GAME|LAN:CO-DESIGNING AND CO-CREATING AN ORCHESTRA OF DIGITAL MUSICAL INSTRUMENTS WITHIN THE FAB LAB NETWORK

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ABSTRACT

This paper presents an ongoing project focused on the co-design and co-creation of a small orchestra of digitally fabricated digital musical instruments (DMIs) based on the Bela board, an open-source embedded computing platform. The project took place in Fab Labs, an international network of digital fabrication laboratories[1]. The orchestra, named *Game|Lan*, is inspired by the traditional Indonesian Gamelan ensembles, their music and philosophy. The project aims to explore the capabilities of the Fab Lab network which runs on an open-access, open-source and open-hardware ethos, for a distributed project of this type. The aspiration is to create an original orchestra for non-musicians, which offers the rich collective experience of being in a music group and explore it as a medium for social interaction. This paper presents the first results of the research project which took place is three Fab Labs in South America and it focuses on the process and the development of the project.

1. INTRODUCTION

In the last two decades, a large number of digital musical instruments have been developed by the sound and music computing community [1],[2]. The international conference for New Interfaces for Musical Expression [2], annually hosts numerous music technology research projects related to musical expression and to digital luthiers. However, very few projects are designed and made by participatory methods and techniques. The Input Devices and Music Interaction Laboratory at McGill University has co-developed the McGill Digital Orchestra which involved collaboration between researchers, composers and performers. More recently, the Augmented Instruments Laboratory at Queen Mary University of London, has started developing a research trajectory related to participatory design and co-design of digital musical instruments. [3],[4].

This paper presents the process of development of a digital musical instrument with participatory design and creation methods: brainstorming sessions, workshops, hands-on experimentation etc. Different approach has been adopted for each stage of the project depending on the resources and research area of each Lab. Focus was given equally to the physical body of the instrument as well as its electronic and digital component where an embedded computing platform for low-latency audio was used and programmed. The sound synthesis algorithms have been designed and developed as an iterative process; it was not possible to employ true participatory techniques in this case as the participants had no necessary experience or necessary skills in music signal processing.

[1] https://fablabs.io/labs/map
[2] http://www.nime.org/

The first section of the paper gives and overview of the open design, co-design and co-creation culture and the Fab Lab network. Section two presents the concept behind this project and outlines the basic idea behind the orchestra, the requirements and constraint of the approach. Finally, section three focus on the design and the making of the instrument during the residencies that the authors had in three Fab Labs in South America.

2. CO-DESIGN AND DIGITAL FABRICATION

2.1. Fab Labs

In the recent years the maker movement has started emerging, in part because of people's need to engage passionately with objects in ways that make them more than consumers [5],[6]. Particularly the Digital Fabrication Laboratories, so called Fab Labs, form part of a larger "maker movement" of high-tech do-it-yourselfers, who are democratising access to the modern means to make things [7],[8].

Fab Labs are often seen as open-innovation contexts in which lead users can develop innovation that may become commercial solutions from which companies can profit. But they may also be seen as platforms for broader participation and new ways of collaborative engagement in design and innovation, pointing at alternative forms of user-driven production [9].

The reason why Fab Labs were chosen over other type of makerspaces is the fact that the philosophy of the Fab Lab Network is the collaboration between its Labs. The fact that each Fab Lab has to share same machines and processes allows for information, projects and people to move freely between them. Also, fabricating the instrument with the principles and practices of a Fab Lab means that anyone can download the open designs, customise them if they need to and fabricate them in any Fab Lab around the world.

2.2. Co-Design and Co-Creation

Co-design is being used as an umbrella term for participatory design and collaborative design. Participatory Design, seen as design of Things, has its roots in the movements toward democratisation of work places in the Scandinavian countries. In the 1970s participation and joint decision-making became important factors in relation to workplaces and the introduction of new technology [10]. Co-design breaks the rules between the traditional designer-client relationship and allows for creative contribution to design decisions. Without excluding the designers in the process, it recognises the important role of the users' participation in the design decisions, as experience experts. This research uses the method of participatory design, a human centered design approach that attempts to involve users and experts to assist in the design process in order to ensure the usability of the product design[11]. The authors have applied and adapted the Participatory Design methods in the Fab Lab environment depending on each user group. Participatory research methods[12], [13] that involve hands on processes and Fab Lab principles both take the same approach of testing feasibility in all stages of work. The authors followed the five stage design thinking model proposed by the Hasso-Plattner Institute of Design at Stanford (d.school). The research was therefore conducted in 5 steps: empathise, define, ideate, prototype, test [3] [4]. For the first two steps a mind map was drawn on a whiteboard, as qualitative data collection tool for generating ideas.

