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MULTIMÉDIA - ESPECIALIZAÇÃO EM MÚSICA INTERACTIVA E DESIGN DE SOM

Music with Plants: Cultivating Bonds Between Grade-Schoolers and Nature Through Sound Design

Rita Ferreira Martins Lêdo

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Abstract

A growing need for environmental awareness requires sensitive strategies to help us rethink the way interactions transform our habitat. Modern cities are now faced with the progressive vanishing of green spaces, resulting in fewer opportunities for children to play. Since plants and humans experience life in very different time frames, humans might mistakenly perceive plants as quiet and motionless living-beings. The ability to sense elements of their surroundings to which we are unaware of, makes plants invaluable allies towards a more conscious relationship with the planet we share.

This work is an artistic proposal: a sonic approach, inspired by organic processes, to nourish the bonds between elementary-school students and nature. Believing that music has the potential to intermediate these interactions and provide meaningful experiences to the young participants by bringing to common ground digital technology, music and plants.

Resumo

Uma necessidade crescente para a consciencialização ambiental requer estratégias sensíveis que nos ajudem a repensar a forma como as interacções transformam o nosso habitat. As cidades modernas enfrentam agora o desaparecimento progressivo dos espaços verdes, do qual resulta a diminuição de oportunidades para as crianças brincarem. Uma vez que as plantas e os seres humanos experienciam a vida em tempos muito diferentes, os últimos podem percepcionar as plantas como seres silenciosos e imóveis. A sua capacidade para sentir os elementos circundantes, para os quais não estamos despertos, tornam as plantas aliadas inestimáveis no caminho para uma relação mais consciente com o planeta que partilhamos.

Este trabalho faz uma proposta artística: uma abordagem de design de som, inspirada por processos orgânicos, para fortalecer os laços entre os alunos do primeiro ciclo e a natureza. Acreditando que a música tem o potencial de intermediar estas interações e proporcionar experiências significativas para os jovens participantes, trazendo para o terreno comum a tecnologia digital, a música e as plantas.

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Esta tese não seria assim, e talvez até nem fosse de todo, sem a amabilidade inestimável das seguintes pessoas, sem a abertura dos seguintes espaços, ou sem a possibilidade dos seguintes momentos. A minha mais sincera gratidão:

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à magia e à música,
sob o risco de ser redundante.

Rita Lêdo

PLEASE BE MINDFUL OF THE TREES,
AVOID PRINTING

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Abbreviations and Symbols

CD	Compact Disc
DIY	Do-It-Yourself
DSP	Digital Signal Processing
GPS	Grande Pesca Sonora
IDE	Integrated Development Environment
LP	Long Playing [record] (vinyl record)
MIDI	Musical Instrument Digital Interface
OJM	Orquestra Jazz de Matosinhos
STEIM	Studio for Electro-Instrumental Music

1. Introduction

A growing need for environmental awareness requires sensitive strategies to help us rethink the way interactions transform our habitat. Modern cities are now faced with the progressive vanishing of green spaces, resulting in fewer opportunities for children to play (Costa & Costa, 2012; Ruggles, 2017). This work proposes a sound design approach to nourish the bonds between elementary-school students and nature.

Since plants and humans experience life in very different time frames, humans might mistakenly perceive plants as quiet and motionless living-beings (Ruggles, 2017; Mancuso & Viola, 2016). The ability to sense elements of their surroundings to which we are unaware of, makes plants invaluable allies towards a more conscious relationship with the planet we share. Fields like acoustic ecology and plant bioacoustics have recently started to bloom, inspiring sound artists to discover the vegetal world combining science and the arts (Patrão, Harvard University: Ex-centric Music Studies Conference, 2018).

In education, by the means of play, plants might perform a significant role in stimulating the senses and the connection between children inhabiting increasingly artificial cities and the world of living things that surrounds them (Costa & Costa, 2012).

This dissertation suggests that sound design has the potential to intermediate these interactions and provide meaningful experiences to the young participants. It proposes an approach based on sonic interaction design, developed for pedagogical purposes.

1.1 Context and Motivation

This research unfolds within the educational service of the Orquestra Jazz de Matosinhos[1] (OJM), a non-profit organization which has been investing in the development of artistic and educational projects with great impact within its local community (Biography, s.d.).

[1] (Eng) Matosinhos' Jazz Orchestra

The work aims to refine the ongoing project “Cant(a)eiro” (Lopes & Ferreira, 2017) whilst designing it for an elementary-school context. “Cant(a)eiro” takes shape in the form of a Clusia “princess” plant in a bamboo vase. An electronic circuit processes data from sensors in the plant, sending it into its own Processing[2] software. It is meant to be used in the classroom, with the help of the teacher and a laptop with the software. The moisture, light and galvanic response levels from the plant then trigger specific samples through the laptop and software.

This involvement between the OJM and Matosinhos’ schools sets the opportunity to engage the students in sonic and environmentally aware activities. It is critical to promote the ecological debate within the younger generations and if we are able to do this in an enjoyable and sensible way, these lessons and experiences can remain in the participants’ memories leading to more conscious behavior and a more sensible relation with plants. Furthermore, it provides a chance to integrate music in the elementary-school curriculum in a multidisciplinary fashion.

For over the last two decades, I have either lived, studied or worked in Matosinhos. I have had the privilege to witness how its inhabitants connect so strongly to the sea and the way the ocean shares the landscape with the buildings in the city, the cultivated fields, and even with some surviving wild spaces. In the municipality I have attended all three levels of basic education in state-run schools, making this dissertation a chance to contribute positively to the system I have once benefitted from. My previous film and audiovisuals training has accustomed me to thinking about artistic projects in a comprehensive and multidisciplinary way. Looking for solutions in unknown and unfamiliar areas and reflecting deeply on the lives of humans, creatures, objects and ideas.

1.2 Project

This dissertation is driven by the creation of an artistic object consisting of a hybrid between digital technology and a plant, in the shape of a flowerpot; and requires the formulation of a protocol and set of activities related to the plant, the rituals associated with the plant, and its flowerpot to be executed in the context of OJM’s educational service and the schools within its area of operation.

This will be a long-term project, since the time of plants unfolds at a slower pace than that of humans. For this reason and due to the technical and artistic complexity required for this project, it was decided that its technical development had to be based on a long-term pedagogical plan. Therefore, the project’s implementation was postponed to a later stage of development, in order not to compromise its execution.

[2] Processing is flexible software sketchbook and a language for learning how to code within he context of the visual arts.

The flowerpot will enclose the electronic and mechanical components such as sensors, microprocessor and transducer. These elements gather the data from the plant's context (sunlight, soil moisture, nearby objects, etc.) and feeds it into a system for sound generation that evolves over time in a moderately unpredictable way. The flowerpots and plants will be distributed per class desk and the responsibility for its care is shared by the children who sit together. The translation of the data into music will enable a better understanding of how the plant is being affected by its environment and by the way it is cared for, contributing to a more sensible and meaningful relationship of the subjects towards the plant.

At the same time, the activities designed should follow the rituals associated with the fulfillment of the plant's needs, foster good in-class behavior and promote cooperation and friendship while simultaneously being flexible enough to enable a case by case revision.

1.3 Problem(s), Hypothesis and Research Goals

The aim of this research is to find a sonic and interactive way to connect grade-schoolers with plants and nature in a sensible way. The experience must be foremost enjoyable in order for this information to be meaningful and understood, while using the information gathered from the plant's context to feed the music that communicates the plant's state and needs to the children.

The main research question is:

- How can we use a sonified plant to explore the relationship with music and the environment in the context of elementary school?

1.4 Methodology

This research begins with a transdisciplinary literature review as it is crucial to understand where plants stand within our planet, our culture, and the arts throughout the times. Concurrently, we study the suitability and the specific needs for the project's implementation within the context of OJM's educational service and the curriculum of the public elementary schools.

A practice-based research aims to generate knowledge through the practice and the outcomes of that practice (Candy, 2006), using the research process to inform the art project and subsequently have the artwork feed back into the research. The work here is, therefore, a generator of knowledge *per se* and the research contributes to the intellectual, cultural and creative discourses it relates to (Impett, 2019).

The process of development, prototyping and implementation of the project is thoroughly documented and frequently put to test in order to adjust whatever is necessary.

The stages of the project's implementation are divided as follows:

- Selection of the plant, gathering information of the plant's needs and ensuing illustration of school-fitting activities based on those rituals;
- Prototype design;
- Programming of the hybrid-plant's behavior and sound design of the data obtained.

1.5 Dissertation Structure

After this (1) Introduction, where I describe the context, motivation, research goals, the project and methodology, I follow with a (2)Literature Review. In that second chapter the place of plants in a zoocentric and anthropocentric world is considered and sound artworks related to plants are observed. In the next section, 3. A Flower Friend — Part I, I describe the problem and the task at hands, followed by the conceptual development of the project. After that, I thoroughly describe the prototype's architecture and implementation in chapter 4. A Flower Friend — Part II. In the final chapter (5. Future Work) I reflect of the completed and the future work.

2. Literature Review

In this chapter I present a summary of relevant theories and models that help understanding the history and neurobiology of plants, situating the vegetal world in the arts and its importance to humanity and the ecosystems. In the section that follows, some ideas about play and interactivity are introduced.

Afterwards I will focus on related works to aid in grounding this dissertation and project regarding its motives, methods and intentions. To do this the chapter is split into two main sections: “Plant as performer” and “Plant as listener”. The first group encompasses practices of generative music by plants and music where plants are used as instrument or interface while the latter consists of music *for* and *about* plants (Patrão, 2017). Within each of those groups I introduce the central ideas surrounding both concepts; then I list a series of art works within that frame of thought, highlighting the pertinent aspects in the context of this project; finally I move into a technological review of the means used in the making of the aforementioned works, once again comparing tools and featuring those which are of interest for the implementation phase of this dissertation.

2.1 Theory and models

2.1.1 Plants in culture

More than three billion and a half years ago (way before the first animals and billions of years apart from the first *Homo sapiens*) the first living beings with the ability to perform photosynthesis arise on the planet. The ancestral green algae made its way onto land, developing into progressively more complex structures and leading to the diverse plant kingdom we know of today. The late emergence of flowers made possible the variety of other kinds of life forms and styles (Lonelyleap, 2013).

We have been sharing the Earth with plants for around two hundred thousand years. (Mancuso & Viola, 2016). Plants "feed us, clothe us [and] provide us with medicine" (Lonelyleap, 2013).

In their book, Mancuso and Viola (2016) brilliantly outline the history of plants in civilization. Starting with religion, which has been deeply embed in almost every culture in the world, plants have many times suffered from a bad reputation — if mentioned at all. In the Bible's Genesis flood narrative, plants were not considered worth being taken into Noah's Ark in order to be preserved. However, as soon as he lands, Noah plants a vine which was probably kept from before the flood. This vine is not mentioned before, as if not belonging together with the other living beings but being instead nothing more than a useful object. During the Inquisition, heavily aromatic or psychotropic plants which were believed to be used for witchcraft (like garlic, parsley fennel or henbane) were condemned together with the witches (Mancuso & Viola, 2016; Rätsch, 2005; Müller-Ebeling, Rätsch, & Storl, 2003). Islamic art, in which the portrayal of Allah or any living being is forbidden, has devoted itself to the depiction of plants and flowers. On the other hand, Native Americans and several indigenous communities regard plants as valuable, sacred beings and psychotropic plants have been used in the course of magic rituals by shamans and other traditions (Mancuso & Viola, 2016; Rätsch, 2005). During the period between 28 B.C and 325 A.D, Roman citizens surrounded themselves with flowers to enjoy their fragrance in dinner parties and flower arrangements were often used to showcase wealth; crowns, scarves and wreaths made of flowers and other plants were worn for symbolic and religious purposes (Griner, 2002).

Some flowers, trees and fruits have enjoyed more mentions in Human culture than others, with added symbolism to them. The fig tree and its fruit, leaves and flowers for instance, are used as metaphor and in proverbs around the world; are depicted in the Book of Genesis and the Bible; and the Buddah attained *Bodhi* (enlightenment) under a fig tree[3] (Gethin, 1998);

In the 18th century, John Bartram, a Quaker with a deep interest in plants which would later be known as the founder of American botany, contributed greatly to the trade of plants between Great-Britain and the Americas partly by means of his "Bartram's boxes" which frequently contained seeds, cuttings, rhizomes, soil, sawdust etc. (TheShowIsNotTheShow, 2015).

People have also used flower arrangements to exchange messages for many decades, perfecting what is called *floriography* (the language of flowers). Flower meanings can differ greatly between cultures which can be demonstrated by a Japanese version *floriography* — hanakotoba[4]. Again in Japan, flower arrangement — ikebana[5], which has a deeply philosophical and spiritual roots, might have been around since the 7th century (Tsuji, 2015; Flood, 2014).

[3] Bohdi tree (बोधि): a sacred and ancient *ficus religiosa* ;
[4] Hanakotoba (花言葉) is a Japanese form of language of flowers;
[5] Also known as Kadou (華道, "Way of Flowers"), is one of the three Japanese arts of refinement, together with Koudou (香道, "Way of Fragrance") and Chadou (茶道, Way of Tea").

As for the last few years, Laura Jane Martin (The Secret and Ancient Lives of Houseplants, 2013) asserts that although people have grown plants in pots for centuries, houseplants are a relatively recent phenomenon. The horticultural industry, new technologies, indoor heating and lightning facilitated the relocation of plants to the inside of our homes. The popularity of houseplants then spread on to artificial plants so that in 2007, botanists proposed the establishment of a new family (of artificial plants): the “Simulacracea” (Martin, 2013).

2.1.2 Plant neurobiology

Philosophers and scientists such as Plato and Darwin have, for centuries, argued that plants possess “brains” or “souls” providing them with the ability to feel and react to external calls (Mancuso & Viola, 2016).

Studies have theorized about “plant intelligence” picturing plants as less intelligent and evolved beings and placing them at the bottom of the “evolutive scale” (Mancuso & Viola, 2016).

A recognized phenomenon called *plant blindness*, was heavily influenced by Aristotle’s centuries’ old “scala naturae” — the ladder of life where plants are placed at the hierarchical bottom, perceived as immobile, insensitive and passive. Wandersee and Schussler (1999) defined plant blindness as:

> (a) the inability to see or notice the plants in one’s environment; (b) the inability to recognize the importance of plants in the biosphere and in human affairs; (c) the inability to appreciate the aesthetic and unique biological features of the life forms that belong to the Plant Kingdom; and (d) the misguided anthropocentric ranking of plants as inferior to animals and thus, as unworthy of consideration. (p. 1)

Today this phenomenon remains influencing researchers and is frequently observable in our everyday lives (Ruggles, 2017).

Unlike human beings, plants are sessile and, since they cannot move from their place, have evolved into modular bodies. Only in the 18th century did Carl Nilsson Linneaus dedicate to the study of plants, thoroughly classifying the species and identifying the plants’ reproductive systems (Mancuso & Viola, 2016; Lonelyleap, 2013). Later that century, Charles Darwin speculates that plants have their brains underground after working together with Burden-Sanderson — the electrophysiologist who first discovered that plants showed electrical signaling similar to the nerves on animals. This electrical activity was later found also in the plants’ roots and in the mycelium that connects them (Leudar, 2015). But it is Francis Darwin, in the year of 1908, who first claims that plants are intelligent beings (Mancuso & Viola, 2016).

