

# **Silence Pulse: The hidden voice of plants**

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## **Introduction:**

Plants play a crucial role in the existence of humans and animals by providing oxygen and food and regulating ecosystem balance (Jose et al., 2019). However, due to the enduring zoocentric cultural bias and the limitations of human perception, plants are often viewed as passive, silent entities or merely part of the background compared to animals within the world (Wandersee & Schussler, 1999; Hall, 2011, pp. 22–27; Kallhoff et al., 2018; Burnusuz et al., 2024). This biased perception results in the public's lack of recognition of plants' biological traits and their ecosystem significance, placing plant conservation at a disadvantage in terms of institutional funding, scientific research, and legal protection, as well as hindering future conservation actions to plants (Fiel'ardh, 2023; Margulies et al., 2019; Gagliano, 2015). Yet, contemporary plant biology research findings have provided insights revealing that plants can communicate through bioelectrical signals, chemical exchanges, and even ultrasonic emissions (Bhandawat and Jayaswall, 2022). For example, plants can emit faint sound-like “screams” when they experience environmental stress (Khait et al., 2023); besides that, evening primrose can adjust their nectar production in response to the vibration signal created by pollinating insects (Veits et al., 2019). Although these communication processes typically lie beyond the scope of human perception, they imply that plants are not merely passive beings. Instead, they actively engage in complex ecological networks, shaping and responding to their surroundings (Marder, 2013). Hence, it is crucial to provide people with a way of perceiving plant life expressions and provide dialogue between humans and living entities. This project encourages people to rethink the role of plants in ecological systems and to reflect on the forms of life people have traditionally regarded as silent or inert. As the voices and actions of plants become perceptible to humans, this project also invites audiences to re-contemplate, in our modern society, whether we have overlooked the lives we cannot hear or the species that communicate in unfamiliar ways. These questions constitute the themes of the “Silence Pulse” project. This project aims to utilise the technology to collect the bioelectrical signals of plants and decode them into audible and visual artistic forms. This project attempts to become a medium for humans to perceive interspecies communication and a new way of listening to the non-human world, enabling people to establish a deeper connection with the world and other diverse inhabitants.

## **2. Conceptual Framework and Literature Review:**

### ***2.1. Background***

As an integral component of the ecosystem, plants constitute approximately eighty per cent of all living biomass, providing essential resources such as shelter, oxygen, and sustenance for the survival of both humans and animals (Jose et al., 2019). However, humans are often unaware of the existence of plants, viewing them as passive, silent entities that merely form part of the world's background (Kallhoff et al., 2018). In 1999, American botanists Wandersee and Schussler (1999) introduced the term "plant blindness," emphasising that this oversight results from people's inability to recognise plants' aesthetics and distinctive biological characteristics. Such a perception points out the long-standing cultural bias against plant life, stemming from zoocentric perspectives that categorise plants as passive and non-conscious due to their lack of mobility compared to animals and the absence of discernible brain-like structures (Wandersee & Schussler, 1999; Hall, 2011, pp. 22–27). In this context, Fiel'ardh (2023) suggested that these biased perspectives can lead to insufficient attention to plants in social cognition, which undermines awareness of their crucial role in maintaining life on the planet. Moreover, the report by Margulies et al (2019) indicated that the phenomenon of plant blindness has been restricted financial support for plant-related research and has resulted in a lack of attention from funding institutions towards the existence of illegal plant trade, resulting in marginalising plants in the government legal system in comparison to animals for an extended period. Therefore, in the lack of public appreciation of the importance of plants, it will become increasingly challenging to prioritise the botanical preservation work at the forefront of human fundamental concerns (Gagliano, 2015).

### ***Recognising Plant Agency Through Perceptual Mediation***

In recent years, a growing number of plant biology studies have demonstrated the vitality and autonomy of plants, indicating that they are more active than previously recognised by

humans. According to Kumar et al. (2020), plants can sense and respond to environmental stimuli, including light, sound, and chemical signals, thereby adjusting their growth, physiology, and behaviour in ways once considered exclusive to animals. The majority of these activities occur slowly or are barely noticeable, requiring close attention from people (Forterre, 2013). Additionally, plants can respond to vibrations emitted by animals. A study published by Veits et al. (2019) demonstrated that evening primroses can detect bee wing vibrations and respond by producing sweeter nectar, potentially increasing their ability to attract pollinators from a distance. Aside from that, Khait et al. (2023) reported that plants emit sound signals that can propagate through the air when under stress, such as during drought or stem cutting; since these signal communications typically occur beyond human auditory thresholds, animals like mice and bats can detect these distress sounds. These biological discoveries reveal that plants are interconnected with all living entities and are not mere passive entities as commonly perceived but active agents within ecosystems of their own means of perception, communication, and existence (Marder, 2013). Nevertheless, despite these biological findings, Burnusuz et al. (2024) argue that the human sensory system is predisposed to prioritise entities that possess display visible or audible dynamic actions, thereby marginalising the perceptual presence of plants and neglecting life forms whose vitality is expressed through slower or more subtle modes of expression from human awareness. According to Gibson (2018), contemporary visual art and culture can serve as an effective means of fostering emotional connections between humans and nonhuman entities by engaging the senses and emotions, which enables the plants' agency and presence to be made more tangible and in a manner that reshapes human perceptions of nature. Also, Ryan (2015) further expands and emphasises that integrating acoustic elements between live plant and artistic approach is able to provide an embodied and

affective means to allow the audience to perceive the plant's own vitality and agency. Chang et al. (2022) assert that adopting modern human-computer interaction approaches is able to compensate for human perceptual limitations, by enabling people to perceive subtle plant communications through the interaction process, which facilitating a shift from anthropocentric and zoocentric perspectives toward a more inclusive appreciation of interspecies relationships as well as fostering empathy for plants.

## **2.2. Case Studies**

In an effort to transcend the sensory threshold of human perception concerning plant life, many contemporary artists have been integrating technology with real-life plants, which offer a new way to intuitively perceive the plant living forms for the public. A notable experimental initiative from Data Garden is the PlantWave device (Patitucci, 2021) (*Figure 1*), which serves both as a scientific exploration tool and as an artistic medium, allowing individuals to perceive the agency of plants through hearing (Samuelsson, 2016). The fundamental principle of the PlantWave device consists of two electrode pads that translate the plant's real-time bioelectric activity into pitches, rhythms, and musical notes, facilitating the synthesis of melodies in real-time through a mobile application (PlantWave, 2022). These bioelectrical signals stem from various physiological processes in plants, such as photosynthesis, transpiration, and reactions to surrounding stimuli (Jayawickrama, n.d.). As a result, the generated sounds may differ based on plant species, environmental conditions, and internal activities, which contribute to the fascinating aspects of plants communicate in a self-governing state as well as foster an emotional connection between individuals and species of plant by allowing the auditory perceptions and interpretations (España Keller, 2024). The sounds generated by plant organisms can evoke audience emotions such as harmony, tranquillity, or unease, depending on the nature of the emitted

signals, thus listening to plant-generated music becomes a profoundly personal and interpretive experience that enhances people's comprehension of plants and their role in the natural world (Evans, 2024).



*Figure 1: PlantWave device in use from PlantWave website (2022)*

While PlantWave converts plant bioelectrical activity from real-time into sound, David Bowen's (2022) artistic installation 'Plant Machete' enables humans to perceive living plant forms in a dynamic visual manner (*Figure 2*). This creative installation utilises electrodes affixed to the surfaces of live plants to capture real-time biological micro-current fluctuations, which are captured by an Arduino device and transformed into the real-time motion of a robotic arm equipped with a machete (Bowen, 2022). In Bowen's work, the concept of the plant as the brain positions the robotic arm not merely as a mechanical device responding to preset programming, but as a continuously evolving corporeal extension that reflects the real-time physiological activity of the plant (Thursd, 2022). Within this installation, the plants' real-time activities and expressions become intuitively perceptible to humans through visual means, as their "swinging" machete behaviour is viewed as a manifesto that challenges traditional perceptions of plants as passive and static organisms.

This manifesto motivates individuals to reflect on the often-overlooked consequences of long-term dismissal of plant autonomy and their importance in ecological impact (Rogers, 2022).



Figure 2: *Plant Machete* by David Bowen (2022)

#### ***2.4. Project Direction by Reconstructing Human Perception***

Based on the aforementioned scientific and artistic insight, the *Silence Pulse* immersive art installation seeks to integrate technology and artistic expression as a way to overcome the human long-standing perceptual and sensory limitations by visual and hearing, which typically caused people to disregard the significance of plant life and their own agency, thereby marginalising plants' protective existence within ecological systems. To be more specific, the project aims to use an Arduino device to capture the real-time biological signals emitted by living plants and transfer them into a multi-sensory experience involving sound and visuals, which attempts to construct an immersive space that enables individuals to intuitively perceive a plant's own autonomy and agency. Drawing on the conceptual

framework by Merleau-Ponty in his book *Phenomenology of Perception* (1945, pp. 272–275), which posits that human perception is inherently synesthetic and embodied and suggests that humans are able to “see sound” or “hear texture.” From this point of view, the installation intends to transfer real-time physical plant biotic activity into musical tunes that dynamically affect the visual state of the digital plant form. Through this interplay approach, people are enabled to see the real-time transformation of the virtual plant form as a manifestation of the living plant's internal ecological rhythms and simultaneously hear the plant's physiological activity as textural sound in space. The project indicates that plants are not passive and silent entities but, as living organisms, possess the ability to express their existence and respond autonomously to surrounding environmental stimuli (Marder, 2012). Within this installation, plants are involved as active participants and collaborators, which can dynamically shape and influence the immersive digital space through their real-time biological responses. Through this process, individuals can engage with plant agency by viewing and listening to plant lifeforms, fostering a connection with the biotic rhythms of plants through human sensory engagement and establishing an emotional connection with plants within digital and real space (Wright & Howden, 2023).