3. CONCEPT

The concept of the project was to co-design and co-fabricate locally a series of elegant and simple to use embedded digital musical instruments for non-musicians. The aim is to create a small orchestra similar to the philosophy of the Gamelan Orchestra [14] and explore it as a medium for social interaction. The percussion-type instruments would be plug-and-play and easy to perform creatively without necessarily any musical background. It is worth mentioning that most Gamelan ensembles, especially in the UK, allow people of all ages and abilities to take part. Both authors of the paper were part of the Cardiff Gamelan ensemble and found very inspiring this fact which eventually constituted one of the main reason to approach the Game|Lan project orchestra in a similar way [5].

A very important aspect of the project was its participatory character and ethos. The instruments had to be co-designed and co-created locally, in Fab Labs. Each Fab Lab with its particular focus, skills and expertise, would contribute to the project accordingly. The authors planned to visit three to four Fab Labs in South America and work for a short period of approximately one week with the makers, engineers, entrepreneurs and designers in their premises.

Moreover, it is worth mentioning that this is a mobile project and follows the authors' idea of "how to make almost anything while travelling". The authors wanted to test how feasible is to do creative work while travelling, following a digital nomads lifestyle [6]. Every single destination would serve as a source of inspiration and every Lab would contribute uniquely to the realisation of the project. Ideally each Lab would develop its own instrument, aligned to its local culture and geographical location. This idea was proven to be too ambitious for the time spent in each Lab and although many prototypes were fabricated in each place, one final instrument was produced at the very end of the trip.

Material and technical-wise, the project had to be digitally fabricated, with open design files and with the machines and technologies shared within the Fab Lab network: 3D printers, CNC machines, laser cutters, high resolution milling machines for printed circuit board milling, electronics and microprocessors. Since the majority of the Fab Labs do not focus on DMIs, the authors had to provide the necessary embedded computing platforms for the development of low-latency audio applications. For that reason, the Bela board has been chosen, an open-source embedded computing platform and Pure Data visual programming language [15]. Other alternative platforms more widespread in the Fab Lab community such as the Arduino with the ATMega328 chip or the ATtiny microcontroller were not appropriate even with extra boards to support audio input and output. The Raspberry Pi could be an alternative but it would also need other peripherals [16].

For the sound creation component of the instrument, the intention was to design and develop a simple sound synthesis system, which would generate timbres and sequenced music material that would be mapped intuitively to the physical interface. Since the performers wouldn't be musicians it was important to make it easy to them to create quite rich musical output with simple gestures.

4. PROCESS

The co-design and co-fabrication sessions of the project were carried out in three Fab Labs in South America: The Fab Lab in the University of Chile in Santiago, the Fab Lab Lima in Peru and the Fab Lab of the National University of Colombia Medellin. It is worth noting that these three sessions, were very different in nature and approach. Furthermore, the participants were not researchers from the DMI community nor were they professional instrument players or digital luthiers, but mainly active members of the Fab Lab network and the Maker movement. That was not necessary a complication in the co-creation process since the instrument addressed this type of performers. Below it is presented chronologically how each Fab Lab contributed to the project and how the authors approached the collaboration with the teams in each location.

Fab Lab - University of Chile

Fab Lab U. de Chile [7]is housed in the Engineering School of Universidad de Chile in Santiago. The Fab Lab quickly embraced the Game|Lan project idea and invited us to work with three of their core team, to discuss our ideas on the physical and digital interaction, form, fabrication method and electronic design.

After having presented the idea and discussed the available resources, the authors collected the information from the mind-maps and started drawing out all important points as discussed with the team onto a whiteboard (see figure 1).The points proved to be our compass for agreeing on a good size, form and interaction; decisions that were made collectively. The figure below shows how the team defined some parameters that would be followed throughout the project. It was equally important to embed the Fab Lab ethos into the project, the mobile nature of the instrument, the electronics restrictions, the aesthetics and the Gamelan philosophy.