Although plants lack the organs we commonly associate to senses, like the eyes, the nose or the ears, neither do they have "brains", they sense their surroundings very accurately and even recognize other beings and communicate (Mancuso & Viola, 2016; Ruggles, 2017).

Devoid of eyes, plants can still sense the light (and the shadow), tell its quality and quantity and the direction from which the sun's rays come from (Wang, 2014; Mancuso & Viola, 2016). Plants are able to smell using their entire bodies, which are filled with tiny receptors that take volatile matter and trigger messages all around the plant's organism. They can appraise the quality of the soil, tasting the present chemical substances. Plants can touch and hear thanks to their mechanosensitive channels. Several species will react to touch by closing their leaves and petals; vines use this sense to climb onto poles. Their sensible bodies can hear what is above the soil and underground. (Mancuso & Viola, 2016)

Some recent studies have also argued about the effects of music on plants. "Musical sounds" seem to influence plant growth by interacting with the plants' genes, helping the exchange of carbon dioxide and oxygen, increasing the movement of cytoplasm, etc. (Sharma, 2018). Artists like Annea Lockwood and Ross Bolleter for example, have explored the reverse path by working on the effects of plant growth on musical instruments by abandoning pianos in fields and gardens (Patrão, 2018).

These senses allow plants to adapt their behavior to their environment. Plants are able to recognize other plants from the same family from those unrelated (Ruggles, 2017); manage resources together and communicate (Wang, 2014) through a vast underground network[6]; defend from attackers by releasing chemicals to repel them or attracting the attackers' predators (Mancuso & Viola, 2016) and even predict these attacks and other important events for their survival (Ruggles, 2017; Wang, 2014). Amazingly as it seems, plants learn and use memories in order to make decisions — take for example the case of *vernalisation*[7]:

> … certain plants must be exposed to the cold before they can flower in spring. The "memory of winter" is what helps plants to distinguish between spring (when pollinators, such as bees, are busy) and autumn (when they are not, and when the decision to flower at the wrong time of year could be reproductively disastrous). (Ruggles, 2017)

Plants are complex organisms which have been communicating, trading information and resources, avoiding common enemies together and being mediators between the Sun and the animals, right under our noses for quite a long time now and music might be one of the best means to guide our attention back to them and perceive them finally as the lively beings they are.

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[6] E.g. the common case of *myrchorrhizal networks* of fungus: a special kind of symbiosis that links the root systems of plants and mushrooms (Ruggles, 2017; Mancuso & Viola, 2016).

[7] The induction of a plant's flowering process by exposure to the prolonged cold of winter, or by an artificial equivalent. (Vernalization. In Wikipedia, The Free Encyclopedia, 2018)

2.2 Plant as performer

This section pertains to works where the plants are the musical performers or producers in addition to other art works which, whilst not being related to plants, are relevant as inspiration for this dissertation. Here I settle this project within the "plant as performer" group, describe its motives and support its sonic choices as well as present the most common methods used for the creation of music with plants.

2.2.1 Is there music in nature?

When in the process of finding a "voice" for plants, the question "Is there music in nature?" (López, 1998) becomes of fundamental importance. Every soundscape[8] that emerges from a wild habitat has a unique signature and is made up of three sources: the nonbiological sounds (geophony), the biological sounds (biophony) and the sound humans make (antrophony) (Krause, 2003). Before the last two decades, sound art focused on the environment has often overlooked the most common element of nature's biotic components: plants (López, 1998). Given how plants have been so frequently disregarded as part of Nature's orchestra, it might be also worth wondering: if a tree falls in a forest and there are people around to hear it, would they listen?

Even though "music itself may be specifically human, some of the fundamental mechanisms that underlie human musicality are shared with other species" (Fitch, 2017, p. viii). Many animal species have been appreciated for their "singing" abilities since we know them. Humpback whale songs are in many ways similar-sounding to man-made music and birds also compose using elements common to our [human] music. In addition, these animals are able to memorize and recognize musical patterns (Gray, et al., 2001).

It is also important to note that musicality seems to be an intrinsic characteristic to humans and that it might have biological origins, as opposed to being a cultural product with no evolutionary history (Honing, 2018; Blacking, 2000). Even those who consider themselves "unmusical" are skilled music listeners and have "implicit knowledge of the musical forms and styles of their culture" (Fitch, 2017, p. vii; Blacking, 2000).

In this dissertation, music is understood as an "aesthetic concept of sound", unrestricted to its classical sense in a similar way as López describes within the homonymous chapter of his work: "It's our *decision* — subjective, intentional, non-universal, not necessarily permanent" (Environmental sound matter, 1998, p. 3), while simultaneously acknowledging forms of music which might be independent from sound — by the means of gesture, dance or sign language for instance.

[8] A soundscape is any acoustic field of study (Shafer, 1993)

It seems adequate, in order to sustain the preference for a generative music path, to point out Brian Eno's statement, as cited by David Toop (2004):

> Generative music is like trying to create a seed, as opposed to classical composition which is like trying to engineer a tree. … I think one of the changes of our consciousness of how things come into being, of how things are made and how they work, is the change from an engineering paradigm, which is to say a design paradigm, to a biological paradigm, which is an evolutionary one. … So a lot of the generative music thing is much more like gardening. When you make a garden, of course you choose some of the things you put in, and of course you have some degree of control over what the thing will be like, but you never know precisely . . . (p.480)

In the same chapter, the gardening metaphor used to describe works of generative nature (in which you provide a set of conditions by which something will come to existence) and the connection between generative approaches in works regarding nature, biology and ecology is persistent. To many sound artists, Nature is a "resource for generative data waiting to be translated into a sonic experience" (Patrão, 2013) and although frequently aided by computers, the creation of generative works is not restricted to digital means (Toop, 2004).

2.2.2 Music with plants

In the last few decades, both science and the arts have taken interest in the life of plants. This might be one of the causes for the ever-increasing number of plant related sound works and artists working with plants. In this section are mentioned some relevant projects where plants are used as instrument or that use data gathered from plants to create music, therefore excluding field recordings and soundscape works. These works are sound installations, music compositions, generative or linear, in real-time or offline; some are interactive and others not so much.

Composer Mamoru Fujieda wired plants using a bioelectric interface conceived by botanist Yuji Dogane. The Plantron consists of electrodes attached to the plant's leaves, which record changes to its surface electric potential; a computer then converts this data to MIDI and transformed into melodic patterns using software Max[9]. The collected patterns are scored to musical instruments such as the koto (琴) and the shou (笙) or to viola de gamba and harpsichord among other instruments. Fujieda's series of albums *Patterns of Plants I* (Fujieda, Patterns of

[9] Max/Msp is a graphic programming environment originally developed by Miller Puckette and others at IRCAM in the 80's. It is now maintained by the software company Cycling '74.

Plants, 1997) and *Patterns of Plants II* (Fujieda, 2008) is composed with this method. (Toop, 2004; Patrão, 2013)

Christine Ödlund, in 2008, composes the score for *Stress Call of the Stinging Nettle* by analyzing the chemical substances released by the plant when the butterfly larvae are feeding on its leaves, and transposing this information into amplitude and intensity of sinus tones (Ölund, s.d.).

Some artists devote their work almost entirely to plants. Such is the case of Mileece Petre whose repertoire ranges from installations of sonified gardens and performances to generative music with plants (Millece, 2002 - present). She has been using programming language SuperCollider[10] for her generative musical works and interactive compositions (Patrão, 2013; Kurutz, 2013). Her installation *Soniferous Eden* (2010) shows her will to bridge communication between humans and plants, and surprisingly between plants too, as they become sensitive to each other and react to humans touching a neighboring plant's leaves (Mileece, 2011a; Mileece, 2011b). The sounds triggered by electric signals can be described as squeeks, crickets, wind, xylophone like melodic tone and bells (Mileece, 2011). Back in 2002, Mileece released a music album based on the captured structures of plant growth, called *Formations* (2002). In the album's notes, she dedicates it to plants. *Formations* is an example of how the margins between music *with* and *for* plants are not always completely clear. The choice of placing this work in this section was based both on believing that keeping Mileece's work together would make an easier read and because the music is partly based on gathered data from the plants.

Influenced partly by Mileece's music album, the group Data Garden begins its journey in plant music (Tyson, 2012). *Data Garden: Quartet* is a bio-reactive installation consisting of four plants with galvanometers attached to their leaves using electrodes that pick up the electrical signals which are then transformed into MIDI notes and control values. To each plant there is an instrument assigned and the public is encouraged to play with the plants, touching them and affecting the music (Patrão, 2013; Cusumano, 2012).

Leslie Garcia's Pulsu(m) Plantae is an ongoing project focused on the plants' communication mechanisms and how these seem intangible to humans. The project's evolution process, software and electronic schematics are comprehensively documented online. It is made up of several interactive experiments using the principles of biofeedback[11] to feed sound synthesis using a sort of "prosthesis" for the plant. (Garcia, 2010 - present)

In *L-fields* (2000), Michael Prime also translates bioactivity from hallucinogenic plants and uses it to control oscillators (Patrão, 2013). Afterwards the sounds of the plant's surrounding environment is compressed and overlaid and mixed with the original signal (Couture, s.d.). He describes this process as if inhabiting "a kind of hinterland between composition, improvisation

[10] Supercollider is a audio synthesis and algorithmic composition software.
[11] Collecting data from physiological functions using sensors.

and process/generative music." (Toop, 2004, p. 484) . In 2003, Prime composes *One Hour As a Plant,* with all sounds produced by a peyote cactus's bioelectrical field, for Ben Green's Resonance FM program, released later in 2005 and 2014 in CD (Michael Prime - One Hour As A PLANT, n.d.).

Alexandra Duvekot is the sound artist responsible for the creation *The Plant Orchestra Amsterdam* which was presented in STEIM (Duvekot, 2013). Before the concert, Duvekot explains the origins of this project, from her interest in ill plants and trying to bring them back to health to trying to find the frequencies plants react more to and the sounds they make (The Plant Orchestra Amsterdam, 2013). After her research she prototypes and produces a system sourced in the plants' electric reaction and plays together with the *plant orchestra*.

In a similar way to the works mentioned above, *Plant Sounds* (2015) by Marc-Alexandre Chan & Thom Christie, *"... how will you conduct yourself in the company of trees*" (2016) by Mehreen Murtaza and Ariel Guzik's *Concierto para plantas* (hibridotube, 2011) use electrodes to detected electric fluctuations in the plants and feed the data to computer programs that translate the data to music. Guzik's *laúd plasmaht* uses the plants to play the lute (Guzik, 2011).

Artist duo Scenocosme has presented several sound installations with living plants since 2007 (Lassere & met den Ancxt, 2015). Their works are strongly focused on interactivity and hybrids of plants and digital technology. *Akousmaflore* (2007) is an interactive installation that resembles an indoor garden filled with musical plants in which each plant reacts differently to contact and proximity. In 2011, the group developed an interactive tree – the *Phonofolium* – which has been adapted, the year after, into part of their sound installations: *Phonofolia* and *Lumifolia*. The *hybrid* trees react to human electrostatic contact with sound (Lassere & met den Ancxt, 2015).

Researcher and artist Rosemary Lee uses carnivorous plants in a 12-channel sound installation entitled *Symbiotic Sound* in the year of 2017. In order to explore the relationships between plants and their environment, sound recording equipment is used as mediator in transforming human's perception of the plants into the image of a predator (Lee, 2017). This installation is preceded by *Sonic Cannibal*, another sound (and light) installation — a *Sarracenia* plant cyborg, equipped with tiny speakers inside its pitchers, using its own membranes and leaves to record its surroundings (Lee, Sonic Cannibal, 2015).

With a very different approach *A Kauri Cries* is a film project in which the moving video images of a Kauri tree infected with dieback are turned into a musical score. An orchestra (members of Auckland Philharmonia Orchestra) composes the music on site as they receive the feed of the cameras tracking down the tree (Syrp, 2017).

Most of the aforementioned works rely on a process of sonification of the plants idiosyncratic or environmental data. Other works approach the plants (or vegetables) as an interface, such is the case of the studio Playtronica (*Taste the Jazz* - 2017; *Metro Unboxed* – 2017; *Have you ever played Vivaldi at the squash?* – 2018) who often uses fruits, vegetables and objects to trigger different sounds in music live performances (Playtronica, 2019).

Due to the amount of music with plants that has recently emerged and the ambiguity of the field's definition we are not able to cover it exhaustively[12] and have therefore prioritized works with a strong digital technology component for data collection and transposition into music preferably with the ability of human-plant interaction as well as artists with multiple sound works using plants.

2.2.3 Technology

The sound works encompassed in the "music with plants" category follow two main technological approaches: sonification and plant as interface.

2.2.3.1 Sonification

Sonification is "the use of non-speech audio to convey information or perceptualize data" (Kramer, et al., 2010, p. 3). In music with plants, artists gather idiosyncratic data from the plant or from the plant's context. Plants are a source of electrical pulses that react to several conditions like weather, water, light, gravity, touch, moon cycles, etc. (Patrão, Plant Consciousness & Communication, 2013).

In the past, artists have commonly used "random sine and saw waves whereby the oscillators become especially chaotic and high pitched when there is a signal" (Leudar, 2015, p. 5); piano or other classic instrument sounds which "anthropomorphize the process involved far too much" (Leudar, 2015, p. 5)

From the plant's physiology we can measure: action potentials, micro-voltages, moisture levels or tension, movement and growth, photon counting (when bioluminescent), resistance and impedance. And from the plant's environment we can collect data on humidity, pH level, soil moisture, temperature, light and ultraviolet light levels (plant_sensing, 2018). In plants, action potentials are fast signals of very short duration while variation potentials might change slowly over long periods of time (Leudar, 2015).

Common sensors used include: (1) the galvanometer and electrodes — to detect the plant's galvanic response, for instance, when the plant is being touched or pressed its electric current varies; (2) the photo-conductive cell — a light-controlled variable resistor to collect information about the plant's environment light condition; (3) a resistor or capacitive soil moisture sensor —

[12] Other works of music with plants: *Child of Tree* (1975) and *Branches* (1976) by John Cage; The Vegetable Orchestra (1998 - present);*Untitled (Greenhouse)* (2002) and *Untitled (Singing Tree)* (2006) by Peter Coffin; Improv:21 - Plants Make Music! (ROVA:Arts, 2006) and *Pieces For Plants* (2013) by Miya Masaoka; *Needles* (2010) by Matmos and So Percussion ; *Sonic Succulents* (2012) by Adrienne Adar; *Tree Songs* (2012) by Leah Barclay and the sonic explorers; *Cactus Rd* (2013) by Jeph Jerman; *Biophonic Garden* (2014) by Sebastian Frischt ; *zu staub* (2015) by Mark Andre; *Playing A Cactus – After John Cage* (2015) by Lindsey French; *Cactus Workestra* (2017) by João Ricardo de Barros Oliveira; *Sounds from the Soil* (2016 - 2019) by Simone Vitale.

to measures the soil's moisture over time. These are usually connected to a microprocessor like Arduino, Raspberry Pi or similar.

Some ready-made and do-it-yourself kits have surfaced recently. Most of the kits are gardening helpers, such is the case of: Botanicalls' DIY kits; Fertometer's feeding indicator for potted plants; Yanko Design's Pet Plant by Junyi Heo; the Daisy Sensor; and GardentBot's DIY guides among many others. For music making, Data Garden as developed the MIDI Sprout, a tiny box which translates the plant's biodata to MIDI and pairs with an iOS application.

