INSTITUTE FOR FUTURE TECHNOLOGIES
DE VINCI HIGHER EDUCATION

Master thesis

How can sensing techniques redefine our interaction with plants ?

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Contents

1 Introduction

1.1 Background motivation

I am an creative technology engineer that is passionate about embedded systems and their hardware/software architecture. Pushed by my principal investigator and eager to take on challenges, I wanted to explore the intersection of biology and electronics. I aim to transform plants into bio-sensors, using their natural sensing capabilities to capture the human-plant interaction. Extending the capacities of a single plant, I want to create a network of plant-based sensors.

I am also interested in the use of sensor data. With no particular appetence for musical creation, my principal investigator challenged me onto create a device that can use the data from the plant and generate sound based on interaction. The musical generation allows the plant to be listened to and to care about it.

1.2 Context and overview

1.3 Problematic

1.4 Research domain

Research domains on the human-plant interaction are wide. The HCI* field is focused during this master thesis. HCI gather all the technologies that allows human to interact with computer. However, it usually only is a new way of interaction, there the plant is a living component that brings its own sensibility and needs (watering, lighting...).

The sensor making and creation field is also focused. In this master thesis plants are transformed into sensor. This transformation...

1.5 Contributions

* Human Computer Interface

2 State of the art

2.1 Plant as sensor

2.1.1 Human-Plant cohabitation

Plants have a lot of benefic effects on human. The study from Charles Hall and Melinda Knuth [1] explain all the benefits of plants on our human system. Watts and al. shows that urban "greening" (add green spaces in urban city) increase tranquility, relieve stress and anxiety [2]. An experience has been conducted in offices by Ikei and al [3] to expose roses to employees. The experience showed that the "parasympathetic nervous activity was sig- nificantly higher while viewing the rose". The subjects were more comfortable being expose to roses than people that were not.

2.1.2 Human-Plant interaction

The human plant interaction has been studied. Seow and al. [4] created a framework that is able to detect when something (and someone) interact with a plant. However, this is not any plant, the plant used is the *Mimosa Pudica*. This plant is special, when something touches its leaves, the plant closes its leaves to protect them from the danger [5]. An electrical impulse is released and is catch by the device Seow and al. developed. The electrical signal is easy to catch and thus can be used as actuator. However, the plant needs time and energy to re-open the leaves. This framework also can't be generalized to other species of plants.

Sato and al. used the process of capacitive sensing to detect interaction with objects of our daily lives [6]. In this paper, they proposed a device called *Touché* that use swept frequency capacitive sensing to detect touch interaction but also more complex interactions (such as interacting with a finger, the whole hand...). More complex interactions are captured using machine learning algorithm.

This paper doesn't apply the device to plants. Poupyrev and al. [7] used the device on plant to demonstrate the usage. This swept frequency technique is usable and better than the previous single frequency technique as it captures more data. In there article, Honigman and al. [8] adapted the *Touché* device to be use with an Arduino† microcontroller. This allowing people to reproduce the set-up easily.

2.1.3 Plant as sensors Plant transformed into sensors

2.1.4 Silicon Made sensors

2.1.5 Sonification on microcontrollers

MCUs‡ [9] is a kind of small computer. Those devices can be used to generate sound. The most common way of doing electronical music is to use MIDI§ [10]. MIDI has been created in order to create music with digital computer. MIDI do not describe directly the audio signal but the human actions to create the signal (such as turn the knob left, push the slider...).

† Open source compute unit
‡ microcontrollers
§ Musical Instrument Digital Interface

MCU are able to produce those kind of directives [11][12]. However, the MCU can produce MIDI but MIDI does not directly generate sounds. A synthetizer is needed to create the sound described.

For our use case of embedding the device, we look at MCU that were able to directly generate the signal from a DAC¶. Projects had been conducted with many microcontrollers such as a small 8 bits AVR microcontrollers (ATmega32) [13]. This paper does not include limitation of such a product but we can guess that the 8 bits microcontroller is limiting the sound quality. A larger project from Shaer and al. [14] is including an Arduino Mega controlling the visual effect of the project, but also the interaction sensors. The Arduino Mega is then sending MIDI information to Teensy 3.2. The Teensy is then generating the sound. The project is still too large to be fully embedded but the Teensy 3.2 is a promising compute unit. The Teensy 3.2 is running at 72 MHz, way faster than the ATmega32 that is operating at 16MHz. The frequency is essential when trying the produce sound signals.