### **3. Beneficiaries**

From a social perspective, the immersive installation of Silence Pulse could provide significant advantages for environmental and nature-oriented organisations and conservation networks, particularly those focused on increasing public engagement with plant life and biodiversity. This includes innovative governance models such as Zoop, which integrates nonhuman interests into organisational decision-making through design and ecological systems (Pedroso-Roussado et al., 2025), as well as global entities like Botanic Gardens Conservation International (BGCI). BGCI links over 500 botanical institutions across more than 100

countries to promote biodiversity education and protection initiatives (Smith, 2016). By converting real-time plant activity into an engaging audio-visual experience, Silence Pulse serves as a valuable asset for organisations and institutions aiming to enhance public ecological awareness, cultivate empathy toward nonhuman life forms, and engage audiences who might otherwise overlook the importance of plant agency within environmental systems (Burke et al., 2022). Meanwhile, Silence Pulse aids in conveying plant ecological communication by blending artistic practices with technology for content distribution. This aligns with the goals of institutions seeking to adhere to the United Nations Environment Programme (2021) Sustainable Development Goal framework. The project may increase public attention on addressing issues related to biodiversity loss and pollution threats, while fostering deeper emotional connections, reinforcing narratives, and generating wider public backing for environmental policy efforts (United Nations Environment Programme, 2021, pp. 51-54). Such support is crucial for securing funding, charitable donations, and enhancing community participation in nature restoration, resource management, and ecological preservation (Kettunen et al., 2021).

Another group that benefits from the Silence Pulse installation includes individuals influenced by cultural biases who find it challenging to acknowledge the vitality and autonomy of plants in their daily lives. This installation provides an engaging, multi-sensory experience that bridges the connection between plants and audiences, enabling them to directly sense the life and agency of plants in real-time through visual and auditory representations. This may enhance cognitive processes for the audience, fostering an appreciation for plant aesthetics, encouraging close observations of natural physiological characteristics, and facilitating a genuine emotional connection with the plant (Wen, 2025). By offering a fresh perspective on plant life, the installation may deepen the audience's understanding of the biological world and

inspire environmentally responsible attitudes and behaviours toward nature conservation (Spangenberg et al., 2024). Also, the installation may prove beneficial in educational settings, such as for students or young children, by strengthening their ecological awareness and sensitivity through immersive participation. In particular, in urban and interdisciplinary contexts, the installation provides multi-sensory experiences through plants' bioelectrical signal that could help prevent 'plant blindness' and enable students to develop correct values and anticipatory thinking. As noted by Hurtado-Soler et al. (2020), integrating artistic and scientific engagement with natural life can positively influence students' creativity, ecological awareness, and interdisciplinary learning outcomes. Consequently, Silence Pulse could serve as a valuable educational resource in both formal and informal learning environments.

Furthermore, the installation may inspire creative practitioners, including musicians, dancers, and artists. In this installation, the plant's real-time bioelectrical signals are transformed into musical and dynamic visual expressions, which create a vivid, unpredictable and non-human ecological melody. This immersive space may enable artists and musicians to become involved more deeply with plant internal physiological processes, which may potentially facilitate innovative cross-disciplinary collaborations and creative thinking by viewing plants not merely as passive elements or resources for human use but rather recognising them as co-creators alongside nonhuman life forms (Vauhkonen, 2025). For dancers, adapting to the installation's real-time and fluctuating plant rhythms might inspire a greater openness to improvisation, increase bodily consciousness, refine sensory perception, and encourage emotional articulation. Movement practices influenced by natural elements have been associated with decreased stress levels, enhanced mood, and a deeper sense of connection to the environment (Hannus, 2023).

#### **4. Time Management**

Establishing a clear and structured timeline was crucial for managing the limited time available at the outset of my final project effectively. To direct the overall workflow and facilitate real-

time progress monitoring (*Figure 3*), I developed an initial Gantt Chart. This visual representation allowed me to allocate sufficient time for each phase of the project and make adjustments in response to unforeseen challenges as they arose. Furthermore, to establish clear task priorities within the project timeline, I introduced a MoSCoW Chart early in the process (*Figure 5*). This method enabled a distinction between critical tasks that must be completed and those that could be adjusted or improved if time allowed. This approach provided structured guidance throughout the design process and facilitated an organised workflow. Based on these priorities, I then utilised a SMART Goals table to set specific, measurable objectives for each phase (*Figure 6*). These short-term goals helped me maintain focus and motivation, ensuring that the project progressed in a goal-oriented and adaptable manner.

#### ***4.1. Gantt Chart***

The initial Gantt Chart was created in Week 2, using a linear workflow model that divided the project into specific phases: concept development, case studies, design process, and thesis writing (*Figure 3*). The benefits of early preparation became clear when I gathered and organised all essential Arduino components in advance. This proactive strategy helped prevent potential delays due to absent equipment and ensured a smooth start to the development phase. As a result, I moved the timeline for programming the Python script that converts MIDI notes into sound earlier in the revised Gantt Chart (*Figure 4*). This early achievement allowed me to take full advantage of the Easter break to work on visual sketches and gather mood board inspirations for three-dimensional virtual plant modelling. Consequently, I had extra time to refine and troubleshoot the integration stage in TouchDesigner, which was vital for improving the visual appeal of the final output, especially in fine-tuning the interaction between sound inputs and visual particle behaviours.

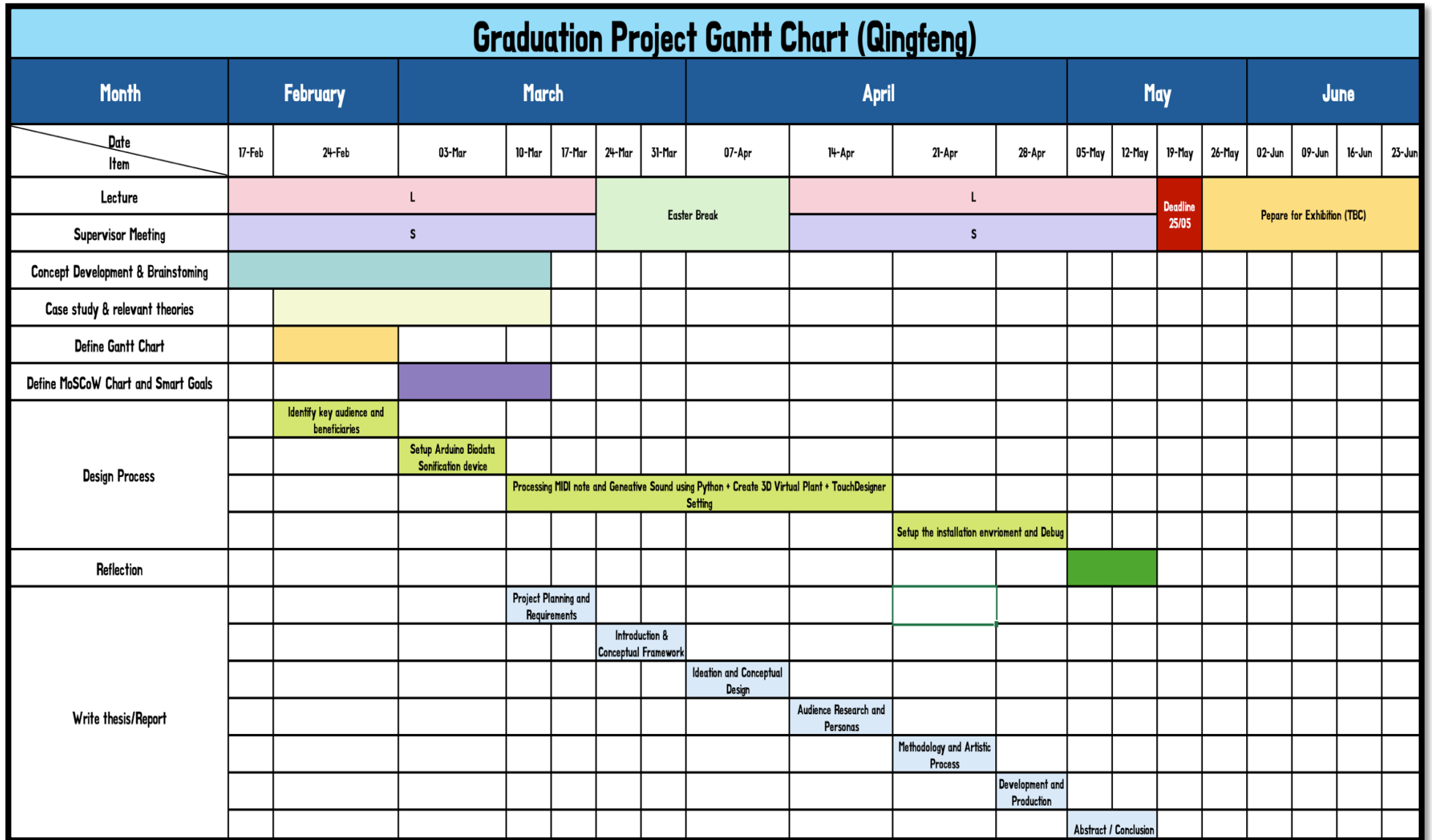


Figure 3. Initial Gantt Chart - [Blog post Click Here](#)