After the data collection, it is usually processed and translated into music by computer software. Some of the aforementioned artists developed programs for this purpose using SuperCollider, Max/Msp, Pure Data[13].

2.2.3.2 Interface

Some other works use plants, vegetables and fruits as a controller to trigger MIDI notes or other values (the works of Playtronica for instance), or as the instrument itself by either amplifying the plant's sound (as is the case of Cage's amplified cactus) or by shaping the vegetables into playable instruments (like the instruments sculpted by The Vegetable Orchestra).

In the case of amplified plants (usually cacti), contact microphones are applied to its surface to amplify their projection and tone (Amplified Cactus, 2018).

To use the plants as a controller there are some ready-made electronic devices available for purchase that rely on electrical conductivity and alligator clips. The most notable examples are the *Makey Makey* controller and Playtronica's *Playtron*.

2.3 Plant as listener

To this section belong music works to be played for plants or dedicated to them. Plants here take a more passive role as the receivers of sounds.

2.3.1 Listening

Percussionist Evelyn Glennie describes hearing as a "specialized form of touch". Profoundly deaf from a young age, when comparing hearing to touch, Glennie questions the reader (Hearing Essay, 2017, p. 194): "If you are standing by the road and a large truck goes by, do you hear or feel the vibration? The answer is both.".

Already in 1993, R. Murray Shafer (1993, p. 11) declared that "hearing is a way of touching at a distance …" . I argue that there are no real boundaries between senses — animals (humans included) and plants alike, all experience the world around them through multiple stimuli captured

[13] Pure Data (Pd) is an open source visual programming language for multimedia developed by Miller Puckette.

by sensitive receptors within their bodies. How humans perceive the world might be better understood with the help of the following explanation from brain researcher Jill Bolte Taylor (My stroke of insight, 2008):

> Information, in the form of energy, streams in simultaneously through all our sensory systems and then it explodes into this enormous collage of what this present moment looks like, what it feels like and what it sounds like.

In Glennie's previously mentioned essay (Hearing Essay, 2017), she goes on to describe how different sound frequencies might be felt with different body parts: the low sounds she feels mainly on her legs and feet, the high sounds in particular places in her face, neck or chest. It is not only touch which is deeply connected to hearing — sight can also help us hear. We can see vibration and movement and that information, if present, adds to the [sound] image we are picturing.

As we have seen before (in section 1.2.1), plants cannot hear in the conventional way we are used to think about "hearing". But once we have realized that hearing and touch are not distinct senses and that plants are fully equipped with the receptors necessary to sense vibrations (even if not through the same organs as humans) we might have found common ground.

But there is more to listening than the senses. Listening requires cognitive processes to help the listener understand what is being heard. Authors and artists such as Pierre Schaffer, Pauline Oliveros and Michel Chion have studied and written thoroughly on the act and modes of listening and the different levels of awareness linked to each of those modes (Chion, 1994; Oliveros, 2005; Etmektsoglou, Mniestris, & Lotis, 2008).

Music helps building and strengthening social and cultural bonds; it instigates companionship and group cohesion (Jao, 2015). Composers and musicians have claimed listening's potential as an ecological exercise — unlike sight (which brings a feeling of separation or "otherness" between the perceiver and the perceived), hearing might contribute positively to a sense of togetherness with the elements of our surroundings (Ingram, 2010). Cultivating a sensorial perception of what surrounds us, hearing aids in entering into "a sympathetic relation with the perceived . . .", being that perception is the ". . . synchronization between [one's] own rhythms and the rhythms of the things themselves. . ." (Abram, 1997, p. 42). Acknowledging this helps us understanding why music and sound art might be effective tools for impelling change and shifting consciousness (Gilmurray, 2017) .

2.3.2 Music for plants

The journey of music to be listened by plants in the musical records history might begin in 1970 with the album *Music to Grow Plants* by Dr.George Milstein and Corelli-Jacobs. This album may help plants grow healthier and stronger by improving the exchange of oxygen and carbon dioxide in the plants' leaves (Patrão, Botanical Rhythms: A Field Guide to Plant Music, 2018). The release included a packet of seeds and an instruction book on how to care for your plants titled *Growing Plants Successfully In The Home*. It was suggested that the album should be played once every day for forty-five minutes in order to affect the plants (Patrão, Plant Consciousness & Communication, 2013).

Three years later Jerry Baker, releases the homonymous album of his first written book about gardening — *Plants Are Like People*. The year after, *Green Sound (Music For Your Plants)* is published by record label Halco.

In 1975, Carmel Records releases a classical music compilation titled *Music For Your Plants*, by various authors, featuring Vivaldi's *The Four Seasons, Spring*, Tchaikovsky's *Waltz of the Flowers* among others.

Then, in 1976, the field of music for plants blooms with several albums being released that year. The most well-known probably being Mort Garson's *Mother Earth's Plantasia* described in its cover as "warm earth music for plants…and the people who love them". The album also comes with a plant care booklet (Patrão, 2013). *Plantasia* then was reissued in 2019. Molly Roth and Jim Bricker talk to [your] houseplants "for you" while you "go about your business" (Roth & Bricker, 1976) and give advice on plant care in *Plant Talk/Sound Advice*. Baroque Bouquet publish the LP *Plant Music* with the note "Music to keep your plants healthy and happy. We know our music will stimulate a favorable response within your growing plants." and finally, Ann Chase releases *A Chant For Your Plants* — spoken word over guitar and flute to ". . . take you on a psychedelic trip through your favorite plant, and into yourself." (Ann Chase — A Chant For Your Plants, n.d.).

The album *De la Musique et des Secrets pour Enchanter vos Plantes* thought by Martin Monestier and composed by Roger Roger is released in 1978 affirming in the back cover ". . . que les plantes n'apprécient guère la solitude, l'indifférence. . ."[14].

Using field recordings of nature sounds, Hiroshi Yoshimura's *Green* (1986) is "alive with rich vegetation and heavy moisture" (Gordon, 2018) , although not expressly dedicated to plants, the minimalist music work has a strong connection to the sounds of the environment.

[14] ". . . that plants do not appreciate loneliness, indifference . . ."

More recently, in 2014, artist Peter Coffins composes *Music for Plants* and has performed it inside a greenhouse in several art studios and galleries. In 2002, Coffin was already working in *Untitled (Greenhouse)*, a project with where a performer "plays" plants by touching their leaves.

Numerous other music albums from various authors claim helping plants grow healthier, keep them company or are simply dedicated to them thus influencing the listeners to look at the plants around them with another insight. In the last few years, platforms like YouTube have seen emerge dozens of music videos and playlists with music bearing the same claims blended with spiritual or meditation music.

2.4 Summary

Artists have taken interest in the life of plants, thereby bringing the vegetal world into the biosphere discourse under a more sensible, renewed light. A desire to facilitate the understanding between humans and plants and to connect the species is moving artists into creative experiments, balancing between displaying data and providing a meaningful experience while seeking for the sweet spot.

This literature review initiated the course into understanding the many ways in which plants are more or less similar to every other living being — human-beings in particular or even more specifically: how are plants similar to *me,* since that is the only point of view within my reach. This urged my imagination into questioning what is it like to be a plant. Answering this question, as suggested by Thomas Nagel's article "What is it Like to be a Bat?" (1974), is an impossible task due to the implications of subjectivity. But merely the act of wondering "what is it like to be" conveys the idea that a plant (our subject) has a conscious experience — a first person, private process (Damásio A. , 1999, p. 33) — and confines the answer only to the limit of one's imagination, and luckily "[T]he imagination is remarkably flexible" (Nagel, 1974, p. 442).

3. A Flower Friend – Part I

The artistic object associated to this dissertation — a sonified performer plant which I have named *Flormiga*[15]— is the legacy of Cant(a)eiro (Lopes & Ferreira, 2017) in many ways.

Here, we seek to adapt that project to a narrower setting while carefully considering past experiences and experiments. Our purpose being also to find the right balance for this particular grade-school context, hopefully providing fruitful knowledge to similar future projects. Considering this, the following chapter describes thoroughly why and how we made the conceptual decisions that piece together this object. It is divided in five sections pertaining to the activity plan and values (3.1 The play and 3.2 The plan), the chosen plant (3.3 The plant), the hardware (3.4 The prosthesis) and the composition/sound design (3.5 The piece). Although divided, these choices were not necessarily made sequentially since every new finding impacts and is influenced by every other.

I will begin this chapter by telling you a story.

3.1 The play

"Who here enjoys singing?" — the teacher asks. Johanna arrived in the classroom just in time before its start and quickly sits at her desk. Her desk-mate Marco was already there, and there was also a strange new object, on top of the desk — a bulb in a vase. Every desk has one.

"Me!", "Me!", "I do!" — is heard all over the room together with the sound of some chairs being dragged. "Do animals sing?" — another question. Johanna thinks about the birds but Marco quickly rises his arm up "Birds!", "Birds. What else sings?"; "The cricket! The cicada!" — answers the child.

"What about plants? Do plants sing?". Throughout the classroom many heads nod in disagreement.

[15] A *portmanteau* from "flor" (flower) and "amiga" (friend).

The teacher asks the class for silence, putting one hand behind one ear as if trying to listen. The children take a little time to quiet down. Some of the kids shush their colleagues as they become aware of some soft tones coming from the flower pots. The room is gradually filled with soft melodies coming from the vases. “The bulbs are waking up!”. Marco quickly names their plant. Johanna would much better like another one, but she didn’t mind too much.

The teacher now talks about how plants need watering and sunlight, how they feed of the soil’s nutrients, but the children are too busy trying to make their own plants sing. Some kids ask the teacher if they can go and get some water from the sink, trying to bring it by holding the water in their hands secured together. Others take the plant to the sink. “Careful, not too much water!” — warns the teacher. “The plants are drinking!”, a crackling sound coming from the inside of the flowerpots is heard, “That’s right, the plants drink much of the water through their roots!”.

Johanna takes her new plant friend closer to the sunlight, to the window sill, while Marco is distracted with another classmate’s plant that seems to sing when you touch its leaves. She swears she could hear her bulb laugh! She asks the bulb to laugh again, unsuccessfully, maybe she should try telling the plant a joke.

Throughout the following weeks, every school day the classroom gets to take care of the plants, right at the beginning of class. The children bring their flower-friend from the side of the window, where they usually remain to get the best sunlight. They press the soil to check if its still moist or if it needs watering and then they leave it on their desks until break time. The leaves begin sprouting from the bulb. Then a flower, then ten flowers. Johanna’s and Marcos’ flower-friend is colored purple, on the bluish side. Occasionally they might sing a melody, or whistle about the temperature rising, otherwise they remain quiet, listening attentively to the class, and on a rare occasion a plant will respond to another and both sing together.

3.2 The plan

The setting for this project is an elementary-school classroom, our participants are children aged 6 to 10 and their teachers. OJM’s educational service is the bridge which brings the music to the students.

Since 2014, the OJM promotes a music and arts program called Grande Pesca Sonora (GPS), gathering students from local schools together with the orchestra’s musicians. In 2017 the theme for the GPS was music with plants [16] and there, high school students explored ideas that connected plants with music and composition. We borrow from those exercises the experience to inform our plan and to help tune the project to much younger participants, arriving to some guidelines for the new setup:

[16] Grande Pesca Sonora: Música com plantas, plantas com Música (Grande Pesca Sonora 2017, n.d.)

1. an informal and practical approach to music is preferred over a more textual one;
2. the sound design/music should sprout from the living plant's data and mimic or evoke organic processes;
3. providing a meaningful experience is preferred over being faithful to the data;
4. the overall classroom activity should last long enough to see the plant grow;
5. the plant should be more performer and less instrument;
6. a more personal connection between a child and their plant should be encouraged.

Using sensors to gather data from the plant into a personal computer and using the computer to play the music; or detecting when the plant is being touched through action potential sensors and then playing the plant in a similar way to a MIDI controller, were not methods we thought would benefit an experience which we wanted to be sensitive and delicate: promoting a relationship where the plant is seen as an active "somebody" instead of a passive "something". Focusing the sound experience in the vase itself, strengthened the illusion that glues the sound to the plant, in a more believable coincidence. There was also the need to design a more direct relationship between the child and the plant by lessening the middleware. In other words, to make the digital technology as invisible as possible, not necessarily by the means of hiding the components better but by using the technology in a way that justifies why it is being used in the first place — like a prosthesis instead of a prop.

For all these reasons, I concluded that the flowerpot should be small, portable and as independent from any other object as much as possible. Instead of aiming for a single *Flormiga* per class for every student to interact with at the same time, I opted, at first, for one *Flormiga* per student. This individualization of the vases then motivated the downsizing of the object and the choice of a different plant than the one being used in Cant(a)eiro. However, having one flowerpot for each student to take care of also meant that a single person was fully responsible for the life and well-being of their own plant and, sometimes, plants die. Even when we take care of them in the best way we know how to. A child whose plant had died, possibly too soon to get to watch it grow, while their classmates go on with the activity with their respective healthy plants, is not a desirable outcome for the class experience, so we agreed that a better way was to distribute several vases in a "one flowerpot per desk" fashion. In grade-school level classes the number of students for desk might vary from school to school or from one class to another, but usually two students will share a desk, going up to five students. In this manner, the responsibility over the plant is shared among the students in a group or team where they cooperate to ensure the wellbeing of their "flower-friend".

3.2.1 Playing together

What we are proposing is a classroom activity in which the sonified plants are attributed to each desk in each participating classroom where, for the period of one month to a full school-term, the students tend their plants into growing healthy, while receiving a sonic feedback of that prolonged interaction. In the end, the blooming plants are brought by their respective children to perform in a concert together with a musician or dancer in the activity's grand finale.

It is important to notice that the plants' rhythm is the guide for the activity. It is not possible to force or rush a plant into growing happy and healthy and that is also the nature of this activity. Some flexibility and improvisation from the schools and teachers to accommodate and make the most out of the experience will be useful.

3.3 The plant

One of our very first challenges was the choice of the plant(s) to take part in this project. Many aspects regarding the needs of the plant, the context of a primary-school, as well as aesthetic judgments were considered.

The starting point was the *Clusia rosea* "princess" already used in Cant(a)eiro. This variety is grown indoors in pots, it is resistant, evergreen, and requires little tending. It is undoubtedly a species fit to withstand some less careful handling; it is not very prone to disease, and its size is suitable for a classroom desk. On the other hand it is not very exciting visually. The clusia grows too slowly and changes too little to be noticeable within the short period of the experience (or even within the length of a full school-year for that matter) adding to the fact that the plants look very similar to one another. The aspects that made us set the clusia aside for this project helped us narrow our choices greatly.

Figure 1: *Clusia rosea* “princess”. From [URL: https://www.hornbach.de]

A more diverse variety was then considered — the succulents. These are fleshy plants due to their ability to store water (which makes them resistant to drought) and are, as the *Clusia rosea*, resistant to rough handling. Succulent plants can be found within approximately sixty different plant families (Succulent plant, 2019), in a wide range of shapes, sizes and colors, making them a popular choice for collectors. As contenders for this project, succulents also grow too slowly, they keep healthy without any tending for long periods of time and are more vulnerable to over-watering than to lack of water. Given this, succulents are probably better off on their own which is not ideal for a short-term experience aiming to foster the bonds between human-participants and the plants.