Further to the research and decisions taken by the team, the instrument had an approximate size of 250x150x150mm with an enclosure that would fit the microcontroller, battery and sensors. The first prototype was done on day three and from there on, we could easily test the interaction. The decision taken was that different faces would allow for a certain tilting of the instrument which would work well with the physical and digital interaction.

The physical structure of the musical instrument embedded sensors, very simple signal conditioning circuits and a small single-board computer for audio and sensor signal processing. The Fab Lab community commonly uses the Arduino board or directly its ATMEGA single-chip microcontroller which unfortunately does not allow on board audio processing. As mentioned on section 3, the Bela board has been chosen for its audio specifications and because it is very well integrated with Pure Data, a very well known open-source programming language for computer music applications that

[3] http://www.nime.org/

[4] https://www.interaction-design.org/literature/article/5-stages-in-the-design-thinking-process

[5] http://artsactive.org.uk/2018/02/09/cardiff-gamelan-community-group/

[6] https://nomadlist.com/

[7] http://www.fablab.uchile.cl/

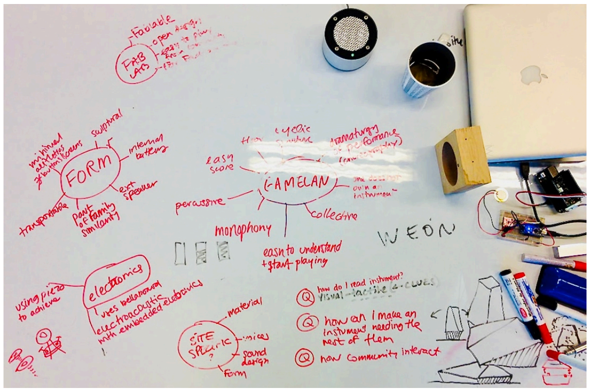

Figure 1: *Points to be considered during design decisions*

is aligned with the open-source philosophy of the Fab Lab community.

In our prototypes in Santiago, the team used a two-axis accelerometer, a piezoelectric sensor and three reed switches. An algorithm was developed in order to detect the active face of the polyhedron from the readings of the accelerometer and accordingly influence the signal processing algorithms. The piezoelectric sensor was measuring pressure on the faces of the instrument which was used either as an audio input or as trigger of samples. The reed switches and the three magnets acted as a 3-bit digital input signal that affected the settings of the instrument. All these electronic components were soldered on a perforated board. An electronic engineer from the local team helped with the electronic development and started programming for the first time in Pure Data.

One of the concepts in Santiago that the team developed, was to have an ensemble of maximum eight reconfigurable, modular and interchangeable instruments. During the music performance, the players would mix the top with the bottom parts of their instrument in order to increase the dramaturgy and the physicality of the performance. This gesture would change the settings of the instrument such as the timbre family or the sequenced music patterns triggered by the performers. The reed sensors mentioned above where used for that reason.

Figure 2: *Co-design and prototyping in Fab Lab U.de Chile*

In the first prototype, the instrument was sampled-based, playing back randomly a collection of samples coming from the same family of sounds. That was enough in order to test the interaction design and study how feasible was for the performers to play the instrument together. A simple score system was devised , similar to the Gamelan Kepatihan notion, where the number would indicate the face to be slapped. The first author was part of the Gamelan orchestra in Cardiff in UK for five years and he was aware of the level of difficulty of performing music with this type of notation. As already mentioned before, one of the main reason why the Gamelan philosophy was adopted for this project was the quick access the beginner performers have, to play notated music within the context of an orchestra. The score was briefly tested with non-musicians in Santiago and was confirmed that learning curve is very smooth and beginners could easily engage with that type of orchestra. More information on the process can be found on the authors' website [8]

Fab Lab - Fab Lab Lima

Fab Lab Lima[9] is a community Fab Lab therefore rather than working with the Fab Lab team, we organised a workshop open to the public with knowledge in either a design related field or electronics, programming or fabrication. We spent two days with a multidisciplinary group of participants with diverge backgrounds ranging from architecture to mathematics, biology, art, electrical engineering, civil engineering as well as members of the community interested in the project. Each one chose to contribute to one of the three areas of interest as designed by the authors: instrument form and design, electronics and programming and 3d prototyping in collaboration with the design group. During the time in Fab Lab Lima the authors repeated the last 3 stages: ideate, prototype, test.