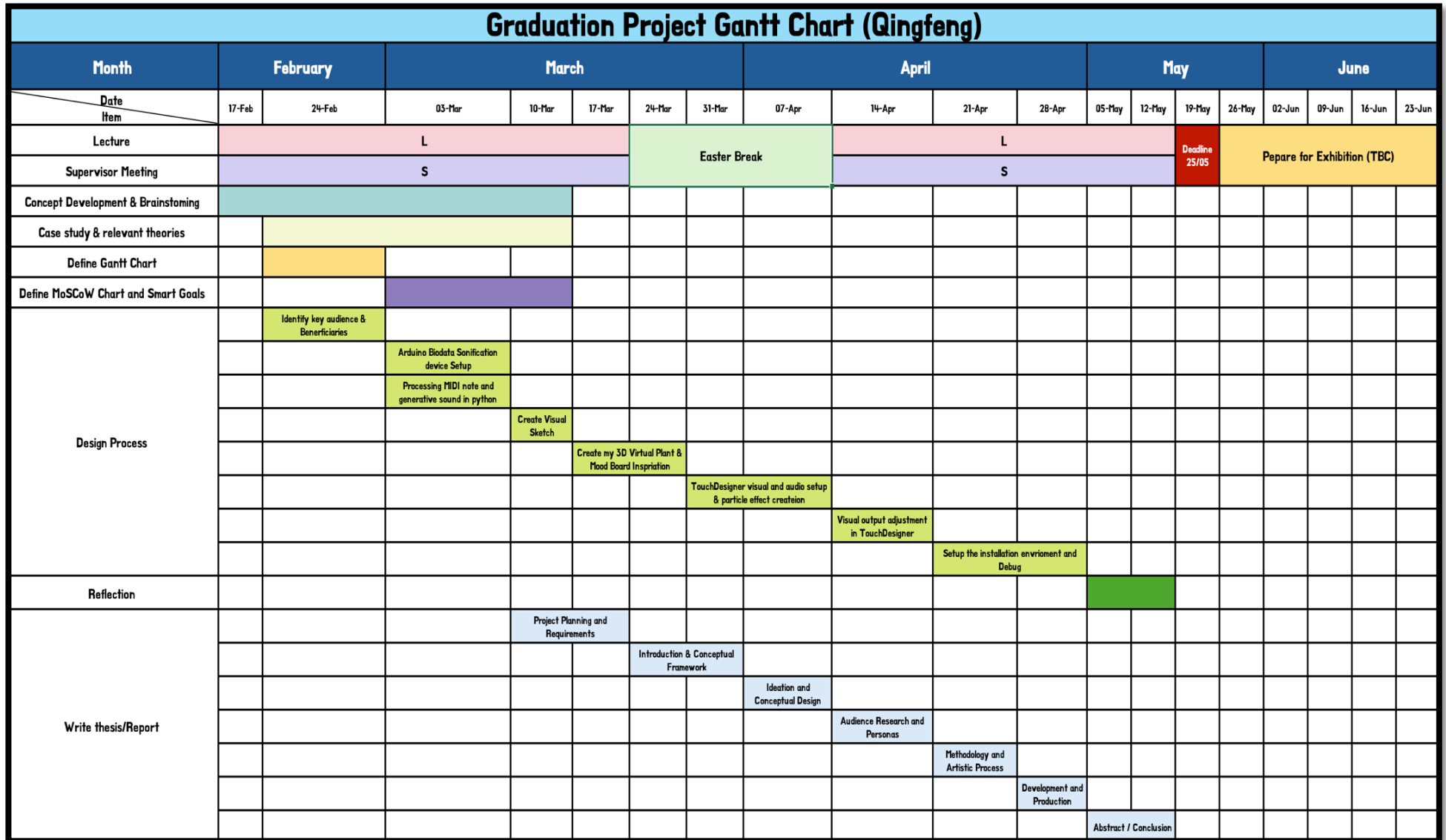


Figure 4. [Revisit Gantt Chart -Blog post Click Here](#)

## 4.2. MoSCow Chart

Before commencing the design process, I developed a MoSCoW Chart to systematically prioritise the functional components of the project (Figure 5).

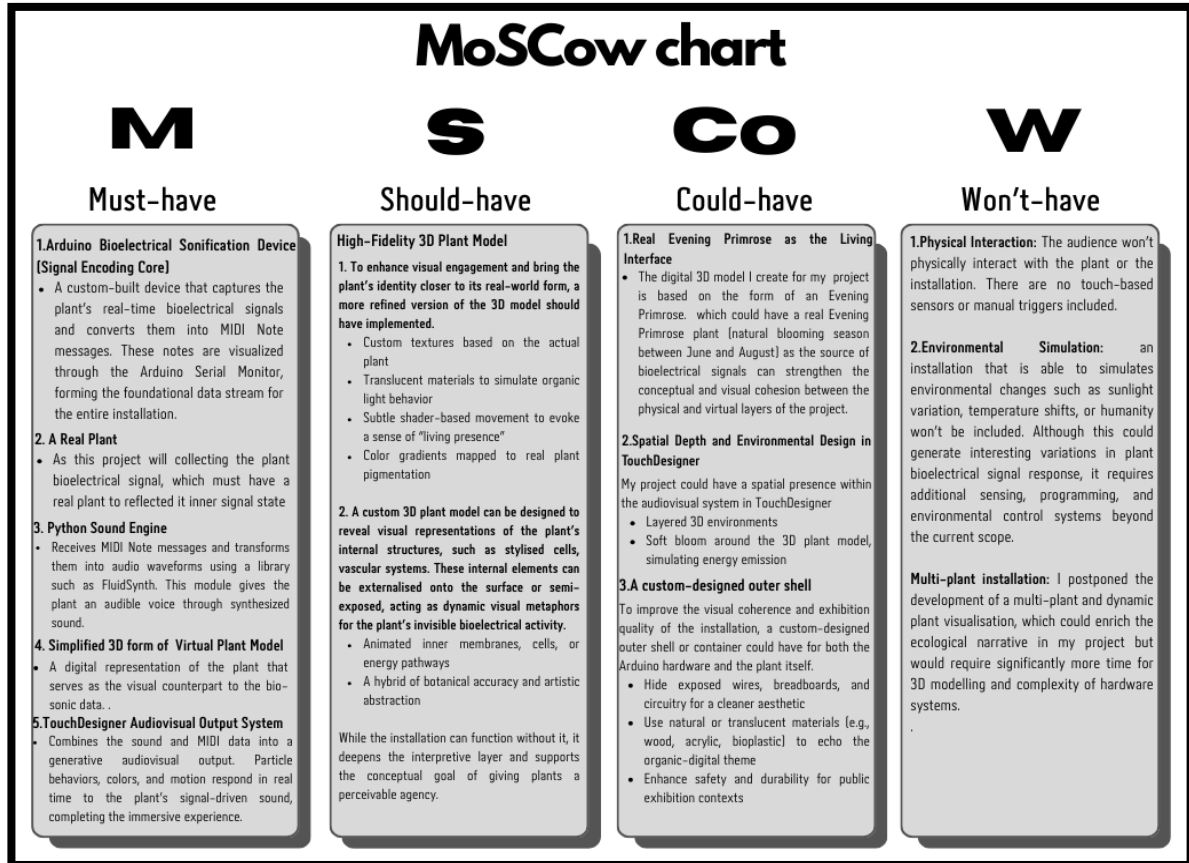


Figure 5. [MoSCow Chart - Blog post Click Here](#)

As part of my must-have checklist, I identified five crucial components: an Arduino-based system to collect bioelectrical signals from plants, the inclusion of a living plant, Python scripts that convert these signals into MIDI notes and associated sounds, a three-dimensional model of the plant, and TouchDesigner-based audiovisual output. The integration of these elements establishes the foundation for transforming biological signals into Immersive sensory experiences. The should-have category emphasises enhanced visual immersion through the integration of translucent materials and subtle animations within a high-fidelity 3D model. In the could-have section, I explored spatial depth design and a custom enclosure to elevate the aesthetic presentation of the installation. The won't-have category deliberately excludes

physical interaction to maintain the conceptual focus on presenting the plant as an active participant in a virtual environment, allowing people to perceive the expression of the plant's activity states. While the collection of data from multiple plants and the simulation of varying environmental conditions falls outside the current scope, they represent potential future avenues that could deepen the audience's understanding of how external factors influence internal plant activity. With the MoSCoW chart, I was able to focus on critical technical pathways while offering a structure for future feature enhancements and effective time management.

### **4.3. SMART Goals**

The SMART goals framework was instrumental in structuring my project with clarity and intention (*Figure 6*). By defining my objectives through specific, measurable, achievable, relevant, and time-bound steps, I transformed abstract concepts into actionable tasks. For instance, the measurable elements enabled me to specify what needed completion and documentation at each phase, from configuring the Arduino device to testing MIDI signal output and integrating audiovisual components in TouchDesigner. This process allowed me to establish short-term objectives for every stage, maintaining my focus and motivation while staying true to the project's main direction. Additionally, the achievable and relevant aspects encouraged me to evaluate my technical skills, available resources, and how well my objectives aligned with the project's overall vision. This oversight ensured that each step remained both ambitious and feasible, rooted in my existing skills and consistent with my project's goals. Furthermore, setting time-bound objectives allowed me to create flexible timelines for each stage, streamlining my research, production, and thesis writing into a manageable and trackable workflow. In summary, the SMART framework clarified my priorities and provided a structured method to monitor creative and technical progress throughout the entire project.

<p><b>S</b></p>	<p><b>SPECIFIC</b></p> <p>Develop an Arduino-based biodata sonification device that captures plant bioelectrical signals and converts them into MIDI notes. Use Python to translate these notes into real-time sound output. Create a basic 3D virtual plant in Blender as the foundation for visual representation. Finally, integrate all components in TouchDesigner to build a synchronized audiovisual installation, where plant-generated sound dynamically influences the visual form. The aim is to allow audiences to experience plant communication beyond the limits of human perception.</p>
<p><b>M</b></p>	<p><b>MEASURABLE</b></p> <p>To track my progress, I will publish weekly blog updates that include photos and videos documenting the development of the Arduino device, MIDI sound tests, 3D modelling process, and TouchDesigner integration. Each post will also record the evolution of my ideas, conceptual reflections, inspirations, and the implementation process. These updates will serve as milestones to assess technical consistency, address challenges, and evaluate whether the audiovisual system responds effectively to plant signals by the end of the build phase.</p>
<p><b>A</b></p>	<p><b>ACHIEVABLE</b></p> <p>I intend to follow the timeline set out in my Gantt chart, aiming to complete a minimum viable installation by the week 10 &amp; 11. To achieve this, I will build upon the practical skills I developed through UAL courses, where I learned how to set up and implement Arduino systems, convert data using Python, and create 3D models in foundation years. My previous experience with TouchDesigner also provides a solid foundation for constructing the audiovisual installation. In addition to applying this prior knowledge, I will actively seek guidance from academic resources, tutorials, and online communities to overcome technical challenges as they arise.</p>
<p><b>R</b></p>	<p><b>RELEVANT</b></p> <p>My installation is inspired by scientific research on how plants communicate through bioelectrical signals in response to environmental changes. This signals that are often imperceptible or overlooked in everyday life. The project aims to explore how plant communication can be made perceptible through technology. Converting bioelectrical signals into sound and visual outputs supports the goal of revealing plant agency through sensory experience. It also engages with broader themes such as non-human communication and ecological awareness. Furthermore, the project draws from key areas of my Creative Computing studies, including physical computing, data sonification, and real-time visual interaction, making it a meaningful and integrated part of both my academic and creative development.</p>
<p><b>T</b></p>	<p><b>TIME BOUND</b></p> <p>I will follow the timeline set in my Gantt chart to ensure steady progress.</p> <ul style="list-style-type: none"> <li>• By mid-March, I aim to complete the brainstorming and research phase, along with the installation and initial testing of the Arduino device.</li> <li>• In preparation for building the minimum viable installation by mid-April, I plan to make effective use of the Easter break to develop the virtual plant model using Blender, implement the Python-based MIDI sound output, and integrate all components within TouchDesigner for audiovisual deployment.</li> <li>• The final visual refinement and debugging aim to be completed by early May, which help to leave time for my thesis writing and final checking before the submission deadline</li> </ul>