Figure 2: Succulents

At this point in the search for a more fitting plant we figured we could certainly benefit from approaching somebody that keeps a close relationship with house or garden plants, asking for their insight. My aunt happens to be just that person, who has been talking with immense love about the plants, flowers and trees in her home garden for many years with great attention to the details and changes over the seasons and the years. I reached to her with a set of requisites for the plant:

1. the plant should be fit to be handled by children aged 5-11;
2. the plant should be able to keep healthy indoors and with *moderate* tending (not too much because the plant is left in the classroom for the weekend, but also not too little as to risk the loss of interest from the students);
3. the plant should undergo some transformation within the period of a school-term (three months at maximum);
4. the plant should fit comfortably in a small, portable vase.

Thus, a variety of bulbous flowers first came to our consideration.

Ornamental bulbs usually live more than two years with the aid of storage organs which keep the moisture and nutrients that help the plant survive harsh conditions while undergoing a dormant state[17]. Many require *vernalisation* before flowering again. This group includes flowering plants such as the amaryllis, narcissi, hyacinths, crocuses, lilies, freesias, orchids or tulips, which bloom into very distinct shapes and vivid colors. The downside being that most of these plants' bulbs are toxic and might cause nausea, vomiting and diarrhea if ingested. This requires a more thoughtful interaction, and the young participants should be taught how to properly handle their plant. All things considered, our main choice is the hyacinth (*Hyacinthus orientalis*).

[17] Under Mediterranean climate (dry summers and wetter winters) most bulbous plants are dormant during the summer, growing during the autumn, winter or spring. Bulbs native to regions with dry winters and wetter summers are typically dormant through the winter, growing in spring, summer and autumn. (Ornamental bulbous plant, 2019)

Figure 3: Hyacinth *(hyacinthus orientalis)*

Hyacinths can be easily found in flower shops or home and garden accessories retailers for under 5 euros, in bulbs or already planted in vases. They are available in colors ranging from blue, purple, pink and white to more uncommon ones like yellow, red or orange, and reach heights between 15 to 30 cm when flowering. The color variety helps with telling the plants apart from each other adding to a sense of identity and welcoming diversity. Since they are dormant during summer, the bulbs can then be stored in a cool, dark place in order to induce flowering in the following winter or spring; meaning that the project fits better either into the first (if planted in the autumn) or the second (if planted in the winter) school terms[18]. These plants undergo some significant changes starting as a simple round bulb with long white roots, then the bright green leaves begin to sprout, eventually growing into long leaf blades sheltering the yet unopened flowers which will finally bloom in a very fragrant and colorful transformation. Shortly after blooming, the hyacinth drops its flowers and the leaves dry and fall returning the plant into a bulb shape to rest for the season before restarting the cycle.

Alternately, other bulbs can be used in place of the hyacinth if they better fit the classroom's needs or mixed to add to the classroom's flower diversity. If the sonified-plant's experience occurs simultaneously in several classes, levels of primary school or even schools, different species could be assigned to each one. The *Crocus* and the *Narcissus* are good options if the

[18] The school year for primary schools in Portugal is split into three school terms: the first term starting in September and ending mid-December; the second term starting in the beginning of January, terminating by the end of March; and the third term starting in April and ending in July for summer break and the end of the school year.

hyacinth's fragrance happens to be an issue. Crocuses grow up to 10 cm tall, being shorter than both hyacinths and narcissus that can reach up to 30cm. Some varieties of *Crocus* (autumn crocus) are dormant during winter instead of summer and flower between the late summer and autumn if the school program benefits from an earlier start. A single bulb of both these species spawns a few flowers each. It should also be considered that the narcissus are just as widely available in Matosinhos and its surroundings (where the OJM and the schools within the range of its educational service are located) as the hyacinths, while crocuses are somewhat harder to come by.

Figure 4: *Crocus*

3.3.1 How to cherish your plant

Hyacinths are perennial and from their bulbs sprout the leaves and the flowers. They usually flower during Spring and they need a chill period before flowering. They enjoy slightly cold weather and their sunlight needs range from full sun to partial shade.

One may help the bulb to bloom by putting the bulb in a vase with water, just lightly touching the water, without submerging the bulb. Then the vase should be wrapped in brown paper and left in a dark and airy room for 10 weeks. This helps the bulbs produce new shoots and then the vase should be exposed to light. Another way to do this is to store the wrapped vase in the fridge for 10 weeks. After that the bulbs should remain in a dark and chilled place until the new shoots appear and the vase must be exposed to the sunlight (Leão, 2013).

Hyacinths should be watered only when the soil is dry. As many other bulbs, they are weak to overwatering. If the weather is cold and humid, the hyacinths should be watered with less frequency. Being moderate with watering might help extend the frequency of "watering" interactions.

3.4 The prosthesis

The project's hardware consists of both the circuity and the vase which encloses it as well its charging means. As mentioned, we wanted the technology to be as invisible as possible and so we have explored how to make it believable that the sound was coming from the inside of the vase, from the plant itself. We experimented to sound the vase using a transducer[19] directly in contact with the vase's material. This way the transducer functions as a speaker whose cone is the vase. The result is a strong illusion of the sound originating from the vase's interior where the plant's roots and bulb are.

In this section I make a short review of the main reasons behind the choices about the hardware and how I arrived to those conclusions. I will go into more detail about the design and construction of a prototype in the next chapter (4).

3.4.1 The vase

The vase used in Cant(a)eiro consists of a plastic cylindrical inside-vase (where the plant and soil are accommodated) inside a larger bamboo outer-vase with a square opening and flat surfaces which make it easier to support the circuitry. But to meet this project's needs we experimented with other materials.

Having the plant already picked, the size of the vase had to be at the very least large enough to accommodate the plants' deep roots and bulb and allow its growth, it should be easy to handle and, to choose its material we had to consider sturdiness, electrical conductivity and resonant proprieties. The first pick was a small galvanized steel vase (Fig.5), 8cm in diameter and 11cm height. Galvanized steel is as sturdy material that has a considerably smaller environmental impact than the plastics which are more commonly used to make pots like polypropylene (PP) or polyethylene (PE). This is also the reason why these plastics were not further considered. The galvanized steel also showed the most appealing resonant properties from all the considered materials, having crisp high and mid frequencies, clear differentiation between frequencies in this range and vibration diffusion throughout the vase's surface. It is also the most conductive material, showing the highest levels of capacitance, easily saturating[20] the capacitance sensor levels just by having a fingertip in direct contact with the vase. For this reason, I proceeded to test other materials.

[19] A speaker without a moving cone. Instead a metal rod is wrapped around with the voice coil and the magnetic field causes the metal to contract and expand.

[20] This saturation (when the values meet the sensor's maximum limit) happens because of the sensor's parasitic capacitance and its relation to the electric field's path to ground which means that, depending on the material's conductivity, the ground plane in which the vase in placed has more or less interference in its capacitance sensing levels.

Figure 5: Galvanized steel vase (from Ikea)

Clay is more fragile, significantly less conductive and also easy to find, but when trying to sound it with the transducer it sounded too flat, making it the less interesting option timbre-wise. I then moved to the other less conductive option, a glass jar. This material presented the most gradation of capacitance levels in a half a meter radius from the jar and it did not saturate immediately when touched. Glass is sturdier than clay, although it is potentially more dangerous if it were to break. Because of its material and shape, it was hard to anticipate how to accommodate the electrical components even when considering some form of appendage. Therefore, I went back to the galvanized steel vase which had the most adequate attributes and a single setback, which was the capacitance levels' saturation. To overcome this issue, I coated the vase's inside with cork, but it did not work as well as expected. So, I decided to make use of this saturation problem as a feature that could contribute to the overall experience.

3.4.2 The circuit

The electrical hardware should be able to gather data from the plant's context, generate and reproduce the music while being as autonomous and affordable enough for a school to have several *Flormiga* in each classroom. First, I considered the wide range of sensors that could be used and those which were most commonly used in other artists' similar works.

In order to avoid the handling of the plant as a tool or instrument I opted to remove those sensors which promoted harsh manipulation, such is the case of action potential or electro-galvanic sensors that sense the plant's electrical activity when touched, pressed or pinched and, if that data is sonified in real-time the feeling for the interacting participant is that themselves are producing that sound instead of feeling that the plant is producing the sound when it is touched. Nonetheless, I wanted to have some sensor that was able to represent how the plant perceives the closeness of other beings in its surroundings. I came across a soil moisture sensor that used capacitive sensing and temperature measuring instead of the most commonly used resistive sensors that use two pads and measure the conductivity between them. With this sensor we can get information with enough gradation on the presence of people around the plant and if the vase or the plant is being touched; and the sensor does not react any better or more intensely when the plant is pressed or pinched. Besides the soil moisture sensor, I used a photo-conductive cell to detect the variation of light levels. These sensors then send the data to a microprocessor board with DSP that is in charge with the real-time generation of the coded music and its analog conversion with the aid of a micro-amplifier, to be finally reproduced by a bone conductor transducer in direct contact with the vase.

In Fig.6 below, I present a chart with possible relations between the plant's environmental or external stimuli and the sensor(s) that could be used for detection.

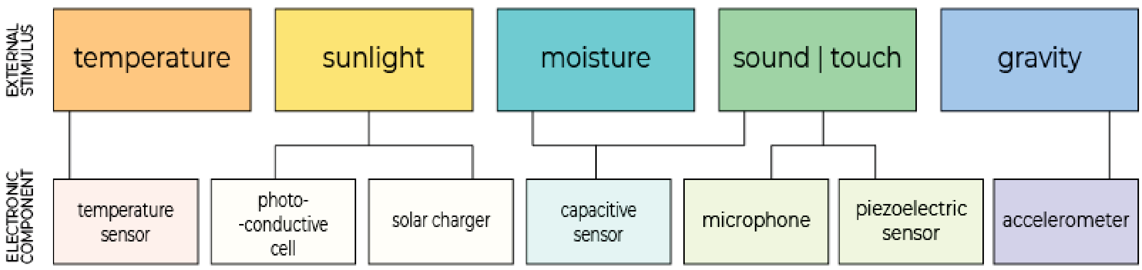

Figure 6: Stimulus to sensor possibilities

3.5 The piece

I already had a vague idea of what a plant would sing *about*. I imagined that, much like a human person, a plant would like to talk about the changes in their surroundings.

I was then left with the question "what would a plant's voice *sound like*?".

I have started by casually approaching colleagues, friends and family with this question, expecting some variety of answers and vocalizations, only to find that in the imaginary of those who were willing to try and imagine, plant's voices sound much like other elements from nature such as birds singing or "the wind", that is — the sound of leaves rustling in the wind.

On the other hand, the literature review made me aware that in most artistic sound projects where the plant is a performer, the most commonly used methodology is the sonification of the data obtained from the sensors, with little to no sound design intervention. This was an approach

I wanted to avoid, believing this kind of data sonification to be less effective in the translation of the plant's senses, time, states, or in boosting affection, than using the very same data but in a sound design fashion. Nevertheless, these compositions could easily be synthetized and electronic sounding. Since plants do not vocalize, there is no comparison in nature, thus my effort should be on making sound *believable*, instead of *realistic*. Furthermore, faithful data sonification in itself was not providing any meaning about or making any sense out of the plant's response to the numerous stimuli. The task at hand became choosing how to better use the data provided from the plant's context.

These were artistic, aesthetic and sometimes deeply personal choices. Yet, with very clear goals while acknowledging that designing the sound for this project would be, to a large extent, to design the interaction between the children and the plants.

The sound compositions were named the *Roots*, the *Leaves* and the *Flower*. In this chapter I go through the conceptual development of the sound design and ensuing interaction, and in chapter 4.2 Sound Design I explain its implementation.

3.5.1 Generative sound design

All things considered, the plant's sound should be generative, procedural and interactive. The system was to be assigned a series of conditions for it to autonomously generate, in real time, the sound/music composition. This decision was strongly motivated by its similarity to organic processes which are, by nature, generative and evolutive in opposition to being designed or engineered (Toop, 2004).

In the universe of programming, concepts such as "seed", "genetic algorithm" or "fitness function" are deeply rooted in natural processes. Accordingly, *Flormiga*'s music, like the plant itself, should grow over time and attempt to better translate what we understand as the "pace of plants" — whose slow rhythm is the main reason for the generalized idea that plants are static beings — to the "pace of people" and maybe instigate some reflection on the latter. Real-time sound generation also allows for a better management of the digital resources while working with limited storage in order to reduce the object's size.

3.5.2 Genetics

I have gathered some inspiration for this project from the field of biology, more specifically from genetics. Genetics is not an uncommon theme in children's media and entertainment. Videogames, like *Pokémon*, focus around notions of evolution, mutation, impact of genetics on personality, heredity, sexual dimorphism, ecotypes, etc. Some of these ideas bring variety and a sense of individual, enriching the experience.

It made sense to me, that the plant's music would appear like any other genotype's expression, following similar rules. Usually, the phenotype is defined as the observable traits or characteristics resulting from the interaction between genotype and environment (Science Learning Hub – Pokapū Akoranga Pūtaiao, 2011) as can be more easily understood by the following relationship:

$$\text{genotype (G)} + \text{environment (E)} \rightarrow \text{phenotype (P)}$$

Thus, the approach should be one that depicts the audible sonic result as a phenotype, i.e, as an observable manifestation of the plant's "sonic genes". However, the hereditary quality of the genotype is not mirrored in this work since it does not add to the overall experience. The plant's "sonic genotype" is then generated stochastically at the start or reset of the activity, when the children get their companion *Flormiga*. Those "traits" are fixed for the duration of the activity.

About the environment: in nature, the influence of the environment in the phenotype is usually observable in the long run, whereas in this activity, since it is short-termed, the environmental factors have a much more immediate and noticeable effect, whilst not disregarding longer-term consequences, in order to promote the good tending of the plant.

The genetic make-up differences between each *Flormiga* also serves the purpose of strengthening the bond between the child and their plant, enabling the former to tell their flower-friend apart from all others increasingly better with time and interaction or appreciate the similarities and differences between the plants and how those might change over time.

Bearing all this in mind, I am left with the task of finding a harmonious way to match these genetics-inspired processes with musical or sound concepts. The first idea emerging was the creation of "personality types" that lead to different sonic expressions or limit the range of the stochastic possibilities. In this way, even with a very limited quantity of "personality types" the many *Flormiga* could express sonically in somewhat different ways.

The following figure shows the relation between the elements of the sound design as inspired by the genetics' concepts.

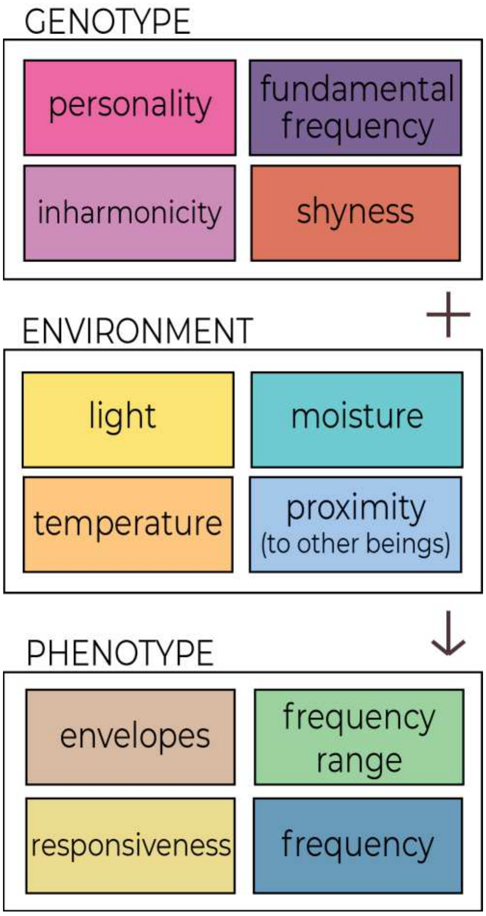

Figure 7: Genetics of the sonified plant

3.5.2.1 Personality

I envisioned three different personality-types for the sonified plants, I have named them: **Bold**, **Timid** and **Impish**.