On the second day of the workshop we experimented with different materials and processes as textiles and weaving, parametrically designed forms and 3d printing etc. Moreover, the electronics were further developed and a PCB board was designed according to the circuit developed in Santiago, Chile. More information on the process can be found on the authors' website [10]

The rest of the time we worked in the Lab refining the interaction design and programming it in Pure Data. Different sound synthesis algorithms where programmed there and presented to the participants. One interesting one, passed the audio signal coming directly from the piezoelectric sensor to a bank of parallel band-pass filters. The central frequency and the Q factor of the filters was mapped to the orientation of the body of the instrument and the performers by tilting it could generate a variety of unexpected sonic textures such as rain drops.

Fab Lab - National University of Colombia Medellin

Fab Lab UNAL [11] is in Medellin, in the Arts and Architecture School of the National University of Colombia. During our week in the Fab Lab, we worked with the Lab's team to co-design a parametric [12]shape for the instrument and fabricate the result in wood. Parametric design and CNC milling was this Lab's strongest asset so we experimented with both.

[8]https://www.stiwdioeverywhere.com/2018/04/20/making-in-fab-lab-u-de-chile/

[9]https://www.fablabs.io/labs/fablablima

[10]https://stiwdioeverywhere.com/2018/05/09/making-in-fab-lab-lima/

[11]https://www.fablabs.io/labs/fablabUNmedellin

[12]https://www.grasshopper3d.com/

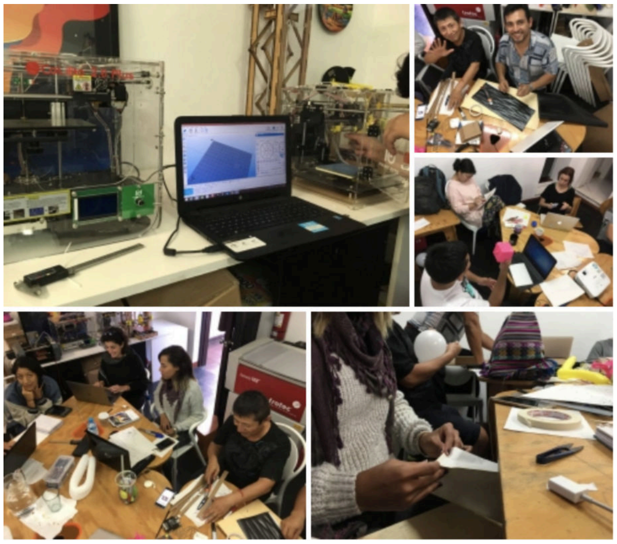

Figure 3: *Co-design and prototyping in Fab Lab Lima*

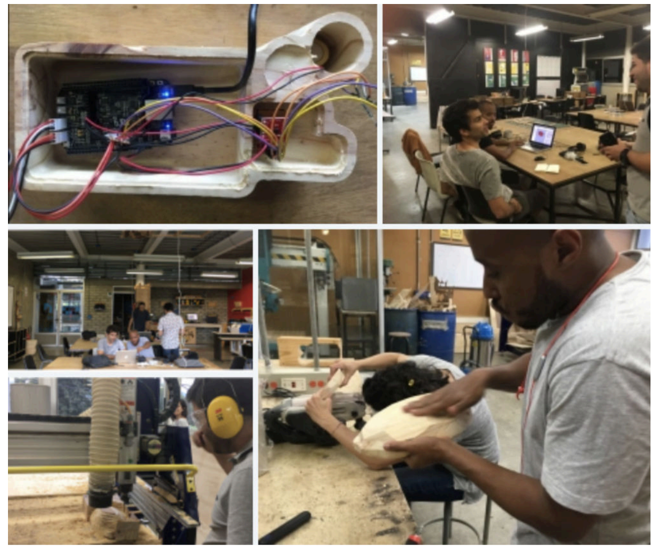

Figure 4: *Making in Medellin*

The team in Colombia had a particular interest in the digital fabrication aspect of the project, testing different types of wood for the end result. Oak, eucalyptus and pine were available to use at the Lab, and after testing the weight, acoustical properties and the milling bits to be used in each case, the team decided to use pine for the two-part instrument as illustrated in figure 5. We made three prototypes out of pine wood to test the size, ergonomics and wood texture and acoustics. The authors decided to repeat stages 3,4 and 5 of the methodology: ideation, prototype and testing. Without a major change in the ergonomics of the instrument, the final result was slightly bigger than the size agreed in Fab Lab U. de Chile, simply because the geometry generated by the algorithm was more complicated. The bottom part enclosed the electronics circuits and had 6 main faces that were used to produce different sounds depending on which angle the performer would decide to tilt it at. More information on the process can be found on the authors' website [13]

The circuit diagram and PCB layout for through-hole components designed in Peru was given to the team for milling. Unfortunately due to software implications, the drivers of the milling machine were not working and there was no alternative way of producing the board with a process used by the Fab Lab community. The widely known etching technique is not supported by the Fab Lab network which is focused to more computer-aided-manufacturing approaches.

For the sound generation part of the instrument, a different approach closer to algorithmic composition has been explored and produced higher lever of musical material. A number of short musical phrases were composed or generated algorithmically, which could be repeated and triggered interactively by the performers. Each face of the polyhedron triggered a different phrase randomly or in a predefined order. Musical parameters of the phrase such as its tempo and dynamics were mapped to the orientation of body. The performers could articulate the phrases, control how many times they are repeated and when they will start playing. This procedure was inspired by *In C* by *Terry Riley*.

