Plant Sonification

Sonification of Plant's Electrical Signals

Technical Report

George Biffin (33774781)

https://github.com/Kunggings/PlantSonification

Supervisor: Dr. J. Forth

Submitted in partial fulfilment of the requirements
for the degree of BSc Creative Computing
of the University of London.
Department of Computing
Goldsmiths, University of London
28th April 2025

1 INTRODUCTION

This project explores usage of data sonification of plant bioelectrical signals as a means to reveal and interpret the living nature of plants through sound. The work investigates how real-time data from living plants can be transformed into an auditory experience and data can be represented, enabling new forms of engagement with the nature.

The outcome of the project is a gallery installation that invited participants to reflect on the hidden complexity of plants and their often-overlooked communication. The piece features two plants; one vibrant and healthy, the other wilting and in decline; offering a contrast that highlights the silent messages sent and the possibility of using this data to measure the health of plants.

Project videos are located on GIThub.

2 IMPLEMENTATION

The implementation of the plant sonification project involved a combination of hardware, data evaluation, signal processing and data sonification. From the offset it was important to consider not only end product, the sonification of the data, but to ensure accuracy of data collection. Early experiments with reading plant response informed both the technical and aesthetic development of the piece. The electrical signals are collected from two plants; one healthy; one dying, via conductive electrodes. These signals are amplified and filtered using a combination of the ECG sensor module (AD8232)[1] and Arduino[2], allowing subtle voltage fluctuations to be read. The AD8232 is specifically designed for measuring the electrical activity of the heart but after testing, can also be used to detect the small electrical signals of plants. The amplified signals from the AD8232 are then run through a noise reduction algorithm on the Arduino and are formatted correctly for supercollider. These “cleaned and formatted signals” are sent to SuperCollider[3] on the serial port to be sonified. Within SuperCollider the signals form the Serial port must be converted to from Ascii to character values[4]. The incoming values are mapped to various sonic parameters; including pitch, amplitude, and timbral changes; resulting in a reactive soundscape that evolves in direct response to the different plant’s electrical signals.

2.1 HARDWARE

2.1.1 Amplifying Signal - AD8232

One of the most important pieces of hardware were the components was the amplification of the electrical signals collected form the electrodes. I considered using general purpose amplification boards such as AD623[5]. However, ultimately, I decided to continue to use the AD8232 as it's what I used in my heart rate monitor prototype. When tested in this context—connected to a plant rather than a human subject—the AD8232 still performed well, successfully picking up subtle fluctuations in voltage that I could then work with for sonification. To create a second signal very little modification was required, it was simple to add a second AD8232 to the Arduino.

2.1.2 Arduino

When selecting a microcontroller / single board computer to handle the data input, I had a few different options: Bela board[6], Arduino and Raspberry Pi[7]. Each platform offered distinct advantages suited to different aspects of the project.

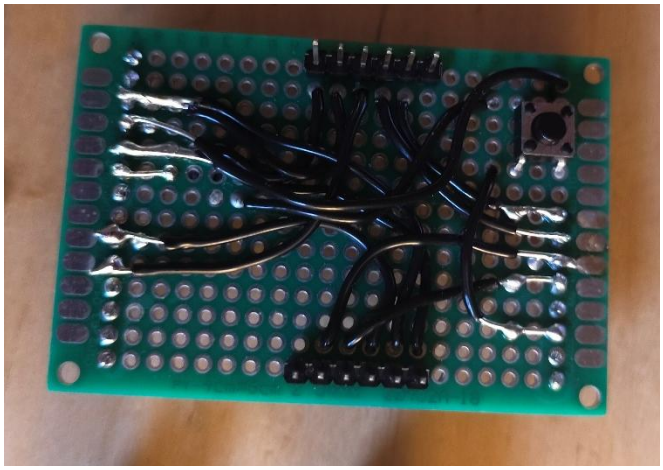
Bela was appealing due to it having the lowest audio latency and being purpose built for real time audio processing. However, I had very limited experience working with Bela, and it is a relatively expensive piece of hardware that I would have needed to rent. This would mean that the project wouldn't be permanent and difficult to transport.