Personalities are related to inaudible factors and probabilities (responsiveness), like the **shyness** which I will describe in more detail ahead (3.5.3.1 Shyness, Heart and Growth) — and audible factors such as the sound's envelopes and amplitude. Personalities limit the range of **shyness** levels, which means that, two plants with the same personality-type might have slightly different **shyness** levels, and also that there is a chance of different-type plants having similar ones. Thus, these personalities would not be immediately perceivable, but instead acknowledged with continued interaction.

In concept, **Bold**-types are the most responsive to interaction and physical contact. They are more communicative and answer harshly. Their envelopes are abrupt, with quick attack and little sustain. **Timid**-types respond more gently and moderately. They have less probability to respond to touch and their envelopes are flatter. Finally, **Impish**-types have steeper envelopes and might respond unpredictably. Their **shyness** range is wider and, because of that, they might sometimes seem either **Bold** or **Timid**.

3.5.2.2 Body states

Body states relate to the ever-changing conditions of the sonified plant. They are discrete, "artificial, momentary slice[s] of life, indicating what was going on in the various organs (…)" during a defined time window (Damásio A. R., 1994, p. 87). These states are revealed by immediate sonorous exteriorizations in the face of external stimuli. We could think about it as "visceral reactions", were the plants to have viscera. In essence, this means the *Flormiga* "feels" when it is being watered; when it becomes sunny after dark; when its leaves are gently caressed; when its vase is rubbed; when the temperature raises or decreases; when its friends are whistling and waiting for an answer. This is where most of the playing opportunities arise.

Two environmental factors are fundamental for almost every (not-necessarily-sonified) plant's development: water and sunlight. Abundant water, but not too much to avoid damaging the plant by overwatering, and all the sunlight the plant can get indoors, are welcome. Hyacinths, the favored plant for this activity, appreciate full sun to partial shade.

For the children to be aware of their impact, the plant performs as soon as it is watered,only *if* it was thirsty before. I have named this sound composition the "Roots". It has a crackling, chewy quality that suggests that the plant's roots are moving and twisting inside the flowerpot, as if looking for the just-poured water in the soil. Secondly, in 30 minute intervals, the *Flormiga* sings about the temperature without the need for any kind of incentive. This sound composition is called "Leaves". It is made up of a central frequency which is the temperature in degrees Celsius (ºC), scaled up to a higher frequency. It has a soft amplitude modulation, inspired by birds' singing abilities, as was suggested by colleagues and friends. This particular singing reaction, can also be triggered by interaction: by whistling, more specifically. A child might attempt to whistle at the same frequency of the scaled temperature degrees, i.e., at the same frequency the plant perceives the temperature at that given moment. If successful, the plant will sing back the same frequency note.

3.5.2.3 To sing and to laugh

On my last anniversary, while already developing this dissertation, I went to an electroacoustic music concert. In one of the compositions, which featured no human voices whatsoever, I have noticed what I believe was a synthetic/digital sound which had a "laughing" quality to it. At that moment I could not precisely describe what was it that felt "laughy" about that particular sound. I still can't; I think, mostly because I can no longer quite remember the sound anymore. But I have since attempted to mimic that sound object's quality that has contaminated *me* with laughter at the time.

I wondered if perceiving "laughter" in another beings, living or inanimate, was somehow similar to the ability to recognize faces in images or random patterns — a pareidolia[21]. And if so, how could I bring about that affordance to the sonified plant, therefore enabling the plant with the power to *start* a very simple and very honest interaction.

Using the same base frequency as the "Leaves", based on the temperature, the plant is able **to laugh** when it is exposed to sunlight after being kept in the dark for a short while. Thus, **to laugh** is an indicator of happiness and enthusiasm, an essential element for playing and mechanism that enables, for example, a peekaboo kind of game.

Besides singing and laughing, the *Flormiga* is also ticklish. This happens when the vase is "tickled" and the plant answers with the "Roots" composition.

Finally, when the plant's body (specially its leaves) is softly caressed, the *Flormiga* might sing its "Flower" melody as a token of gratitude. The responsiveness to this kind of interaction is nonetheless dependent on other factors related to personality-type, **heart** and **shyness**. Enabling the *Flormiga* to refuse answering.

3.5.3 Memories and affection

A significant relationship can only be built over feelings of empathy. Conditions like voluntary participation, reciprocity and willingness, among others, play an essential role on building this empathy and providing meaning to the interactions between two beings (Penha, 2015). Memories are also a fundamental factor for humans to recognize in others what Damásio (1999) calls extended consciousness[22] and a sense of identity.

To embed this sense of *self* I had to conjure an illusion of memory and consciousness into the sonified plant. I have made this by endowing the plants with "feelings" of restraint (**shyness**) and courage (**heart**) and the ability to "grow" over time (**growth**).

At the very start of the school activity, when to each desk and group of children a sonic-plant *Flormiga* is attributed, the following individual features are stochastically determined: (1) personality-type, (2) shyness level, (3) fundamental frequency, and (4) inharmonicity[23] level.

From the fundamental frequency, a melody is generated — I will call the melody "Flower". The choice of a song based on the harmonic series has to do with the fact that the partials are

[21] Pareidolia (a type of Apophenia) is a psychological tendency to interpret a vague stimulus (like an image or a sound) as something known or meaningful to the observer.

[22] In his book "The Feeling of What Happens", António Damásio states the inextricable connection between consciousness and emotion and presents a theory of consciousness divided into three layers: (1) the **protoself**: a basic level of awareness or a non-conscious level; (2) the **core consciousness**: a simple biological phenomenon, where the organism becomes aware of feelings and is provided with a sense of *self*, but also where there is no time but the present moment, and not place but the one it is in; and (3) the **extended consciousness:** a complex biological phenomenon, which has many levels and provides a complex sense of *self* and identity in a specific point in time, as well as a sense of a lived past and foreseeable future; extended consciousness relies of conventional and operational memories and, according to the author, is only available, in a higher level, to human beings.

[23] **Inharmonicity** is the deviation of the frequencies of the harmonics from the exact multiples of the fundamental (Berg, 2019).

naturally occurring phenomena and musical training is not necessary to recognize partials as belonging together. This happens because every musical note is usually perceived as a single sound albeit being composed by many partials, with different strengths.

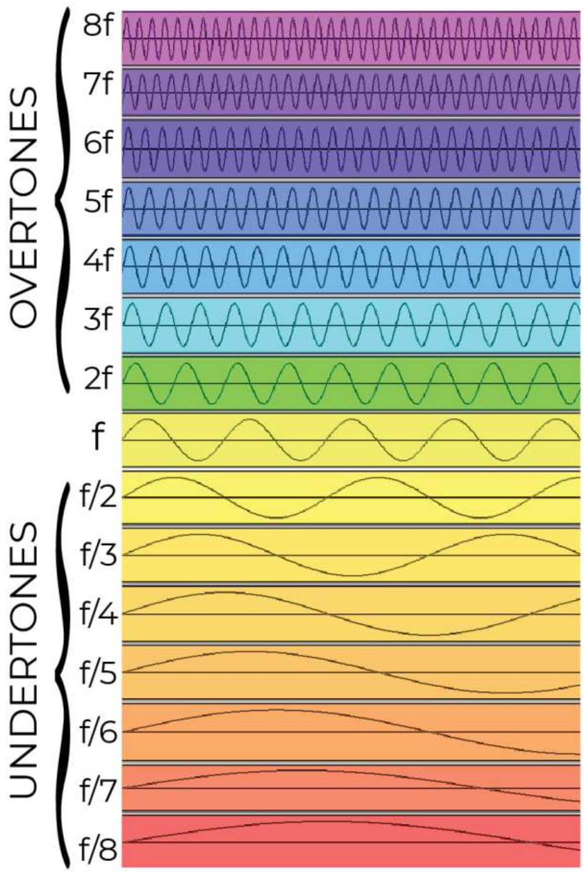

Figure 8: Frequency ratios of harmonics (overtones) and subharmonics (undertones). (f) fundamental.

The “Flower” is made up of the fundamental frequency (f), its overtones[24] (up to 8th overtone, excluding the 7th), and its undertones[25] (down to the 8th undertone, excluding the 7th).

The overtones, excluding the octaves (3f, 5f and 6f) are tuned with the sunlight, in real time. When exposed to enough light, these overtones become tuned, otherwise they will become out of tune to a varying degree. The undertones, excluding the octaves (f/3, f/5 and f/6) have a similar behavior. Being tuned by the soil’s moisture.

The harmonic and subharmonic octaves (2f, 4f, 8f, f/2, f/4 and f/8) become harmonized in a longer term by the growth factor, which I will explain next.

[24] **Overtones** or harmonics, are integer multiples above the fundamental frequency.
[25] **Undertones** or subharmonics, are integer submultiples of the fundamental frequency.

3.5.3.1 Shyness. Heart and Growth

Growth is the chance of reducing the inharmonicity level of the octaves[26] (harmonics 2f, 4f and 8f and subharmonics f/2, f/4 and f/8) which is updated every day and might be accelerated with the proper tending of the plant. Meaning that, a plant that is kept well hydrated and receives enough sunlight has a higher probability of harmonizing the octaves in its melody. The remaining harmonics and subharmonics are tuned or detuned by immediate factors, or states, as we have seen before.

So, *when does a* Flormiga *sing its melody?*

I conceived two probabilistic factors that determine when plant sings — the **heart** and the **shyness**. Together they make up the *Flormiga*'s initiative.

The **heart** feature is inspired by the multiple different interpretations of japanese words sounding the same as heart[27], such as the words for attempt[28] and resolution[29]. It is a simple system that represents the plant's "will to sing" and it determines the minimum amount of time between each time the plant sings. Proper tending also affects the plant's **heart**, rewarding the listeners with shorter minimum waiting times for the "Flower" song. Yet, this "will" does not always translate into an actual performance of the song. The *Flormiga* might be restrained by its **shyness**.

The **shyness** is the level of inhibition, or restraint of the sonic plant. It is the last factor when deciding if the plant *actually* sings when willing to. As mentioned above, **shyness** is fixed feature that is linked to the personality-type. E.g. a bold plant, which has probably little shyness will sing more frequently than a timid plant, which has probably higher shyness, despite having the same **heart**. Notwithstanding, a plant with high **shyness** that was well tended the day before, might sing more frequently.

3.5.3.2 Rewards

Going back to the idea of memory. To assist with the translation from the "pace of plants" to the "pace of people", positive interaction (watering the plant, keeping the plant in a sunny place) affects the music in both short and long terms separately.

The long-term effects consist of the harmonization of the melody's main frequency's octaves, as described in the section (3.5.3.1).

The short-term effects are shaped as daily rewards. Rewards are, in essence, a point-attribution system. A day passing by grants 1 point; a day the plant is watered and kept well

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[26] Octaves are notes related by factors of two, i.e., notes with different pitch bit in the same pitch class.

[27] Noun. Kanji: 心. Kana: こころ. Romanization: **kokoro**. Meaning: heart; mind. (From the online dictionary jisho.org)

[28] Noun. Kanji: 試み. Kana: こころみ. Romanization: **kokoro**mi. Meaning: (1) attempt; trial; experiment; (2) effort, initiative. (From the online dictionary jisho.org)

[29] Noun. Kanji: 志ざ. Kana: こころざし. Romanization: **kokoro**zashi. Meaning: (1) will; resolution; intention; (2) kindness; kind offer; (3) gift (as a token of gratitude). (From the online dictionary jisho.org)

hydrated most of the time grants 1 point; a day the plant is abundantly exposed to the sun grants 1 point. This means that, every day, the plant is able to gather from 1 up to 3 reward points.

These points impact: the **heart**, in the short run — more points translate into the plant "wanting" to sing more often the next day; and **growth**, in the long run — more points translate into a higher chance of harmonizing the octaves.

4. A Flower Friend – Part II

I would like to begin this chapter by talking about *littleness*.

The idea of *littleness* has accompanied all the aspects of the development of flower-friend prototype. A tiny vase, micro components, a little flower, a faint voice.

It came to me while I was visiting a photography exhibition where I came across a work consisting of about a dozen pictures. All of which depicted living beings, despite some of them not being alive anymore. About half the photographs in that series were particularly small, either when compared to the other pictures in the same series or the other pictures in the exhibition. These tiny elements were not easily perceivable at the distance I was keeping from the walls throughout the visit.

It was in the act of leaning closer to inspect a small photograph, that depicted a sprouting seed emerging from the ground, that I fully realized how littleness asks for gentleness.

In the sections below, I describe thoroughly how a prototype of a sonified interactive plant was put together. It is the turning to matter of the ideas presented in the last chapter.

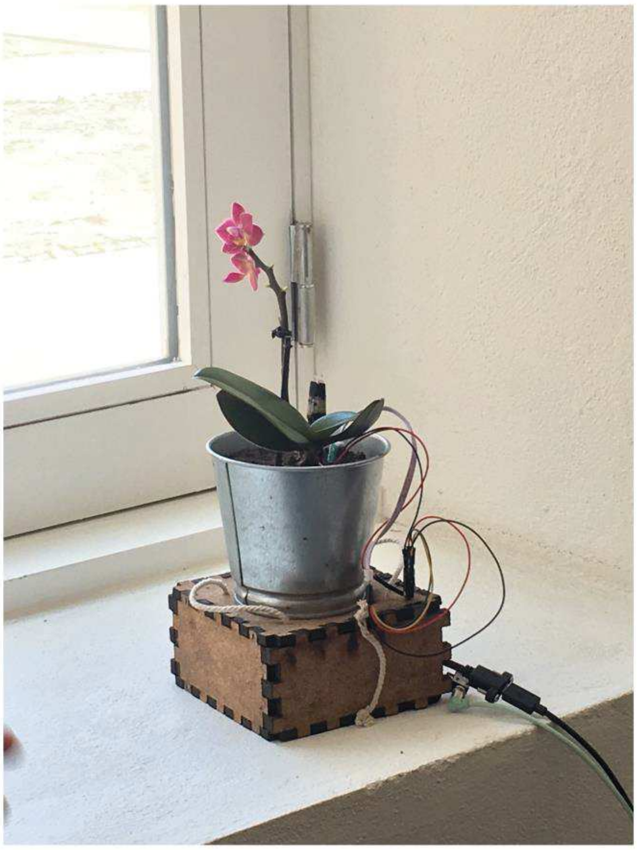

Figure 9: *Flormiga* — a flower-friend prototype.

4.1 Electronics

In this project, the electronic hardware's task is to obtain data from the plant's environment, to process that information and feed it to a sound generation system and make the sound play directly on the vase. To build this prototype I gathered sensors, a microprocessor, a transducer and a laptop.

The smallest possible components were selected and connected in a half-breadboard for testing. Its small size made it possible to enclose the whole circuit, except the cables connecting to the sensors, in a small base container.