Figure 6. SMART Goals Table -[Blog post Click Here](#)

## 5. Ideation and Conceptual Design

During the early brainstorming and research phase, I conceptualised the project's design in two interconnected technical aspects. The first aspect involves a signal processing framework designed to convert plant bio-electrical signals into musical sounds. The second aspect further extends on the previous approach by enabling the generated sounds to dynamically affect the behaviour of a three-dimensional virtual plant particle effect in real-time. In combination, the two aspects create the basis for a multi-sensory installation experience. Rather than acting as separate outputs, the auditory and visual components are sequentially linked, forming a cohesive sensory feedback loop. While this thesis does not adhere to the chronological sequence of the initial sketching and prototyping stages, it is instead organised around the evolving ideas and technical focus that have developed throughout the process. Comprehensive reflections on early development, along with sketches, can be found in the blog post. During the preliminary sketching phase, I developed a conceptual diagram that outlined the overall flow and structure of my project (*Figure 7*).

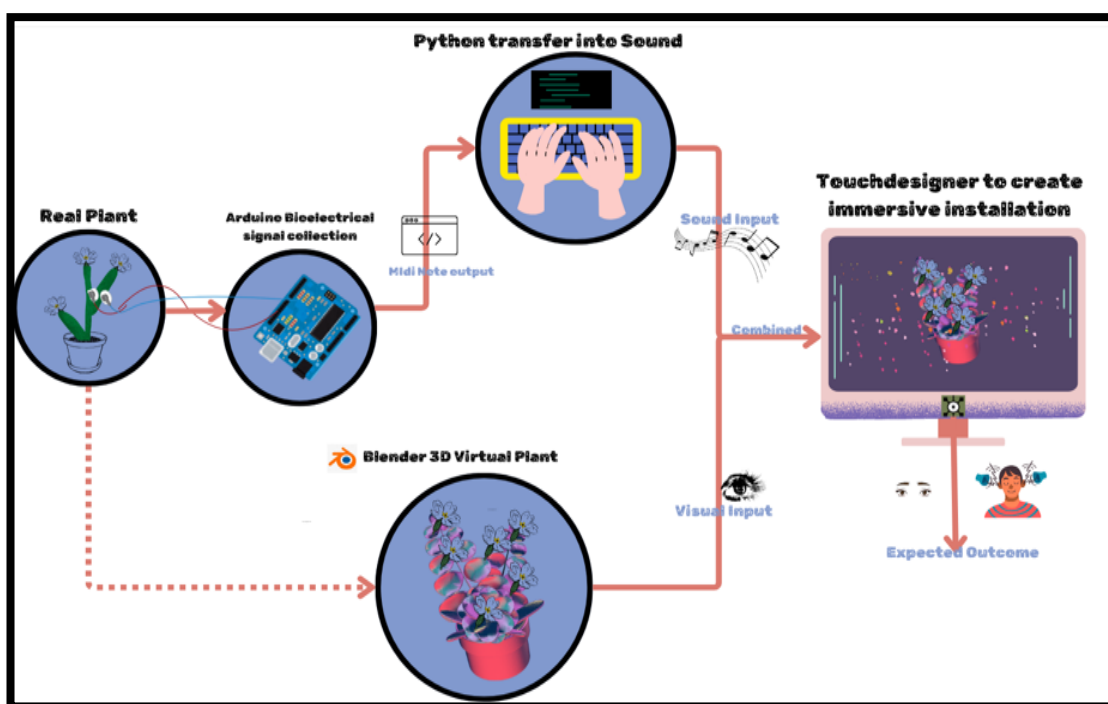


Figure 7. [Diagram of the conceptual flow from plant biodata signal to audiovisual output -Blog post Click Here](#)

### ***5.1 Auditory Concept Development***

The initial inspiration for this project stemmed from a personal curiosity about the vitality of everyday plants, which significantly shaped the direction of my subsequent research and artistic exploration in its early stages. During the project ideation phase, I drew insights from various scientific and artistic case studies. In particular, the research by Khait et al. (2023) has revealed that plants emit distress signals in the form of airborne ultrasonic sounds when under stress. Although these sounds fall outside the human auditory range and thus remain imperceptible, they suggest a form of plant communication that is typically overlooked in daily life. This scientific finding prompted me to consider how people might perceive plant sounds, thereby gaining insight into their ecological responses and expressions in natural environments. This association formed the foundation for the project's initial auditory concept. A case study on the PlantWave device further deepened this direction by demonstrating how plant leaves' bioelectrical signals can be translated into musical sounds, thereby creating emotional connections between humans and plants (PlantWave, 2022). This approach inspired me to explore the transformation of plant signals into musical notes, enabling individuals to reflect on the relationship between humanity and nature through sonically generated experiences.

### ***5.2 Visual Concept Development***

As part of the project, visual inspiration was drawn from Samuelsson's (2016) paper, which highlights how plants communicate with the external environment through their roots, leaves, and volatile compounds. These intricate behaviours can be identified as plants' "language". I was inspired by this research to create a virtual representation of plants that reveals aspects of plant inner structure often overlooked by people, including cell structures

and cortical processes (Figure 8), thus enabling individuals to intuitively perceive the characteristics of plants' internal activities.

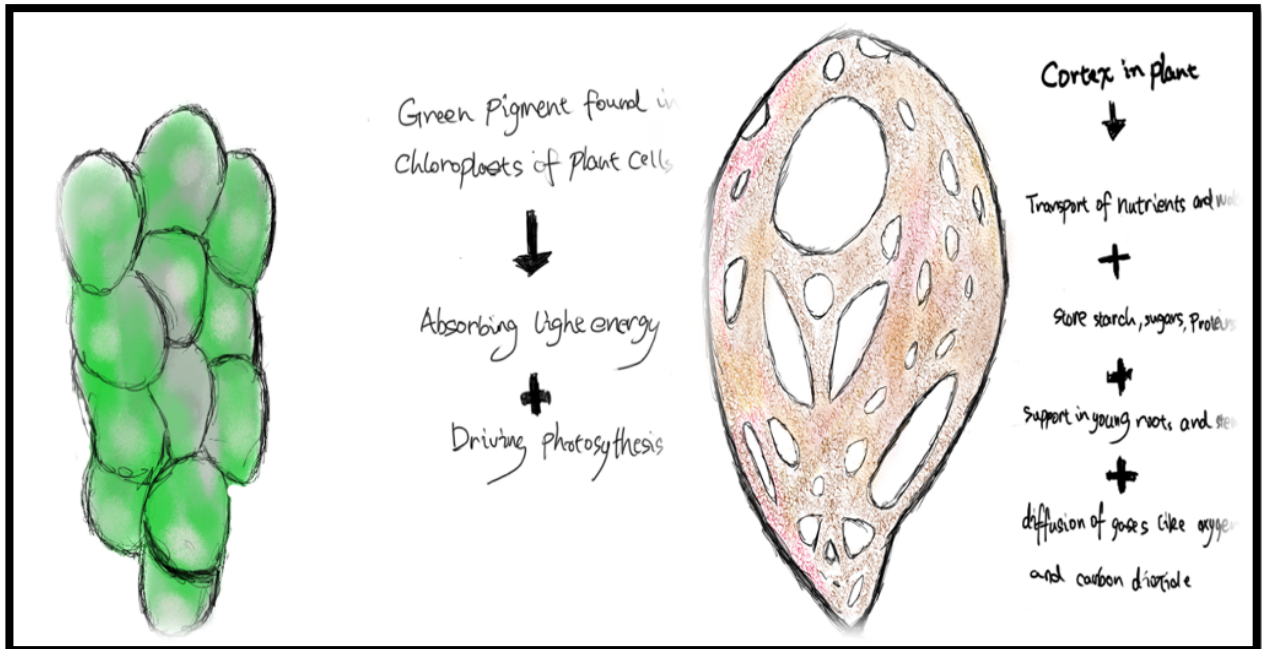


Figure 8. Visual sketch of a plant cell and cortex -[Blog Post Click Here](#)

Moreover, Veits et al. (2019) demonstrated that evening primroses can detect the vibrations of bees' wings and respond by secreting more and sweeter nectar, potentially increasing their potential to attract pollinators at a distance. The ecological interactions among organisms prompted me to envision the movement of pollen particles flowing through the air during the pollination process, which is imperceptible to people through direct vision in their daily lives. Hence, this line of thinking led me to explore ways of presenting the virtual plant form through particles in a digital environment, enabling the audience to intuitively visualise the continuous vitality and motility of plants and their subtle ways of interacting with the world. To support visual development, an early sketch was created as a means of externalising the plant's internal activity through visual expression (Figure 9) and contemplating the plant's potential form as a particle-based virtual entity.