2.1.6 Commercial products

2.2 Internet of Plants

2.2.1 Distributed instruments

2.2.2 Sonification using software

¶ Digital to Analog Converter

3 Plant as sensor

3.1 The electronic interface

The electronic interface is the interface that allows a compute unit to capture and interpret the plant signal and communication. The interface is a device made by us for this use case. The printed circuit board (PCB) device is composed of 3 main parts:

- The core of the circuit, the microcontroller, an ESP32 Wroom 32
- An electronic filter connected using an electrode to the plant
- A sound part of the PCB that is including an audio amplifier, a volume knob and a terminal block to connect a speaker

The design of the PCB has been done using the open source software Kicad. As said previously, the circuit contain 3 parts.

The core of the circuit is the computation part, including the microcontroller, an ESP32. All the other devices of the circuit are connected to the ESP32. The choice to use a devkit has been done to ease the electronic conception and to avoid any communication and soldering issue with the MCU*.

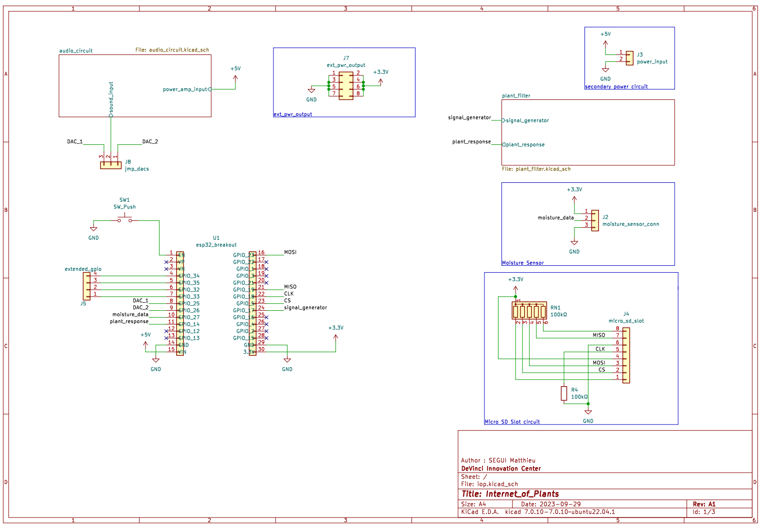

Figure 1: The core of the circuit, the microcontroller, an ESP32 Wroom 32. All the other parts of circuits are plugged in.

The circuit component that allows us to read data from the plant is the electronic filter. This filter has been designed by *Jakub Nikonowicz* and *Łukasz Matuszewski* from *Politechnika Poznańska*. Thanks to them, I adapted it for my application on my embedded device.

The last part of the circuit is the sound output/rendering. This circuit includes a small amplifier, the LM386 from Texas Instruments. The rest of the circuit are components needed in order to induce amplification on the signal without creating to many noise and saturation.

Once the schematic is done, we have to route the tracks. It exists multiple way to route PCB (single-sided, double-sided, multiple layers). We choose double sided, 2 layers on each side of the PCB.