4.1.1 Input

Input-wise, I used:

- a soil moisture capacitive sensor[30], which detects capacitance and temperature;
- a photo-conductive cell (CdS photoresist tor)[31], which detects brightness;
- a microphone, part of a TRRS phone connector (3.5mm audio jack).

A range finder sensor was also considered, but it was made unnecessary by the capacitance detection.

4.1.1.1 Soil moisture and proximity

On the other hand, the capacitive sensor became a tricky ingredient in the electronics recipe. When the soil is moist, it barely detects any other elements in the vase's surroundings. When the soil is fully dry, it is extremely sensitive and saturates rapidly. The capacitance value was of great importance since it relates not only to when the plant is watered but also to when it is touched and if not used sensibly, this value could encourage the users to press the plant harder. I tried solving this issue testing out other materials for the base, as I mentioned in chapter 3.4.1, and also by coating the vase's interior with a 6mm thick cork sheet. But none of these solutions were satisfying, so I ended up getting around the problem with programming.

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[30] Adafruit STEMMA Soil Sensor: https://learn.adafruit.com/adafruit-stemma-soil-sensor-i2c-capacitive-moisture-sensor

[31] Photo cell (CdS photoresistor): https://www.adafruit.com/product/161

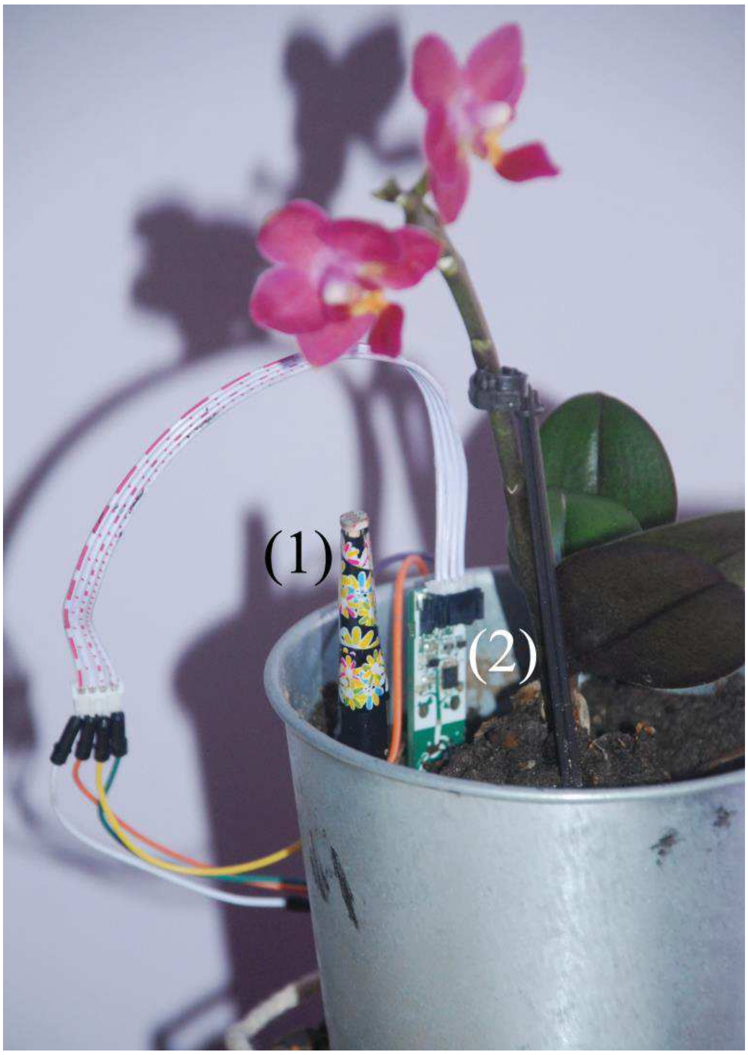

Figure 10: Detail. (1) photo-conductive cell; (2) soil moisture sensor.

4.1.1.2 Light

The light detecting photo-conductive cell is a type of resistor that changes its value depending on how much light it is exposed to. To scale its voltage values, in order to fit the projects' needs, a 10KΩ resistor was added in its path to the microprocessor. This component was placed near the soil moisture sensor, secured by a popsicle stick and insulating tape. It is important for the photo-conductive cell to remain uncovered as exposed to the room light as possible.

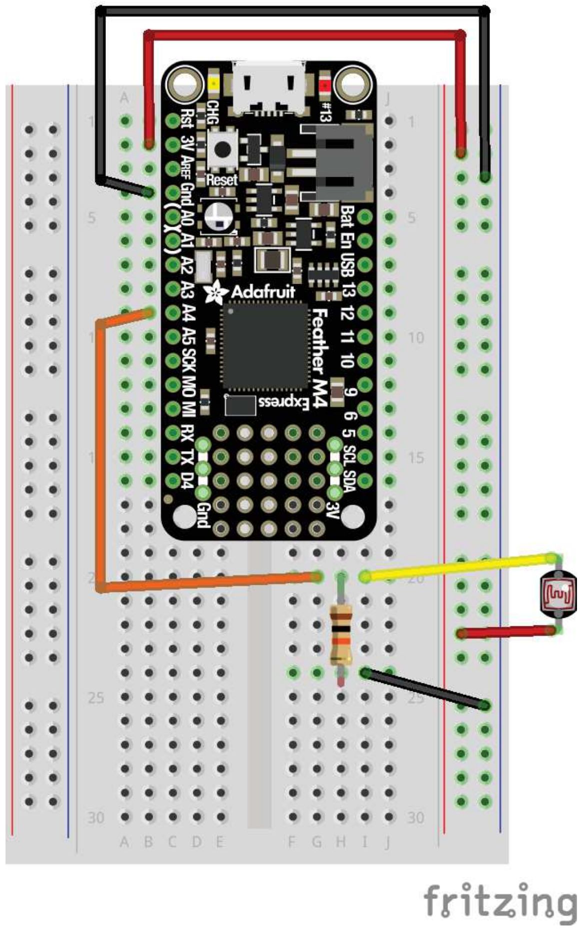

Figure 11: Photo-conductive cell to microprocessor path.

4.1.1.3 Sound

The microphone appeared later on the prototype's development. As a result of the need to connect the microprocessor to a computer, where the sound was being generated as I will explain next (4.1.2), I used a phone connector cable (TRRS) which has a microphone. This enabled the testing of the microphone functionalities, which can be later adapted, using a tiny electret microphone.

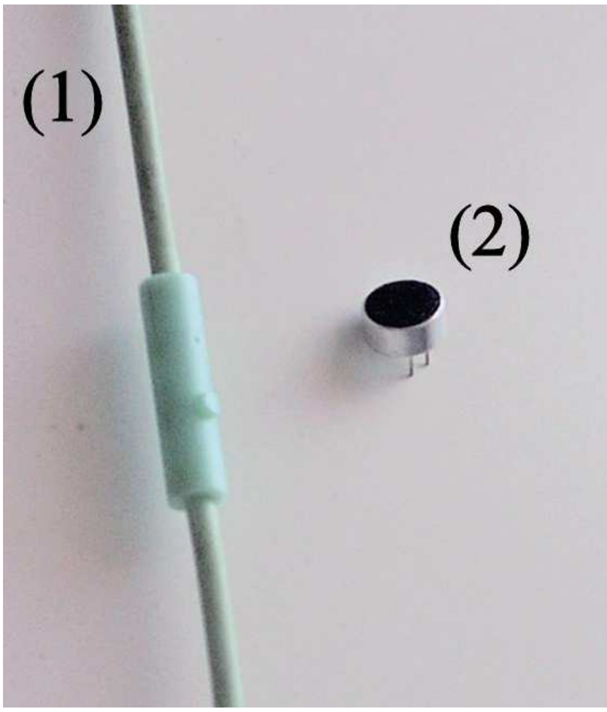

Figure 12: (1) Microphone from a phone connector (TRRS, 3.5mm audio jack); (2) Electret microphone.

4.1.2 Core

For this prototype I used software Max/Msp to program and design the sound, bearing in mind the limitations of the microprocessor development board[32], which is powered by an ATSAMD51J19 chip with a 120MHz Cortex M4. This board works with the Arduino language, which is a simplification of C/C++; or CircuitPython, which is a simplification of Python. In Max/Msp, the patch was built with this future translation in mind.

On account of some early communication difficulties between the microprocessor and the software, I developed a series of sensor simulators by observing their behavior through an IDE while connected. Since then I have been able to connect the microprocessor to Max/Msp through serial port. Nevertheless, the simulators continued to be useful for sound design testing without needing to connect to the circuit albeit not being possible to test the interaction in real-time. Furthermore, even if the circuit is connected through serial port, the simulator enables a preview of the *Flormiga*'s **growth** function, as we can simulate the passing of the days.

[32] Adafruit Feather M4 Express: https://learn.adafruit.com/adafruit-feather-m4-express-atsamd51/overview

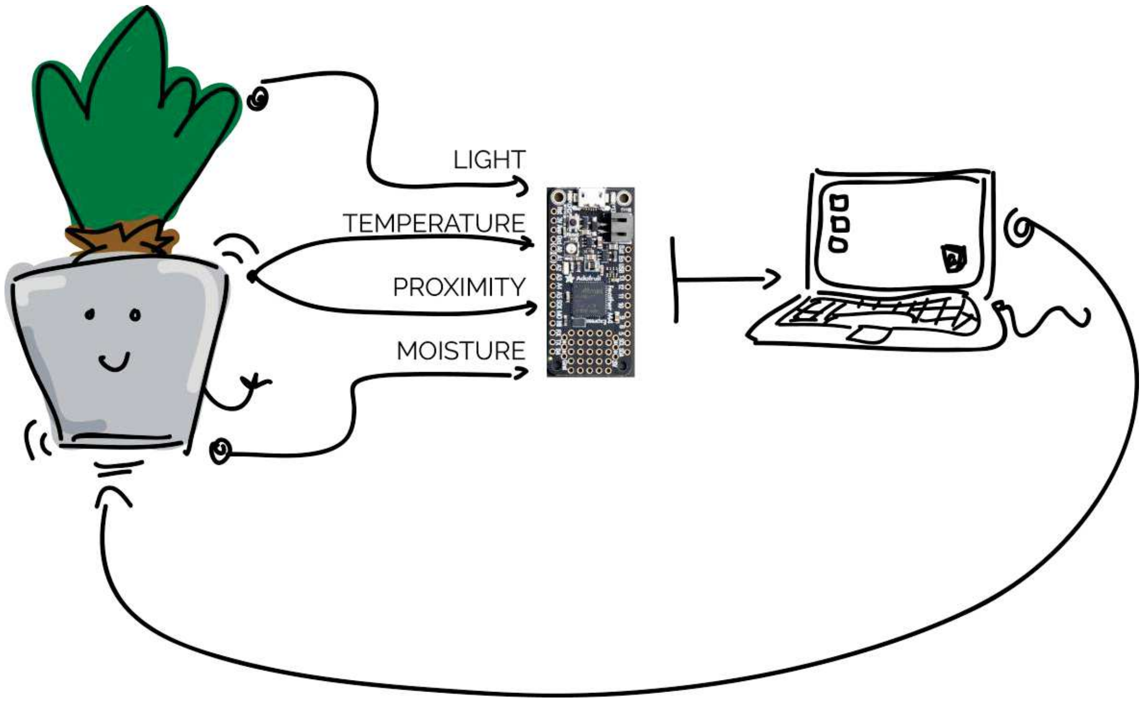

Figure 13: Prototype scheme — The sensors in the plant send data to the microcrontroller which then sends the data to the computer software via serial port. The sound is generated in Max/Msp and played in the surface of the vase with a transducer.

4.1.3 Output

The microprocessor gathers the data from the sensors then sending it through serial port to software Max/Msp in a computer where the sound generation based those values happens. The sound is then sent, via an audio cable (a phone connector 3.5mm audio jack in this case) into a microamplifier and is then played by the vibration of a transducer on the surface of the steel vase.

4.1.3.1 Amplifier

To amplify the signal coming from the computer, or the microprocessor, into the transducer, a small amplifier was used. Although the transducer is only able to play monophonic signal, I used a stereo amplifier[33] in this project, which is able to receive analog signal from an audio cable. In a future prototype, when the computer connection is not needed, a mono digital audio amplifier[34] should be considered.

[33] Stereo 3.7W Class D Audio Amplifier: https://learn.adafruit.com/stereo-3-7w-class-d-audio-amplifier
[34] Adafruit MAX98357 I2S Class-D Mono Amp: https://learn.adafruit.com/adafruit-max98357-i2s-class-d-mono-amp/overview

4.1.3.2 Tranducer

The transducer is a kind of speaker without the cone. Here, the steel vase becomes the cone of the speaker. I experimented at first with a large sized surface transducer, which sounded wonderfully but was too big for this project. So I went to get a bone conductor transducer[35], which is surprisingly small and light, and as a result of the coil's magnetic field, it is attracted to the vase's surface without the need of any extra pieces.

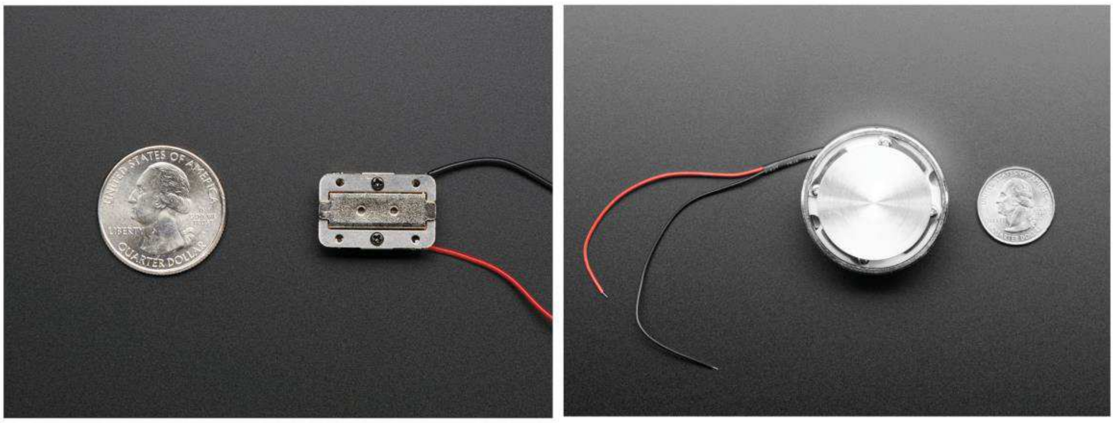

Figure 14: Transducer size comparison: (left) bone conductor transducer; (right) large size transducer. From [URL: https://www.adafruit.com]

4.1.4 Power

To support the energy needs I used a lithium-polymer (Li-Pol) 3.7V 1200 mAh battery that should be charged through a solar panel when the vase is not in use. At the beginning, I imagined that a small solar panel could be attached to the vase permanently, gathering energy to the battery at all times. But for the project's energy requirements this is an unviable solution. We would need to find some way to attach a panel too large for the vase's small size at the right angle of incidence for the sunlight to properly reach it and even considering a flexible solar panel we still would not meet the flowerpot's daily requirements. Thus, I opted to charge the flowerpot's circuit using an external 5V 12000 mAh solar power bank that can either be solar or electrically charged if need be, preserving the idea of a solar-powered object while ensuring the activity's performance by allowing charging through more reliable means. The *Flormiga*'s sunlight detection remains, however, independent from its power supplies.