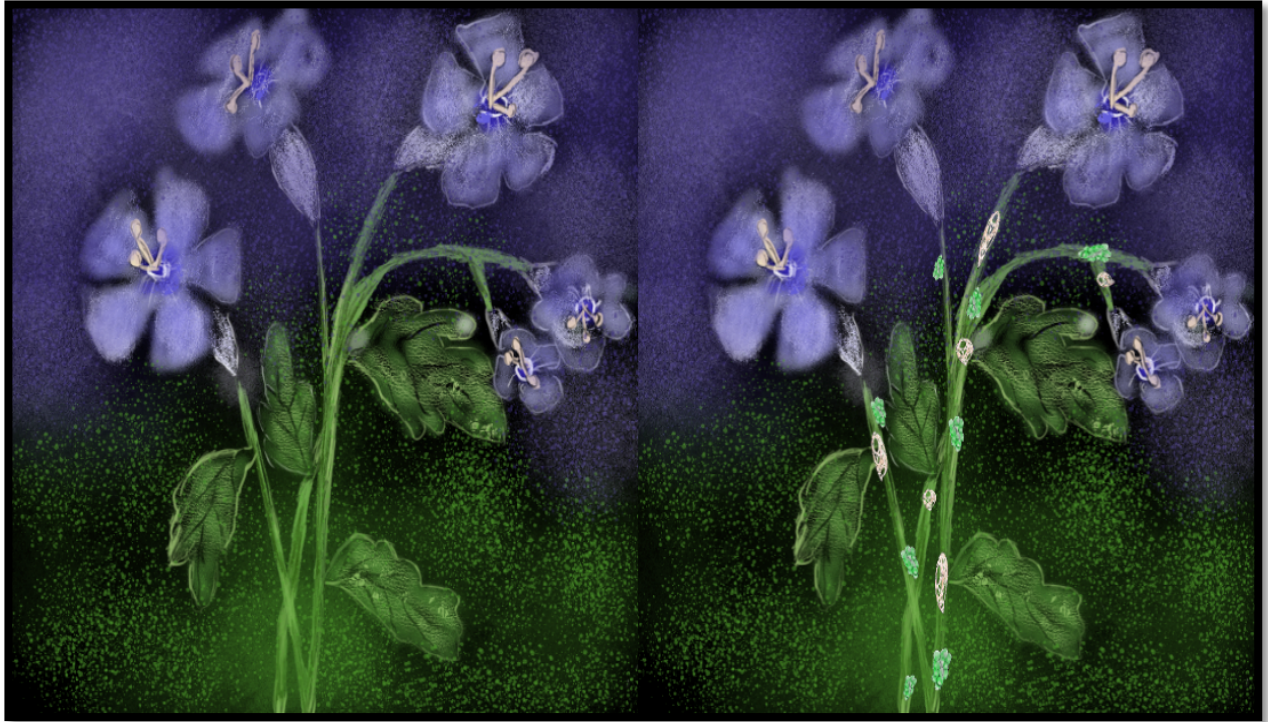


Figure 9. Initial and iterative sketch of a virtual plant form – Blog Post Click [First](#) and [Second](#)

## 6. Design Process

As part of my initial research and methodological exploration, I developed a mind map to clarify the technical structure of the project design phase (*Figure 10*). Based on this diagram, the project design process can be divided into four fundamental technical stages, aimed at making plants' overlooked communication and internal activities perceivable through auditory and visual outputs. The first stage involves the use of an Arduino-based bioelectric device, integrated with MIDI note-translation scripts, to capture real-time signals from a live plant. In the second stage, these MIDI messages are processed within a Python environment to produce corresponding sound outputs. The visual aspect of the project was achieved using a virtual plant model based on Blender. A final stage combines and synchronises the auditory and visual components using TouchDesigner software, enabling audiences to visualise and hear a plant's bioelectrical signals simultaneously. My weekly blog will include more details about the design process.

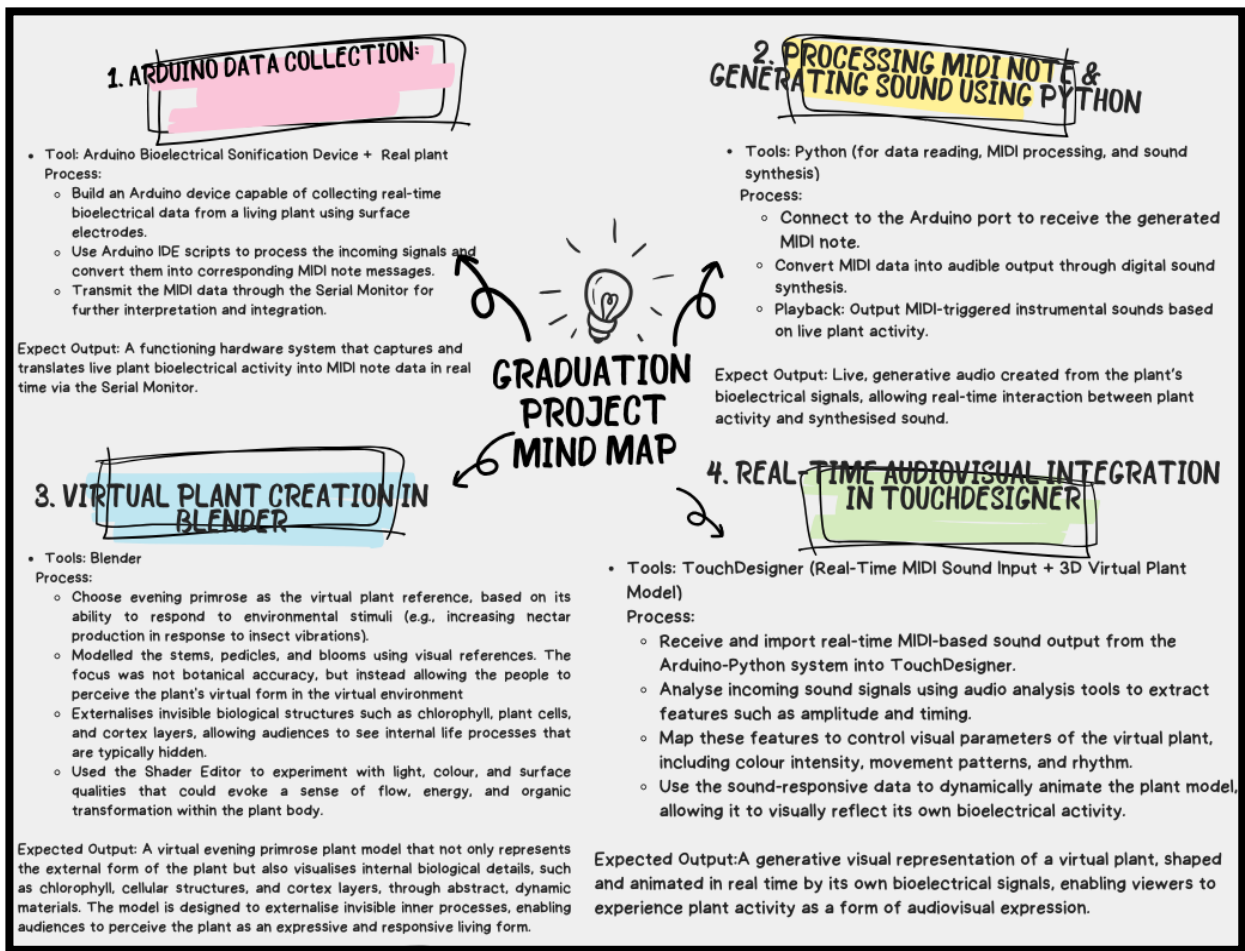


Figure 10. Mind map outlines the project's technical structure -[Blog Post Click Here](#)

## 6.1 Arduino Bioelectrical Sonification Installation Process

During the research and experimentation phase, I found a technical guide on the Electricity for Progress website which outlined the process of using Arduino hardware to convert plant bioelectrical signals into sound (Cusumano, 2020). It provided step-by-step instructions as well as the corresponding code, which can be found on GitHub. It provides a clear and actionable framework for developing the first stage of my project, significantly accelerating the initial Arduino development stage. Before installing the physical components, I utilised Fritzing software to design the breadboard layout and circuit diagram (Figure 11). Using this method, I was able to systematically plan the wiring structure and verify the feasibility of the installation.

