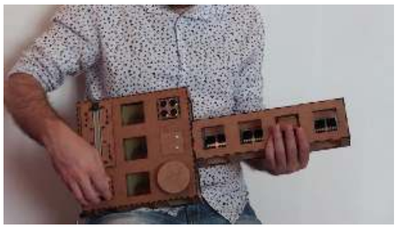

Figure 20: Probatio Prototype

This research was developed during Filipe Calegario's Ph.D. and since then has a continuous collaboration with the Input Devices and Musical Interaction Laboratory (IDMIL[11]), Centre for Interdisciplinary Research in Music Media and Technology (CIRMMT[12]), McGill University, Canada, and Inria Lille, France.

Members involved: Filipe Calegario, Evandro Natividade, Giordano Cabral, Geber Ramalho

3.21 *Marine*

marine [13] is an open-source software focused in lowering the usability entry barrier for interactive poetics experimentation in performing arts, through the use of motion capture sensors to control lighting, image projections, sound, and connected objects [8].

The system is built over Processing 3+ and uses EyesWeb to compute movement features that, together with performers' position, can be used to control stage. Java developers may implement and publish new interactive behaviors as "*marine* elements," so that artists can import and configure them through a user interface. In short, *marine* proposes a UI paradigm shift for interactivity experimentation in performing arts, from the most used visual programming software - which requires programming

[10] `http://probat.io`
[11] `http://idmil.org`
[12] `http://cirmmt.org`
[13] `http://www.marineframework.org`

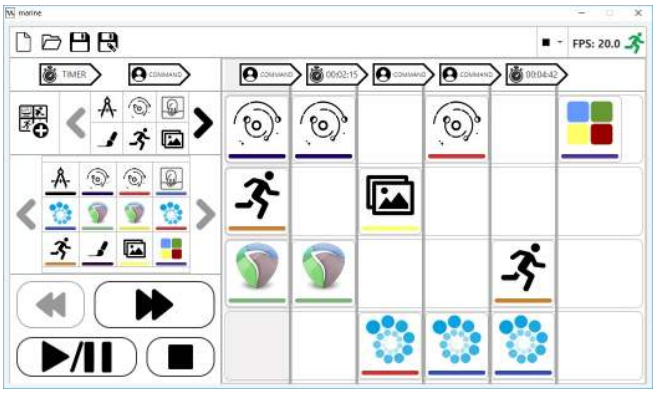

Figure 21: Screenshot of marine GUI

knowledge - to a higher level timeline oriented one - which does not.

Figure 22: *3 catástrofes sobre o prazer* using *marine* to control lighting, sound and projections

A formal evaluation of *marine* occurred through comparative tests and interviews with ten dancers. The results showed that *marine* improved effectiveness, efficiency, engagement and ease of learning, providing a more pleasant user experience when compared to visual programming software. So far, the system has been used in the performance *3 catástrofes sobre o prazer*[14] [15] [16] [17] and the interactive art installation *materia animata*[18].

Members involved: Ricardo Scholz, Geber Ramalho

4 A Cluster of Innovation in Music via Technology

The work of the MusTIC group led to many different initiatives (either startups or consolidated companies). Daccord Music Software, Batebit, LiVES, CESAR music-related projects, MusiGames Studio, Audio Alerta, ISI-TICs CIMUS, and a dozen of others were directly related to MusTIC.

Former and current researchers include Alexandre Braz, Dalton Araujo, Didimo Junior, Douglas Brito, Eduardo Santos, Erika Pessoa, Ernesto Trajano, Evandro Natividade, Filipe Calegario, Fulvio Figueroa, Gabriel Finch, Geber Ramalho, Giordano Cabral, Horhanna Oliveira, Hugo Santana, Izabel Zanforlin, Jader Abreu, Jarbas Jácome, Jaziel Vitalino, Jerônimo Barbosa, José Menezes, João Paulo Cerquinho, João Tragtenberg, Luca Dias, Luiz Delando Junior, Marcio Dahia, Mariane Marins, Michael Lopes, Mychelline Souto Cunha, Nélson Almeida, Paulo Sérgio Nunes, Pedro Aléssio, Raphael Holanda, Renato Celso, Ricardo Brazileiro, Ricardo Scholz, Rodrigo Medeiros, Rute Maxsuelly, Samuel Martins, Sidney Cunha, Sofia Galvão and Valter Jorge.

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[8] Ricardo E P Scholz and Geber L Ramalho. Lowering the Usability Entry Barrier to Interactive Poetics Experimentation in Dance. *Interacting with Computers*, 31(1):59–82, jan 2019.

[14] solo 1: `http://youtu.be/El6dmWhvGZo`
[15] solo 2: `http://youtu.be/66NuQ9i2WbY`
[16] solo 3: `http://youtu.be/V9gY8ELjACg`
[17] solo 4: `http://youtu.be/owB2sz2b9XE`
[18] `https://youtu.be/-MHRwlLUobM`