[35] Bone Conductor Transducer: https://www.adafruit.com/product/1674

Figure 15: Solar power bank (top view)

4.1.5 Schematics

The list below depicts the circuit which was used in this first prototype. It uses of the following components:

- Adafruit Feather M4 Express;
- Adafruit STEMMA Soil Sensor;
- Adafruit Stereo 3.7W Class D Audio Amplifier;
- Photo-conductive cell;
- 3.5mm stereo headphone jack;
- 10KΩ resistor;
- Bone conductor transducer;
- Li-poly 3.7V 1200mAh battery (JTS connector);
- A laptop with software Max/Msp.

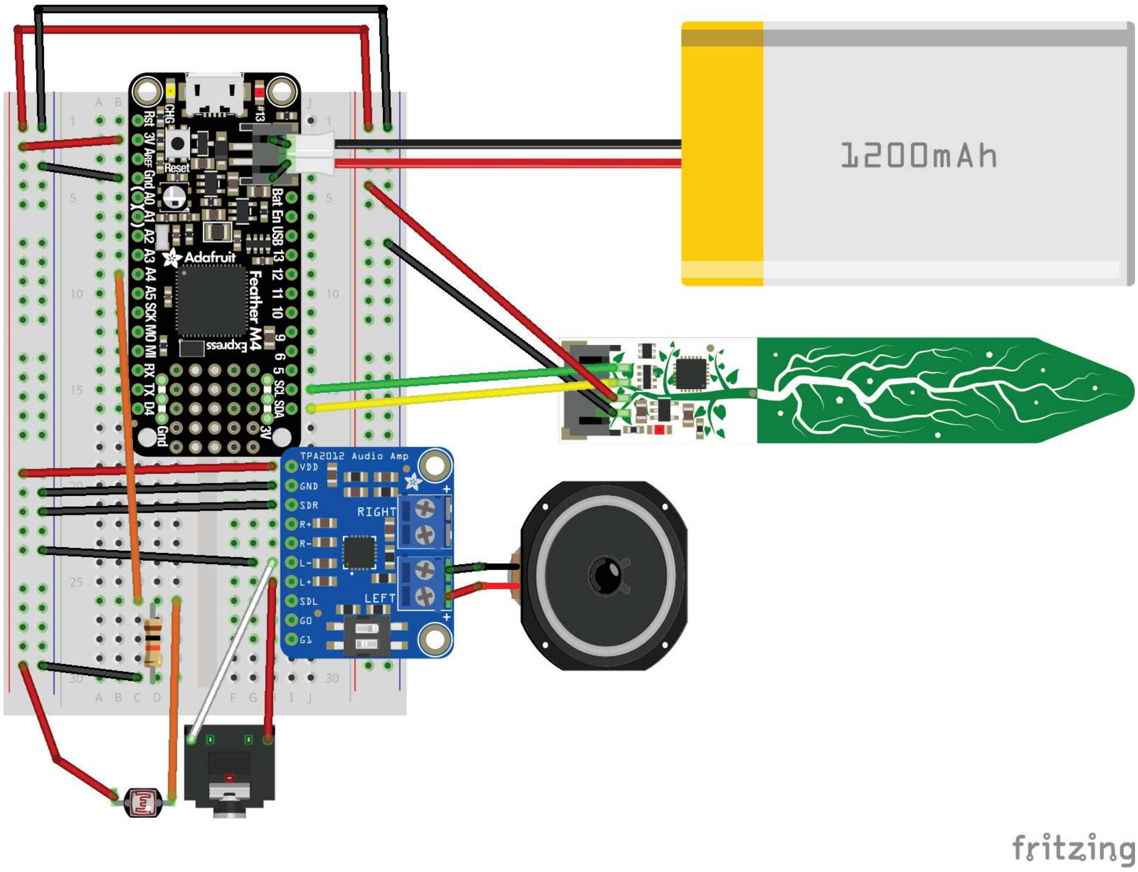

Figure 16: Circuit Schematics — as was used in this prototype, where the sound generation happens in the computer software. A speaker is depicted in place of bone conductor transducer.

4.2 Sound design

As explained above, the sound design for this project was created and programmed in software Max/Msp. The Max patch[36] is fed with the data from the sensors installed in the plant's context.

The resonant proprieties of the galvanized steel vase, that present crisp high and mid frequencies, also turned some other frequencies hard to tame. The composition's sonic output, when played through the laptop's speaker or through headphones is completely different from the sonic output achieved through transducer + vase combination, this sometimes called for fine adjustments.

[36] The Flormiga Max Patch is avaliable at [URL: https://github.com/rizumirai/Flormiga].

Keeping in mind that sense of littleness, the sound output is always soft. Sometimes it might ask for silence in the surroundings or, like the small photographs, to get closer.

In the image of all organic life, the hexagrams in the Book of Changes are built from the ground up. And in the image of both, I have composed the sound design starting from the **Roots**, into the **Leaves** and arriving in the **Flower**.

4.2.1 Roots

The Roots[37] consist of crackling sounds, as if the plant's roots were turning and scrabbling inside the vase.

This composition is played when the soil is watered after being identified as dry. The capacitance levels are then scaled up to make up the main frequency that initially feeds this system. The crackling quality is achieved by repeatedly chopping off the generated sound waves before they are able to smoothly fade out.

This is also the composition that plays when the plant is "tickled". In this case, it is triggered by a sudden increase in the capacitance levels, meaning that the vase is being touched.

4.2.2 Leaves

The Leaves'[38] composition feeds off of the temperature. The temperature values are scaled to become the central note's frequency of a sawtooth wave. The scaling differs with personality, but it remains an octave of the original frequency. It has a slight amplitude modulation and separate envelopes depending on the temperature rising or decreasing (within a time window). These two envelopes are also determined by personality-type (Fig.17).

Figure 17: Personality-types and respective envelope examples.

This composition is also the foundation of the plant's "laughing"[39] sound. Which has a separate envelope (Fig.18).

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[37]*Roots* audio sample at [URL: https://soundcloud.com/rizumirai/roots/s-x7E7G].
[38]*Leaves* audio sample at [URL: https://soundcloud.com/rizumirai/leaves/s-XFmh5].
[39]*Laugh* audio samples at [URL: https://soundcloud.com/rizumirai/laugh-001/s-P7kRh] and [URL: https://soundcloud.com/rizumirai/laugh-002/s-wUknd].

Figure 18: Laugh envelopes for each personality-type.

4.2.3 Flower

The Flower[40] is a melody made up of a central fundamental frequency and its harmonics and subharmonics, adding up to 13 notes, as I described in chapter (3.5.3). It might play by the system's initiative, or by gently caressing the plant's body. Which the system understands as a very slight and momentaneous increase in capacitance within a short time window. The probability of actually playing the melody with interaction is also dependent on the **shyness** and **heart** factors, as described in chapter (3.5.3.1).

The sequence is the same every time: the fundamental frequency rings throughout the piece, as a single breath; followed sequentially by harmonics f/2, 8f, 3f, f/6, f/4, f/5, 5f, 4f, 6f, f/3, f/8 and 2f. The rhythm is determined by determining the time interval between the triggering of the fundamental and the second note; a random choice between 300ms to 700ms, which is then multiplied by integers up to 12 to determine the period between each note. This rhythm is picked every time the Flower is to be played.

To these algorithmically determined partials, a degree of inharmonicity is added, which can be altered by immediate or long-term factors, like **growth**. This is done with the implementation of a comb filter with feedforward and feedback delay control. The fundamental becomes a triangular wave's center frequency which then has its depth and rate modulated by the external conditions (moisture, sunlight, growth). By connecting the depth and rate modulations together the inharmonicity is emphasized by a beating of the note.

The triangular waves were picked because they are less prone to harmonic distortion when played on these conditions.

4.3 Flowerpot design

I approached this challenge with an ecological mindset, determined to avoid producing waste as much as possible. I was offered a couple of cork sheets to test the capacitance variation. I ended up using the remaining cork crafting the enclosure for the circuitry.

[40] *Flower* audio samples at [URL: https://soundcloud.com/rizumirai/flower-001/s-mTT92] and [URL: https://soundcloud.com/rizumirai/flower-002/s-Ed2oS].

I would like to point out how cork is an incredibly versatile material. It is impermeable, (fire) resistant, elastic, biodegradable and its production is environmentally sustainable. Furthermore, more than half of the world's production of cork comes from Portugal. For all these reasons, cork is also a material to be considered for future prototypes.

I made yet again the effort to make this object as small as possible, whilst being large enough to accommodate the breadboard with the circuit and in the future, the smaller final PCB.

The circuit's cork enclosure is parallelipedical, made of 6 pieces that are held together by a "teeth" system (see Appendix A) and secured by adhesive and long thin nails that penetrate the cork, easily making little damage. The laser cut cork pieces can be easily and accurately reproduced any number of times. On one of the four lateral pieces a rope was set in order to mark it as the piece to be removed when there is the need to open the enclosure for circuit maintenance.

In the top piece (Appendix A), a circular whole assures the contact between the transducer and the vase's steel bottom. The vase is then held to the cork enclosure with the aid of a couple of magnets. In opposite sides in that same piece, cotton rope handles were placed. These are secured to the piece with simple knots. The handles favor a certain way of transporting the *Flormiga* when necessary. The cables connecting the soil moisture and light sensors to the breadboard pass through a narrow aperture in this top piece.

5. Future work

This dissertation addressed an artistic proposal to strengthen the bonds between grade-schoolers and nature. Believing that this could be achieved by providing meaningful experiences through play, a sonic and interactive approach to materialize the "voice" of the plants that were to temporarily belong to the classroom and school environments was followed.

Many plant-related sound artworks were observed as well as the relationship artists maintain with plants and their efforts to bring the secret vegetal world into the realm of humans. Still, an approach to a school context and younger audience was lacking.

These sound works follow two main trends: the ones that are made for, or dedicated to plants — where the plant is the listener — and the ones that are made by or with plants — where the plant is the performer. However, these categories often overlap.

The project developed together with this dissertation could be classified as a sonified performer plant, which I have named *Flormiga*.

In the beginning of this research I thought I was entering a somewhat environmentalist endeavor. I then realized that this dissertation's range of actions was much smaller and narrower; that I could only act on the particular relationship a child maintains with their flower-friend, and the relationship two or more children can establish by sharing responsibility over this friend in common.

I also figured that by designing the sound I was also designing interaction by providing cues on how and when to approach a plant; how to behave in their presence. I thought that, maybe, by designing this interaction with a special plant in the classroom I could also impact the way the children interact with all other "not sonified" plants.

So this work is, in essence, about creating meaning. Thus, I decided early on that providing a meaningful experience was preferred over being faithful to the data.

In the process, I was faced with some important questions: "what would a plant sing about?", "what would a singing plant sound like?". By diving into these questions, I figured that plants might enjoy singing about the changes on their surroundings and that the sound — the main challenge of this dissertation — could easily be synthesized. Since there is no comparison in nature, it was a matter of making it believe and not about being realistic.

The sound design is fully generative, as a result of my belief that the similarity to organic process emphasizes what is happening with the plant. In this manner, I have composed an evolutive, interactive sound system while prototyping the *Flormiga*'s hardware.

5.1 Near-future work

In the future we will take the *Flormiga* to schools and learn more from the children's interactions. Our aim being to provide a flower-friend, per desk in classroom in as many schools as we are able to reach and plan and program some new sound interactions between the plants too. In the end of each activity's period, have a *flowerchestra*, bringing the "grown" sonic plants, the schools and Orquestra Jazz de Matosinhos musicians together.

To take the *Flormiga* to that scale we need to design and fabricate the final PCB's.

The charging means are a much complex issue that I originally thought and I have envisioned a possibility for wireless charging. An outdoors solar panel charging base where the plants could "rest" and charge every day after playing with the children.

5.2 What might the plants learn from the children?

I presented this dissertation in the 21st International Conference Consciousness Reframed whose theme this year was "Sentient States: Bio-mind and Tecnho-nature".

In the end of my presentation I was asked the following question, "[we can imagine what the children can learn from plants but,] *what do you think the plants might learn from the children?*". At that moment I simply answered "patience", imagining the enthusiastic first contact with touching, lots of moving around and a little too much watering. But this question can also take us to a far-off future. Philosophical movements like Transhumanism, have been expanding our notions of the body and the human condition by arguing favorably about the transformation and enhancement of the body and mind with the aid of technology. In this work, I developed a sonic prosthesis for a plant. Sessile beings have not evolved to vocalize, so we might assume that vocalizing brings *them* no evolutional advantage. But *what if…*

What if the plants somehow learn to communicate to humans? What will they tell us? Will we *listen*? Will we be able to understand them? And if so, how will that change our lives and their lives? What if they are able to communicate what is "hurting"? Will that translate into better survival chances for the plants? Maybe in that kind of future the learning between the species becomes bi-directional.

6. References

(n.d.). Retrieved June 13, 2019, from Adafruit: https://www.adafruit.com

Abram, D. (1997). *The Spell of the Sensuous — Perception and Language in a More-Than-Human World.* New York: Vintage Books.

Andre, M. (2015). zu staub [Recorded by Ensemble Dal Niente]. New York, DiMenna Center for Classical Music: Ernst von Siemens Music Foundation. Retrieved from https://www.youtube.com/watch?v=oYKR7CGDbHg

Ann Chase — A Chant For Your Plants. (n.d.). Retrieved February 5, 2019, from Discogs: https://www.discogs.com/fr/Ann-Chase-A-Chant-For-Your-Plants/release/5752567

Attali, J. (1985). *Noise: The Political Economy of Music.* (B. Massumi, Trans.) Minneapolis, USA: University of Minnesota Press.

Barclay, L. (2013). Sonic ecologies: Exploring the agency of soundscapes in ecological crisis. *Soundscape The journal of Acoustic Ecology*, 12(1).

Barclay, L. (2015, March). *Biosphere Soundscapes*. Retrieved from Biosphere Soundscapes: http://www.biospheresoundscapes.org/the-project.html

Berg, R. E. (2019, March 6). *Sound*. (i. Encyclopædia Britannica, Editor) Retrieved june 10, 2019, from Encyclopædia Britannica: https://www.britannica.com/science/sound-physics/The-Helmholtz-resonator

Biography. (n.d.). Retrieved January 12, 2019, from Orquestra Jazz de Matosinhos: http://www.ojm.pt/en/orquestra/bio/

Blacking, J. (2000). *How Musical is Man* (6 ed.). Seattle and London: University of Washington Press.

Botanicalls - Kits. (n.d.). Retrieved February 4, 2019, from Botanicalls: https://www.botanicalls.com/kits/

Candy, L. (2006). *Practice Based Research: A Guide.* Syndey: CSS Report.

Chion, M. (1994). *Audio-vision: Sound on Screen.* (C. Gorban, Ed., & C. Gorban, Trans.) New York: Columbia University Press.

contibutors, W. (2019, February 13). *Ornamental bulbous plant*, 883134336. Retrieved April 28, 2019, from Wikipedia, The Free Encyclopedia: https://en.wikipedia.org/w/index.php?title=Ornamental_bulbous_plant&oldid=883134336

Costa, M., & Costa, S. (2012). *As plantas ornamentais como elemento lúdico-pedagógico.* Retrieved January 2019, from http://www.drapalg.min-agricultura.pt/downloads/mediateca/Plantas_Ornamentais_ludicas.pdf

Couture, F. (n.d.). *Michael Prime: L-Fields*. Retrieved February 3, 2019, from All Music: https://www.allmusic.com/album/l-fields-mw0000066456

Cusumano, S. (2012, April 24). Interacting With Plants To Create Polyphonic Music. (A. Bruley, Interviewer) Creators, Vice. Retrieved Fabruary 3, 2019, from https://www.vice.com/en_us/article/nzdxy7/interacting-with-plants-to-create-polyphonic-music

Damásio, A. (1999). *O mistério da consciência — Do corpo e das emoções ao conhecimento em si* (2 ed.). (L. T. Motta, Trans.) São Paulo, Brazil: Editora Schwarcz LTDA.