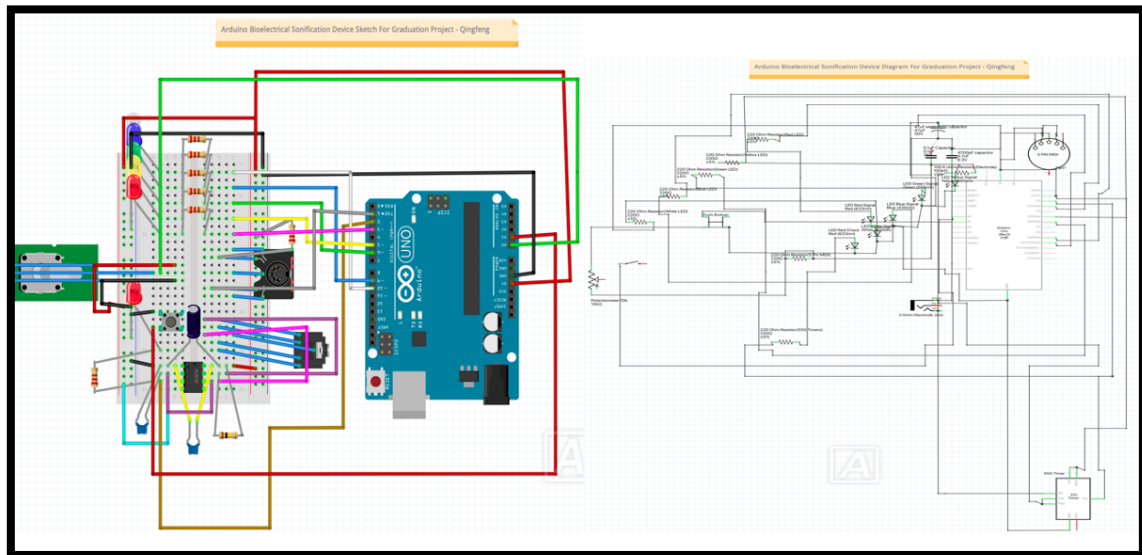


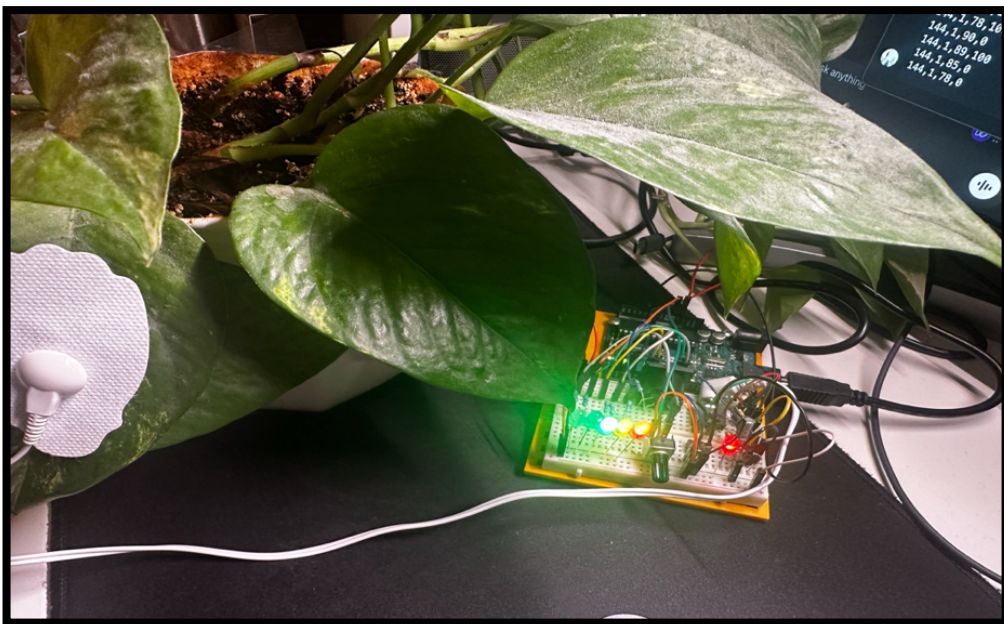
Figure 11. Early sketch of Arduino breadboard layout and circuit diagram using Fritzing software

According to the sketch diagram, I created a checklist of components and ordered the necessary parts (Figure 12). The experience I gained during the UAL workshop and lecture on Arduino hardware and circuit assembly enabled me to efficiently build and connect an Arduino bioelectrical sonification device. In order to detect bioelectrical signals, this device utilises a 3.5mm electrode lead with two pads attached to the leaf of the plant. LED lights indicate whether or not a signal has been detected. A 555-timer conductor is used to process the plant signals, and the output is converted into MIDI note messages using a 5-pin MIDI socket (Figure 12).

Count	Components
1	Arduino – Uno
1	Breadboard
7	Resistor 220 Ohm
1	Resistor 100k
1	Capacitor 4700pF
1	47 uF capacitor
1	0.1uF capacitor
2	Red LED
1	Green LED
1	Blue LED
1	White LED
1	MIDI 5 pin DIN
1	Potentiometer 10k
1	555 Timer IC
1	Tactile Button switch
1	3.5mm Jack
1	Electrode Leads 3.5mm jack to dual snap
2	Electrode Pad(Snap)
22	Jump Wires(black, brown, blue, yellow, red)

Figure 12. Arduino component checklist and Arduino bioelectrical sonification device- [Blog post Click Here](#)

To convert the plant bioelectrical signals into MIDI notes, I used an Arduino script from the Electricity for Progress GitHub repository. Although the upload was successful, the Serial Monitor displayed unreadable characters due to a baud rate mismatch. Updating the rate to 31250 MIDI standard did not resolve the issue. In my subsequent investigation, I discovered that `Serial.write()` was being used for binary output, which cannot be read by humans. It was only after replacing it with `Serial.print()` that I was able to receive MIDI note messages in the serial monitor (*Figure 13*).



*Figure 13. Real-time plant signal received in Arduino and converted into MIDI note messages*

## **6.2 Python MIDI Processing and Audio Output**

During this phase, I developed a Python script to connect to the Arduino and receive MIDI notes in real-time. In this script, FluidSynth is integrated with the Fluid3\_gm SoundFont files and continuously monitors the serial port, reading incoming MIDI values and mapping them to their sound outputs (*Figure 14*). This technical approach effectively translates live plant bioelectrical signals into audible feedback, forming a crucial part of the project's audio pipeline and allowing the audience to perceive forms of plant communication that are imperceptible in everyday human experience through real-time sound.

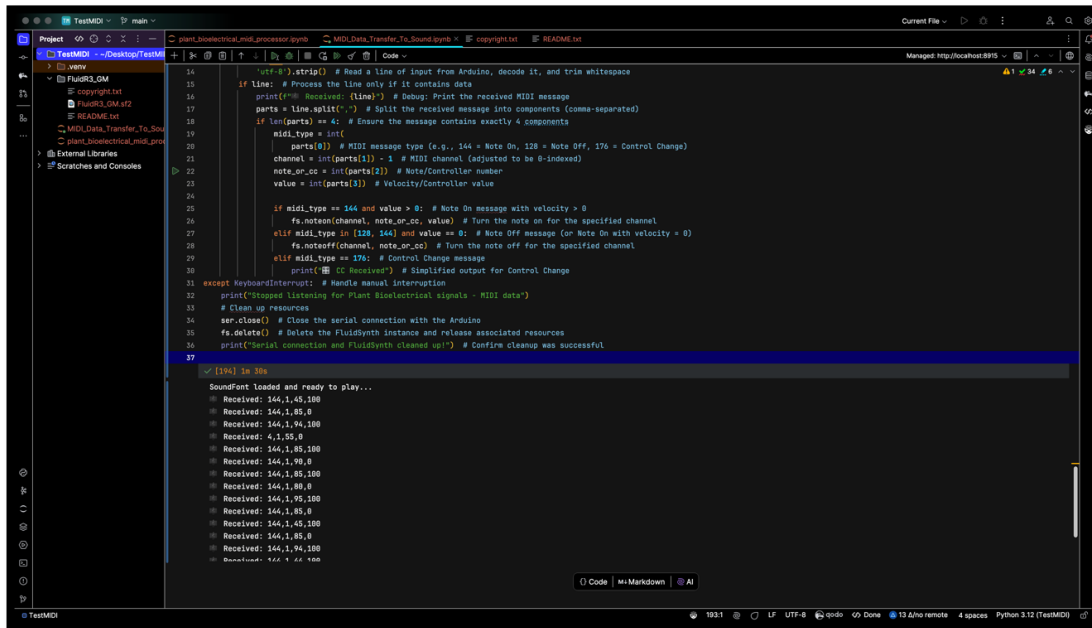


Figure 14. Translating MIDI notes into audio output Using a python script

After testing the Arduino, I noticed that it reliably transmitted MIDI notes, effectively capturing the plant's ongoing bioelectric activity. However, the Python script experienced delays in processing incoming signals in real-time, resulting in some MIDI notes being skipped and occasional failures in sound generation. As a solution to this problem, I added a one-second delay to the Arduino script (Figure 15). Through this modification, every MIDI note generated by the plant is processed without omissions, enabling the audience to experience the plant's bioelectrical activity as a seamless and continuous soundscape expression.

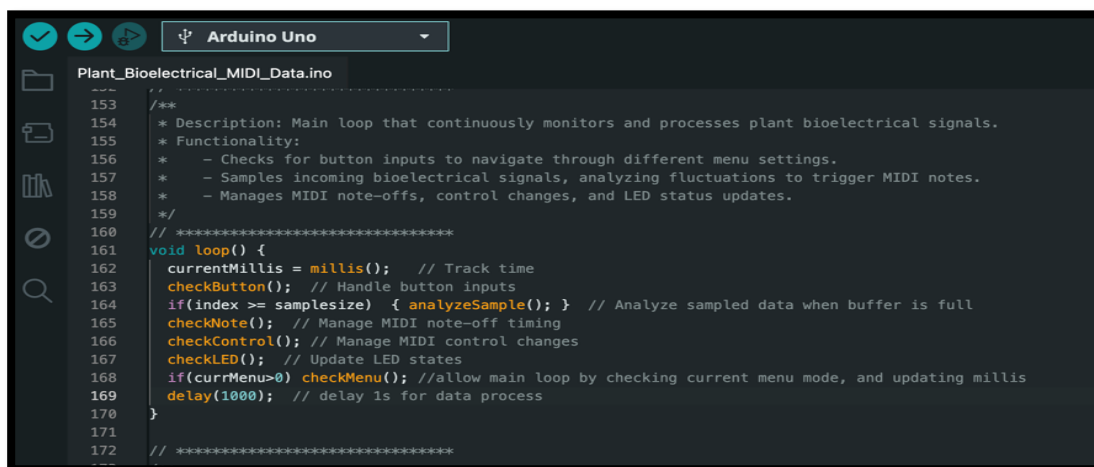
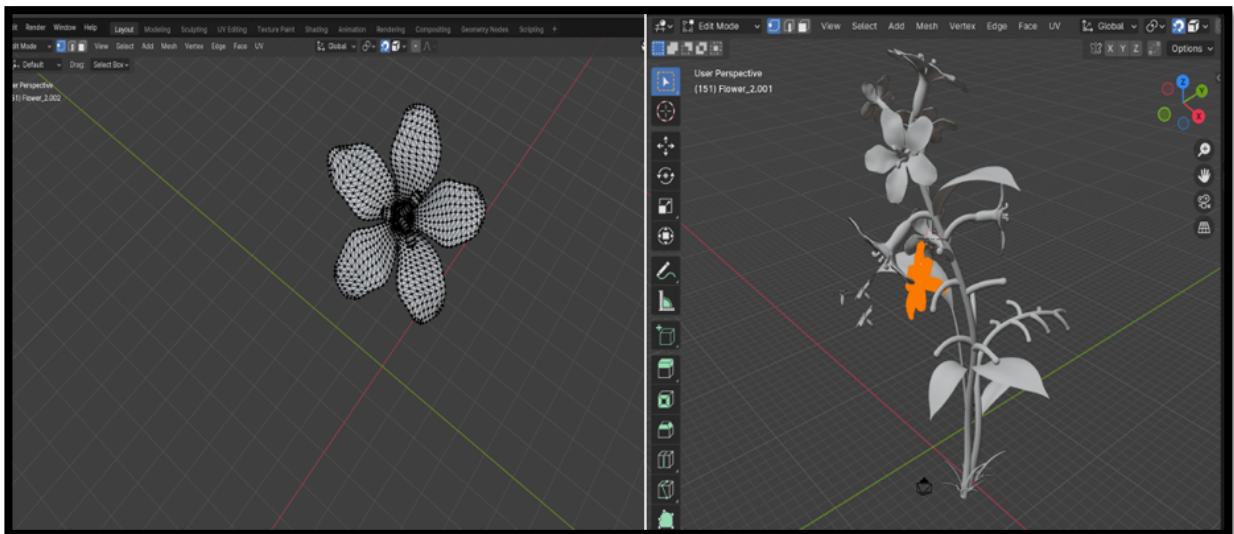


Figure 15. Reducing MIDI data frequency for smoother audio playback

### 6.3 Blender-Based Virtual Plant Modelling

Drawing from my previous studies on evening primrose, I developed a virtual 3D model of the plant using Blender for the project's visual component. The model reflects the overall structure of the plant based on my initial sketches and online references. The simplified version of the flower, stem, and leaves reflects the overall structure of the actual plant (*Figure 16*). The decision was made to maintain visual coherence and aesthetic continuity throughout the project. Since the real-time bioelectrical signals in this project are collected from a living evening primrose, the presence of a corresponding virtual plant allows the audience to intuitively perceive the link between the biological source and its digital expression. It prevents a visual disconnect between the physical and virtual elements of the installation, thereby maintaining its immersive quality.