* Microcontroller Unit

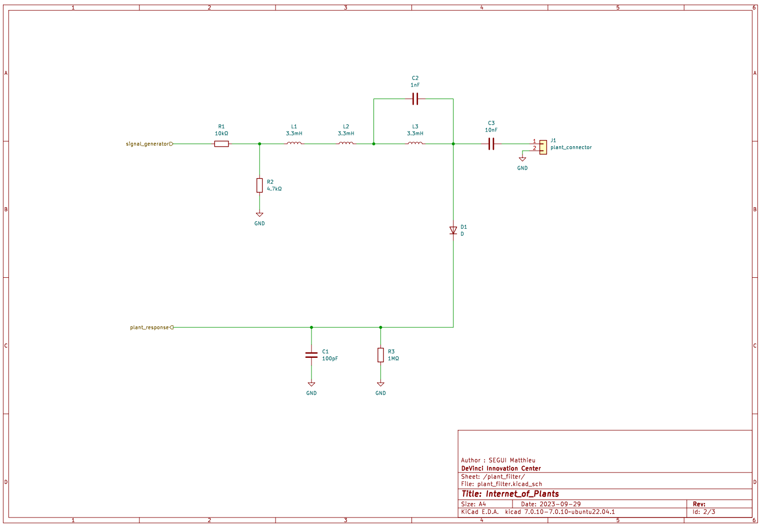

Figure 2: The electronic circuit designed to capture the interaction by analyzing the electronic frequency response. The circuit includes 3 resistors, 3 inductors and 3 capacitors as main components

3.2 Human interaction

3.2.1

3.2.2 User study

3.3 ...

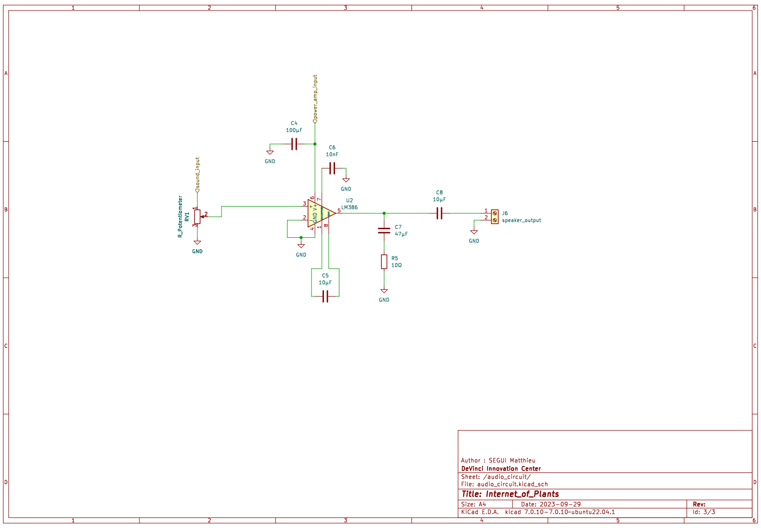

Figure 3: The sound output part of the circuit that is used to render the sound. This part includes a small amplifier, the LM386. The circuit also includes the components necessary to control and handle the amplification (reduce noise and saturation)

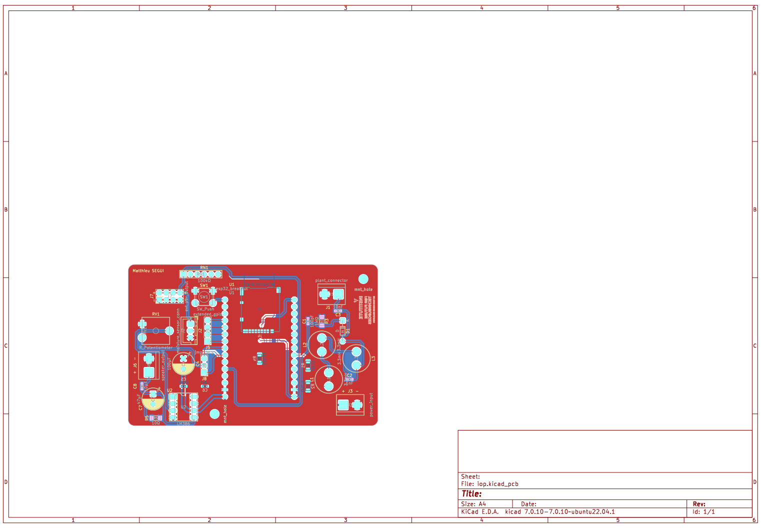

Figure 4: The routed double sided PCB.

4 Internet of Plants

4.1 Overview

4.2 Communication

4.3 Server

4.4 Deployment and application

4.5 Conclusion

5 Conclusion

References

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