Damásio, A. R. (1994). *Descartes Error — Emotion, Reason and the Human Brain.* New York, New York, U.S.A: Avon Books.

Duvekot, A. (2013, July 12). *The Plant Orchestra Amsterdam*. Retrieved February 3, 2019, from Steim: https://www.youtube.com/watch?v=XJ5zwNS9Pj0

Etmektsoglou, I., Mniestris, A., & Lotis, T. (2008). Balancing Between Shafer and Shaeffer in Refining Young Children's Aural Perception within an Ecological Approach to Education. *Electroacoacoustic Music Studies Network Internationl Conference.* Paris. Retrieved from http://www.ems-network.org

Fitch, W. T. (2017). Foreword. In H. Honing, *The Origins of Musicality* (pp. vii-viii). London, England: MIT Press.

Flood, D. (2014, September 11). *Ikebana*. Retrieved February 4, 2019, from FloodSlicer's Vimeo: https://vimeo.com/105940471

Fujieda, M. (1997). Patterns of Plants. [CD, Album]. US: M. Fujieda.

Fujieda, M. (2008). Patterns Of Plants II . [CD]. US: Tzadik.

Garcia, L. (2010 - present). — *Pulsu(m) Plantae*. Retrieved January 28, 2019, from Less_Null_Void: http://lessnullvoid.cc/pulsum/

Gethin, R. (1998). *The Foundations of Buddhism.* OUP Oxford.

Gilmurray, J. (2017). Ecological Sound Art: Steps towards a new field. *Organised Sound*, 22(1), 32-41.

References

Glennie, E. (2017). Hearing Essay. In C. Cox, & D. Warner, *Audio Culture, Revised Edition: Readings in Modern Music* (pp. 193-197). USA: Bloomsbury Publishing.

Gordon, L. (2018, January 14). Another Green World: How Japanese ambient music found a new audience. *FACT Mag*. Retrieved February 5, 2019, from https://www.factmag.com/2018/01/14/japanese-ambient-hiroshi-yoshimora-midori-takada/

Grande Pesca Sonora 2017. (n.d.). Retrieved May 19, 2019, from Orquestra Jazz de Matosinhos: http://www.ojm.pt/pt/projectos/servico-educativo/grande-pesca-sonora-2017/sobre

Gray, P. M., Krause, B., Atema, J., Payne, R., Krumhansl, C., & Baptista, L. (2001). The music of nature and the nature of music. *Science, 291(5501)*, 52-54.

Griner, C. (2002). *Floriculture — Designing & Merchandising* (2 ed.). New York: Delmar.

Guzik, A. (2011, November 9). *laúd plasmaht Ariel Guzik*. Retrieved February 4, 2019, from Ariel Guzik's Vimeo: https://vimeo.com/31877773

hibridotube. (2011, November 1). *Concierto para plantas de Ariel Guzik en Guanajuato*. Retrieved February 3, 2019, from Youtube: http://lessnullvoid.cc/pulsum/ariel-guzik-concierto-para-plantas/#more

Honing, H. (2018). Musicality as an Upbeat to Music: Introduction and Research Agenda. In H. Honing, *The Origins of Musicality* (pp. 22-41). London, England: MIT Press.

Impett, J. (2019, January 29). *Artistic Research in Music – an IntroductionedX.* Retrieved January 2019, 30, from edX: https://www.edx.org/course/artistic-research-in-music-an-introduction

Ingram, D. (2010). *The Jukebox in the Garden: Ecocriticism and American Popular Music since 1969.* (H. van den Berg, A. Goodbody, & M. Wissenburg, Eds.) Amsterdam, New York: Rodopi.

Jao, C. (2015, July 2). Sonifying the world. *Aeon*. Retrieved January 28, 2019, from https://aeon.co/essays/how-the-sounds-of-data-and-nature-join-to-make-sweet-music

Kramer, G., Walker, B., Bonebright, T., Cook, P., Flowers, J. H., Miner, N., & Neuhoff, J. (2010, March). Sonification Report: Status of the Field and Research Agenda.

Krause, B. (2003, June). *TEDGlobal 2013.* Retrieved January 2019, from TED: https://www.ted.com/talks/bernie_krause_the_voice_of_the_natural_world#t-861461

Kurutz, S. (2013, August 28). A Haven for Making Music With Plants. *The New York Times*. Retrieved January 29, 2019, from https://www.nytimes.com/2013/08/29/garden/a-haven-for-making-music-with-plants.html?ref=garden&_r=0

Lassere, G., & met den Ancxt, A. (2015). Hybrid & Sensory Interactive Works. Scenocosme.

Leão, E. (2013, March). *Jacintos*. Retrieved June 14, 2019, from Jardim da Terra: https://jardimdaterra.blogspot.com/2013/03/jacintos.html

Lee, R. (2015). *Sonic Cannibal*. Retrieved January 29, 2019, from Rosemary Lee: http://rosemary-lee.com/Sonic-Cannibal

Lee, R. (2017). *Symbiotic Sound*. Retrieved January 29, 2019, from Rosemary Lee: http://rosemary-lee.com/Symbiotic-Sound

Leudar, A. (2015). *Surrounded: A Series of Sound Installations that Combine Plant Electrophysiology and 3D Sonic Art.* ISAST. doi:10.1162/LEON_a_01338

Lonelyleap (Director). (2013). *The Plant Family Tree* [Motion Picture]. Retrieved Januray 25, 2019, from https://aeon.co/videos/how-our-developing-understanding-of-plants-changed-our-knowledge-of-life-itself

Lopes, F., & Ferreira, R. (2017). Cant(a)eiro: A program for music creation in schools. *X International Research in Music Education Conference* (pp. 66-67). UK: Bath-Spa University.

López, F. (1998). Environmental sound matter. *La Selva (Sound environments from a Neotropical rain forest)(CD) Holanda: V2_Archief. Cobertura.*

Mancuso, S., & Viola, A. (2016). *Verde Brilhante — A Sensibilidade e a Inteligência das Plantas* (1 ed.). (I. Canhoto, Trans.) Lisboa: gradiva.

Martin, L. J. (2013, April 21). *The Secret and Ancient Lives of Houseplants*. Retrieved Januray 17, 2019, from Your Wild Life: http://yourwildlife.org/2013/04/the-secret-and-ancient-lives-of-houseplants/

McKibben, W. E. (2009, August). *Four Years After My Pleading Essay, Climate Art is Hot*. Retrieved from Grist: http://grist.org/article/2009-08-05-essay-climate-art-update-bill-mckibben

Michael Prime - One Hour As A PLANT. (n.d.). Retrieved February 4, 2019, from and/OAR: https://www.and-oar.org/pop_and_42.html

Mileece (2002). [CD, Album]. UK: Lo Recordings.

Mileece. (2011, March 10). *Glitter Philodendron, Squeeks, Crickets and Wind Sounds.* Retrieved from Mileece Channel on Vimeo: https://vimeo.com/20902226

Mileece. (2011a, March 10). *Soniferous Eden at MOMA's Pacific Design Centre, 2010.* Retrieved January 28, 2019, from Mileece Channel on Vimeo: https://vimeo.com/20900941

Mileece. (2011b, March 10). *A explanation of some elements to Soniferous Eden.* Retrieved from Mileece Channel on Vimeo: https://vimeo.com/20902953

Millece. (2002 - present). *mileece*s exploratorium*. Retrieved from Tumblr: http://mileece.tumblr.com/

Müller-Ebeling, C., Rätsch, C., & Storl, W.-D. (2003). *Witchcraft Medicine: Healing Arts, Shamanic Practices, and Forbidden Plants.* Simon and Schuster.

Murtaza, M. (2016, October 2). *"...how will you conduct yourself in the company of trees" 2015*. Retrieved February 3, 2019, from Vimeo: https://vimeo.com/185210484

Nagel, T. (1974, October). What Is It Like to Be a Bat? *The Philosophical Review, 83*(4), 435-450. doi:10.2307/2183914

Oliveros, P. (2005). *Deep listening: A composer's sound pratice.* IUniverse.

References

Ölund, C. (n.d.). *Stress Call of the Stinging Nettle*. Retrieved February 4, 2019, from Christine Ölund: http://www.christineodlund.se/audio/01.html

Patrão, C. (2013, January 19). *Plant Consciousness & Communication*. Retrieved January 21, 2019, from Zepelim — The Inner Reaches of Outsider Communication: https://zeppelinruc.wordpress.com/2013/01/19/zepelim-plant-consciouness-communication/

Patrão, C. (2017, June 25). *Plant Music Article in Good Things Mag*. Retrieved January 21, 2019, from Zepelim — The Inner Reaches of Outsider Radio: https://zeppelinruc.wordpress.com/2017/06/25/plant-music-article-in-good-things-mag/

Patrão, C. (2018, February 26). *Botanical Rhythms: A Field Guide to Plant Music*. Retrieved February 5, 2019, from Sounding Out!: https://soundstudiesblog.com/2018/02/26/botanical-rhythms-a-field-guide-to-plant-music/

Patrão, C. (2018, January 17). *Harvard University: Ex-centric Music Studies Conference*. Retrieved January 21, 2019, from Zepelim — The Inner Reaches of Outsider Radio: https://zeppelinruc.wordpress.com/2018/01/17/harvard-university-ex-centric-music-studies-conference/

Penha, R. (2015). *Resono*. Retrieved June 10, 2019, from Rui Penha: http://ruipenha.pt/works/resono/

plant_sensing. (2018, April 11). Retrieved February 4, 2019, from librarytnth: https://libarynth.org/plant_sensing

Playtronica. (2019, Februray 3). Retrieved from Playtronica: https://studio.playtronica.com/

Prime, M. (2000). L-Fields. On *L-Fields* [CD, Album]. Sonoris.

Rätsch, C. (2005). *The Encyclopedia of Psychoactive Plants: Ethnopharmacology and Its Applications.* Simon and Schuster.

Roth, M., & Bricker, J. (1976). Plant Talk/Sound Advice. US.

ROVA:Arts. (2006). *Improv:21 - Plants Make Music!: An Informance with Miya Masaoka*. Retrieved February 3, 2019, from Archive.org: https://archive.org/details/IMP_2006_03_08

Ruggles, L. (2017, December 12). The minds of plants: From the memories of flowers to the sociability of trees, the cognitive capacities of our vegetal cousins are all around us. *Aeon*. Retrieved January 25, 2019, from Aeon: https://aeon.co/essays/beyond-the-animal-brain-plants-have-cognitive-capacities-too

Science Learning Hub – Pokapū Akoranga Pūtaiao. (2011, June 10). *Genotype and phenotype*. Retrieved June 3, 2019, from Science Learning Hub — Pokapū Akoranga Pūtaiao: https://www.sciencelearn.org.nz/resources/207-genotype-and-phenotype

Shafer, R. M. (1993). *The soundscape: Our sonic environment and the tuning of the world.* Simon and Schuster.

Sharma, S. (2018, Fabruary 22). *The Effect of Music on Plant Growth and Pests.* Retrieved January 21, 2019, from Owlcation: https://owlcation.com/stem/The-Effect-of-Music-on-Plant-Growth-and-Pests

speakingplants. (2013, June 18). *The Plant Orchestra Amsterdam*. Retrieved February 3, 2019, from YouTube: https://www.youtube.com/watch?v=XJ5zwNS9Pj0

Syrp. (2017, February 8). *A Kauri Cries - Behind the Scenes*. Retrieved February 3, 2019, from Vimeo: https://vimeo.com/203221477

Taylor, J. B. (2008, February). *My stroke of insight at TED2008.* Retrieved January 27, 2019, from TED: https://www.ted.com/talks/jill_bolte_taylor_s_powerful_stroke_of_insight

The Vegetable Orchestra. (1998 - present). Retrieved February 3, 2019, from The Vegetable Orchestra: http://vegetableorchestra.org/about.php

TheShowIsNotTheShow. (2015, September 4). r/AskHistorians — Answer to: Did colonists from Europe in the 18th & 19th century take live plants (trees, nursery stock, etc.) for cultivation purposes to the Americas and Australia, or just seeds? Retrieved January 17, 2019, from https://www.reddit.com/r/AskHistorians/comments/3jjtgu/did_colonists_from_europe_in_the_18th_19th/cupyaoz/

TomuTomu. (2015, April 21). *Plant Sounds*. Retrieved February 3, 2019, from Youtube: https://www.youtube.com/watch?v=VvWPT4VhKTk

Toop, D. (2004). The Generation Game: Experimental Music and Digital Culture. In C. Cox, & D. Warner, *Audio Culture, Revised Edition: Readings in Modern Music* (pp. 475-488). USA: Bloosmbury Publishing.

Tree Songs: Transient Sound Installation. (2012). Retrieved February 3, 2019, from Leah Barclay: https://leahbarclay.com/treesongs-transient-sound-installation/

Tsuji, Y. (2015, April 4). *Ikebana ~Beyond Japanese art of flower~.* Retrieved January 27, 2019, from Tedx Talks - TEDxShimizu: https://www.youtube.com/watch?v=jLwwCeBsNkE

Tyson, A. (2012, April 24). Interacting With Plants To Create Polyphonic Music. (A. Bruley, Interviewer) Creators, Vice. Retrieved February 3, 2019, from https://www.vice.com/en_us/article/nzdxy7/interacting-with-plants-to-create-polyphonic-music

Vitale, S. (2016 - 2019). *The Sound of Golden Light*. Retrieved February 3, 2019, from Bandcamp: https://soundofgoldenlight.bandcamp.com/music

Wandersee, J. H., & Schussler, E. E. (1999, February). Preventing Plant Blindness. *The American Biology Teacher, 61*(2), 82-86. doi:10.2307/4450624

Wang, T. (2014, January 22). *The Secret Life of Plants.* Retrieved January 27, 2019, from Harvard Science Review: https://harvardsciencereview.com/2014/01/22/the-secret-life-of-plants/

Wikipedia contributors. (2018, December 6). *Amplified Cactus*, ID: 872340604. (Wikipedia, The Free Encyclopedia) Retrieved February 4, 2019, from Wikipedia: https://en.wikipedia.org/w/index.php?title=Amplified_cactus&oldid=872340604

References

Wikipedia contributors. (2018, July 22). *Vernalization. In Wikipedia, The Free Encyclopedia*, ID: 851492151. Retrieved January 27, 2019, from Wikipedia, The Free Encyclopedia.: https://en.wikipedia.org/w/index.php?title=Vernalization&oldid=851492151

Wikipedia contributors. (2019, March 21). *Succulent plant*, 888796831. (Wikipedia, The Free Encyclopedia.) Retrieved April 26, 2019, from Wikipedia, The Free Encyclopedia.: https://en.wikipedia.org/w/index.php?title=Succulent_plant&oldid=888796831

Appendix A