*Figure 16. Basis of the 3d virtual plant creation process*

After completing the basic structure of the virtual plant in Blender, I created a mood board (*Figure 17*) to develop ideas for the surface and material design. I gathered references from both scientific sources and artistic works, focusing on how internal plant activity is represented visually. These references included leaf textures, tree rings, and branching vein structures similar to circulatory systems.

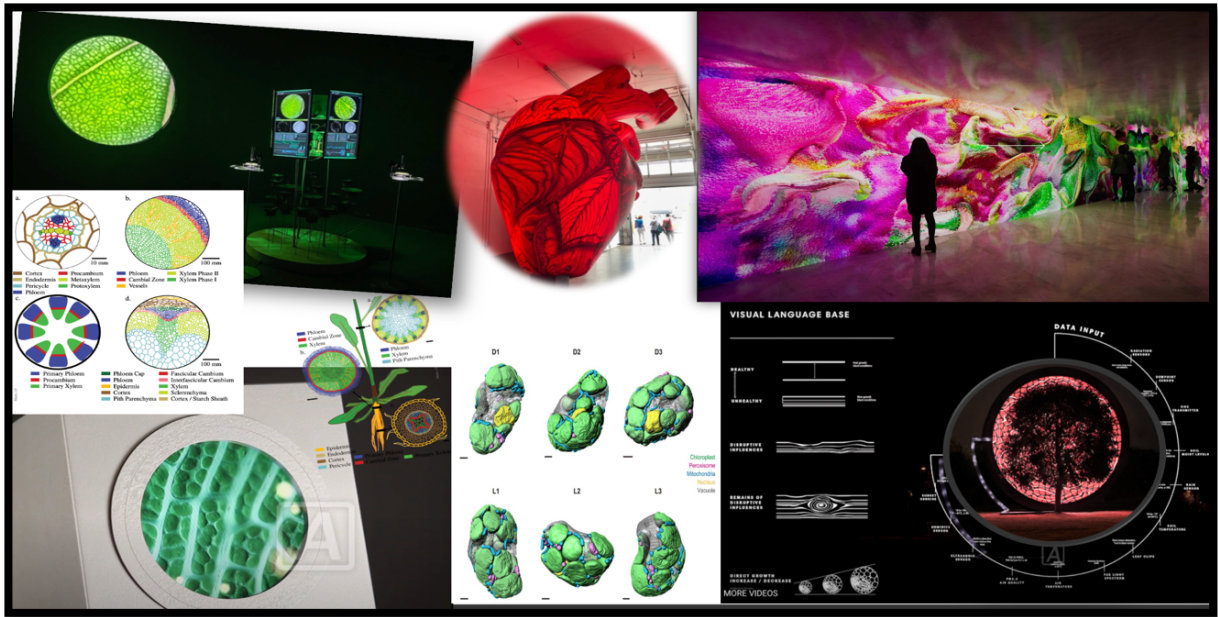


Figure 17. Mood board exploration for virtual plant design

Based on these references, I incorporated chlorophyll gradients, cortex-like networks, and layered materials into the virtual plant model (Figure 18). These components play a crucial role in various plant functions, including photosynthesis, nutrient storage, and cell-to-cell communication. The aim was to render the plant's invisible processes visible, employing a visual structure to indicate its internal activity.



Figure 18. Virtual plant model with chlorophyll and cortex inspired surface design -[Video Link](#)

#### 6.4 Real-Time Audiovisual Integration in TouchDesigner

To prepare the particle-based visualisation of the virtual plant in TouchDesigner, I exported the model from Blender in *OBJ* format and used MeshLab to convert it into *PLY* format (Figure 19). This conversion reduced the model size and enabled access to vertex positions, which were essential for generating the particle system. Since Blender does not directly support exporting vertex colour data for this purpose, MeshLab provided the structure needed to build a responsive particle-based plant. This approach helps the virtual plant react fluidly to incoming MIDI-driven audio, visually reflecting the plant's internal signals in real time.

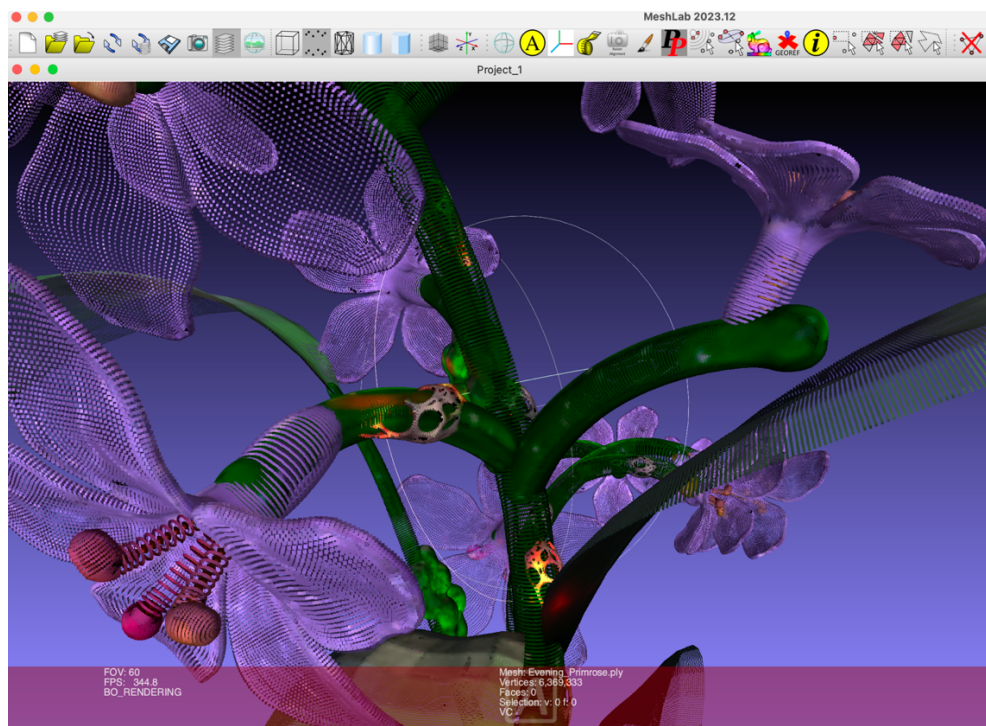


Figure 19. Preparing model geometry for particle cloud in MeshLab- [Blog post Click Here](#)

At this stage, I successfully deployed the audiovisual pipeline in TouchDesigner. I conducted testing by running the Arduino setup to capture bioelectrical signals from a live plant (Figure 20). These signals were processed by a Python script, which converted them into sound output and transferred the data to TouchDesigner. The pitch and duration of the generative MIDI sounds derived from each signal influenced the behaviour of the virtual plant particle cloud. These parameters controlled the structure, colour, and dispersal trajectory of the virtual plant. Although the test utilised a plant other than the evening primrose, the resulting dynamic flow

and motion of particles in the virtual space effectively demonstrated the intended visual outcome of the project.

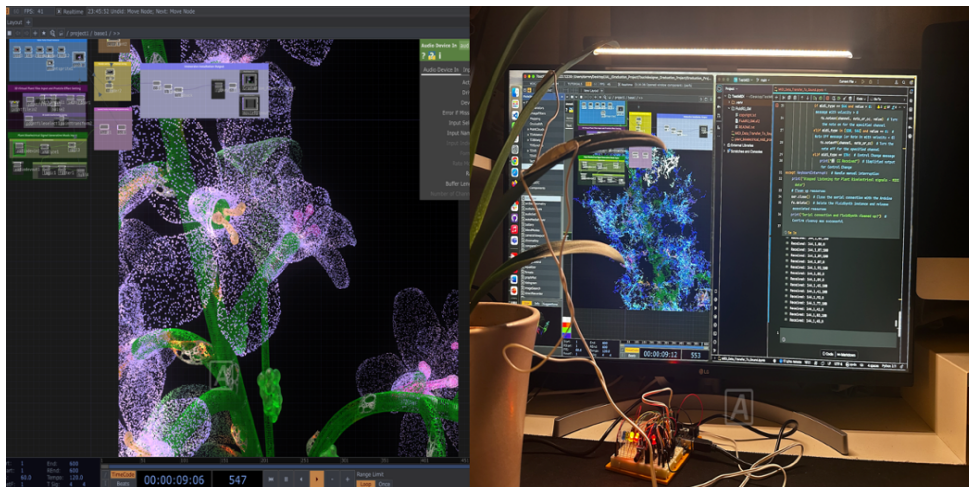


Figure 20. Deployment and Testing of the Audiovisual Components in TouchDesigner for the Project -[Blog Post Click Here](#)

Following the testing phase, I refined the visual aesthetics of the virtual plant in TouchDesigner. This refinement was guided by prior research on the ecological behaviors of the evening primrose, which becomes active after dusk and increases nectar production during nighttime to attract pollinators under low-light conditions. To visually depict this often-overlooked ecological activity of the real plant, I adjusted the Dry/Wet parameter within the Feedback TOP component in TouchDesigner (Figure 21). This adjustment generated a soft glowing effect, subtly illuminating the virtual primrose in the digital environment. The aim was to enhance visual feedback and enable viewers to perceive the subtle biological behaviors of the plant through the visual experience provided by the project.