[13] https://stiwdioeverywhere.com/2018/05/21/making-in-fab-lab-unal-medellin/

Figure 5: *Two part CNC milled prototype in Medellin*

5. CONCLUSIONS

The GamelLan project was an interesting experiment, trying to match the participatory approach in design and fabrication with the culture of the digital nomads.The different teams have managed to develop one finalised instrument and equally importantly to share knowledge, skills and ideas beyond their cultural barriers. The authors were flexible and worked with each Lab in a different way, respecting the diversity within the Fab Lab network. Unfortunately, there was no time left to experiment musically or perform with the instrument. Upon reflection, there are a few areas for improvement and points to consider for others who decide to do a similar project:

1. It was not an easy task to accomplish especially while travelling. The authors spent 8 days working in Fab Lab U.de Chile and managed to go through all stages of the design. In the other two locations they had to spend less time.

2. An ambitious project that would normally take a certain of amount of time in one's local Fab Lab, may take up to three times more time in other places especially when one is not familiar with the local settings. This does not apply for smaller projects or projects in collaboration with university students.

3. The Fab Labs' website that shows the location, machines and activity of each Fab Lab in the world needs an update: not all places were active or had the equipment needed and this cut the project short.

Despite the points above, the authors managed to gather an important body of knowledge related to the project, a series of alternative design ideas fabrication methods. The important points highlighted during the first days of the project in Fab lab U. de Chile set the rules, the design values to be followed. This part proved to be vital to the project, not only during the first week in Chile, but throughout the whole duration of the project. The participants whether this was in Colombia or Peru, understood and respected the decisions that were taken collectively by the first team in Chile. It was difficult for the participants to make sure they would address all the points when co-designing and prototyping the instruments in each place, however they happily accepted the challenge. There were always points where new decisions were discussed and tested; this gave a sense of empowerment and ownership in each place.

The overall challenge of co-creation, especially when not all participants have collaborated before, may delay the final result. However, each person's knowledge, ideas, or experiences added significant value to the project. Co-creation in spaces like the Fab Labs seems to come naturally by its members and the authors are optimistic that there will be more examples in the future.

This is work in progress; future work includes improved, longer in duration workshops where one instrument per location will be fabricated. All designs and music scores are to be uploaded on a web-based hosting service for version control such as GitHub so they are accessible to the community and step by step instructions and documentation of the fabrication are to be shared on the authors' website. Moreover a series of concerts are envisaged that could take place remotely as network performances or in the International Fab Lab conferences.

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