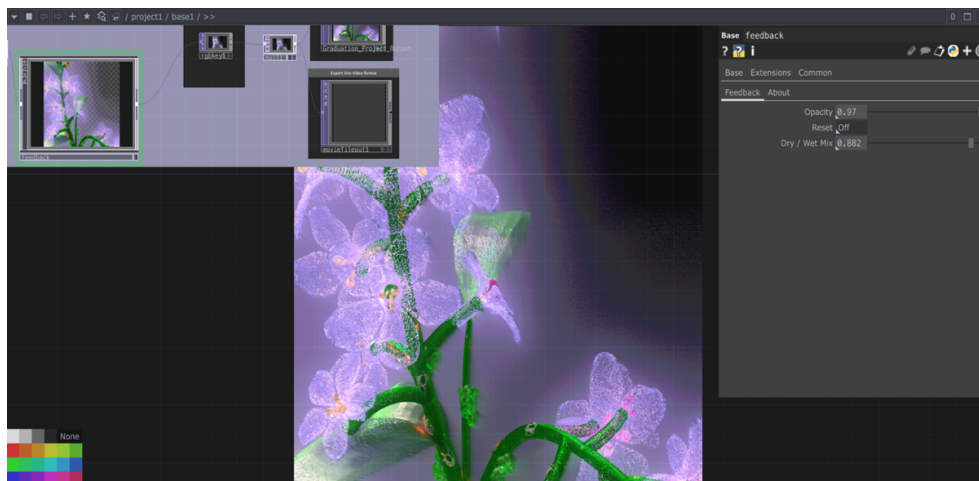


Figure 21. Soft Glow Visual Adjustment of the Virtual Plant in TouchDesigner -[Blog post Click Here](#)

During the testing phase, I conducted repeated observations of the movement of the virtual plant's particle system within the digital space. While the particles demonstrated dynamic movement in three dimensions, the overall visual presentation lacked adequate contrast and spatial clarity. To remedy this issue, I implemented a rectangular frame around the screen in TouchDesigner (Figure 22). This visual enhancement aimed to improve the depth and dimensionality of the space, thereby providing a clearer sense of structure and spatial layering within the project's visual output.

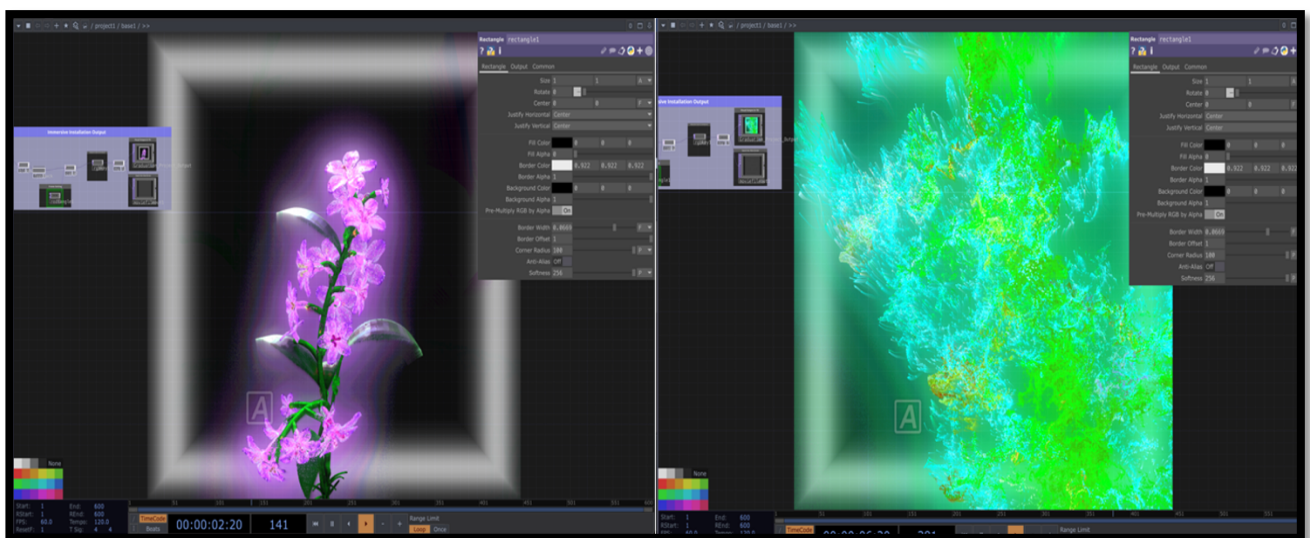


Figure 22. Addition of a Visual Border in TouchDesigner to Enhance Spatial Depth and Contrast

## **Outcome:**

All in all, my project *Silence Pulse* is an immersive audiovisual installation achieved through the integration of multiple cross-platform technologies. Specifically, Arduino hardware devices are employed to collect bioelectrical signals from the surface of plant leaves and convert them into MIDI notes. Python scripts are subsequently utilised to process these MIDI messages, generating real-time sound output that enables individuals to perceive the bioelectrical activity of plants through auditory means. Additionally, Blender software has been used to create 3D virtual plant models, exploring how the internal structure of real plants can be visually represented on the external surfaces of virtual plant structures, thus creating aesthetically perceivable forms. Furthermore, TouchDesigner software facilitates the construction of immersive virtual environments by converting MIDI audio signals into real-time soundscapes and driving the colour, structure, and movement trajectory of virtual plant particles. This results in transforming otherwise imperceptible plant bioelectric signals into tangible audiovisual sensory experiences. Through the creation process, I have developed a deeper understanding of how to integrate biological signals with real-time audiovisual projects across both hardware installation and software platforms. With the implementation of these technologies in the project, real plants form active participants in shaping and influencing this digital environment. In this installation, technology is used not only as a tool but also as a platform to enable the audience to perceive and engage with the hidden bioelectrical signals of plants.

## **Reflection and possible improvement**

Due to time and equipment limitations, the project's current version focuses solely on a single plant species for bioelectric signal collection and conversion. For future development and expansion, it could consider incorporating multiple Arduino devices connected to different plant entities, allowing for the collection of bioelectric signals from various plants under

everyday conditions. The virtual modelling techniques could be combined with audiovisual outputs generated according to each plant's unique signal characteristics. This approach would enable audiences to observe and compare the expressions of different plants both visually and auditorily. Further research could explore how environmental factors such as drought, light intensity, or temperature variations influence a plant's bioelectrical signals. These changing signals could then be analysed and mapped to visual or sonic parameters using Python scripts, allowing the audience to understand plant behaviour under varying ecological conditions and communicate these differences through context-specific soundscapes and visual responses.

**Final Outcome( *Figure 23*):**

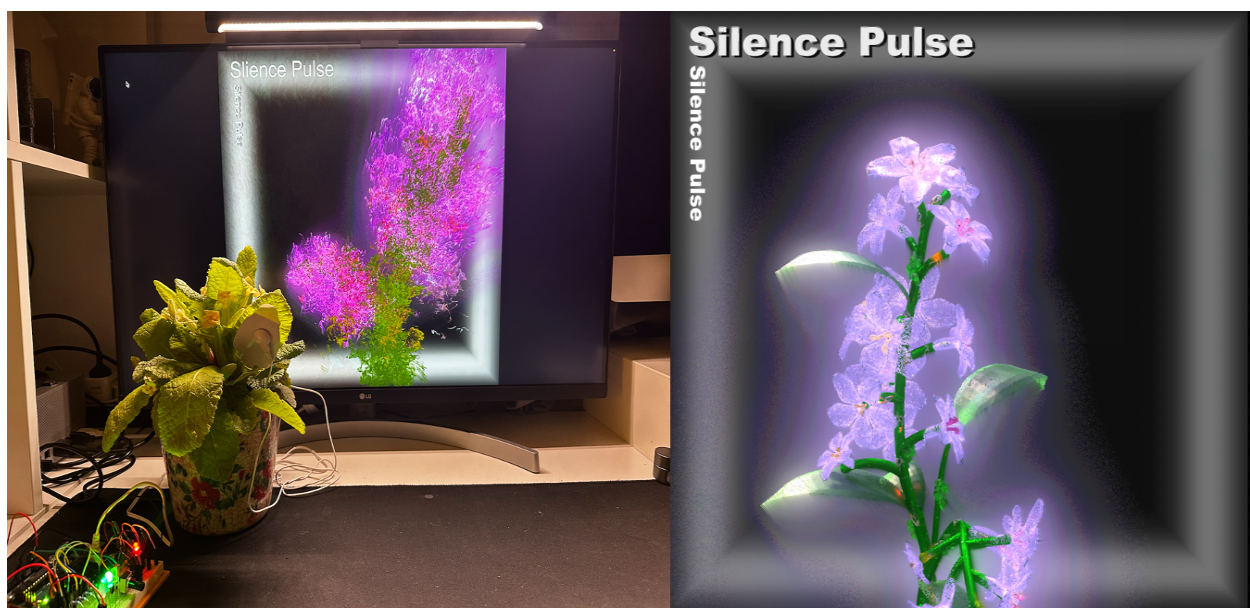


Figure 23: Silence Pulse Immersive Installation final outcome -[Blog post Click Here](#) / [Video Click Here](#)

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## AI Assistance Log

Instance	AI Tool used	Purpose	Section of the Thesis
1	Grammarly	Grammar checked	Introduction, Conceptual Framework and Literature Review, Beneficiaries
2	DeepL Translator	Translating and paraphrasing text from Chinese to English	Conceptual Framework and Literature Review
3	Cite This for Me	Generating and formatting Reference in Harvard Style	References
4	Open AI ChatGPT 4	Improving language clarity	Time management, Ideation and Conceptual Design, Design Process