Raspberry Pi, would have allowed a single system solution. It could have managed both the AD8232 sensor data and signal processing, while also running SuperCollider for sound synthesis. Again, due to my limited experience with the platform and the time constraints of the project, I ultimately chose not to pursue this option. The steep learning curve required to get everything running effectively could have shifted my focus away from the core creative and conceptual aims of the project.

Ultimately, I chose to use the Arduino. While it offers fewer features and capabilities, it is a platform which I am much more familiar with. Its simplicity, small size, and ease of use allowed me to concentrate on the implementation of the sonification itself, rather than getting bogged down in hardware or software complications. This made the development of the technical parts of the project much quicker and less issue prone.

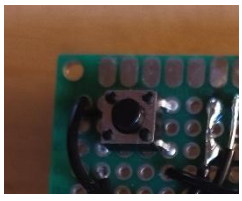
2.1.3 Circuit layout – The Hat

Having had issues in the development stage with different Arduinos boards and signal stability. I decided to make a hat (or shield) for the Arduino, allowing me to simply swap in and out the boards without having to rebuild or rewire the entire circuit. This approach came with the benefit of increasing the durability and stability of the circuit board.



2.1.4 Button

I decided include a button so the users could swap between audificaiton and sonfication modes. I felt it was a good idea to provide the raw data and the processed data, offering a more comprehensive understanding of the signal. I opted for a push button rather than a switch simply because it's what I had access to but also because it offered greater flexibility. A push button would make it easier to implement additional modes in the future without changing the hardware.



2.1.5 Casing

I 3D printed a simple casing to house the hardware, while I thought about making a watertight system to help protect the sensor during plant watering. I decided this was beyond the scope of

my project and added very little practical benefit. The simple case offers a small amount of protection and hides the hardware from the user, removing the focus from it. This minimal design choice helps maintain the aesthetic and conceptual clarity of the installation.

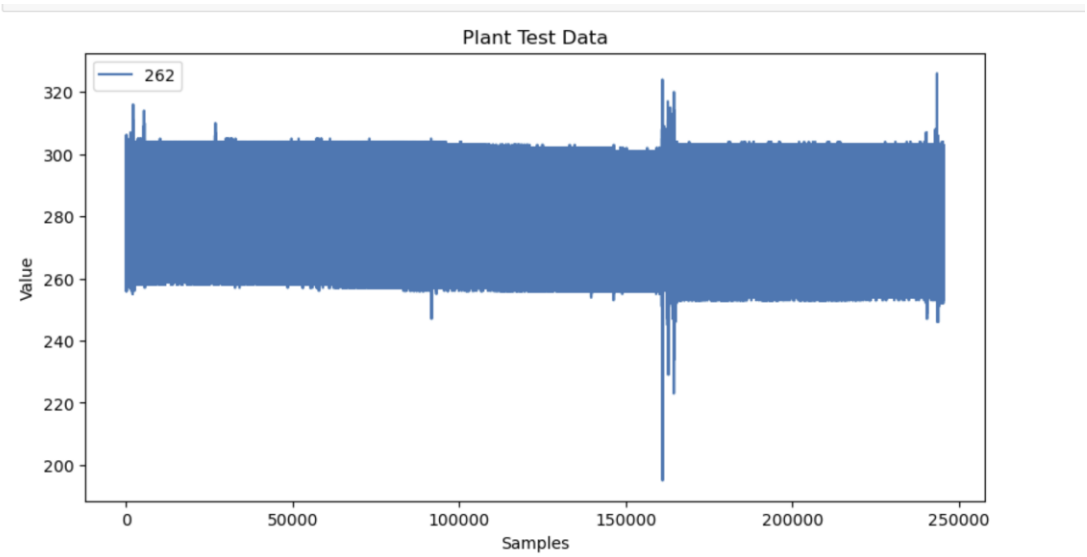
2.2 Data Evaluation

2.2.1 CSV

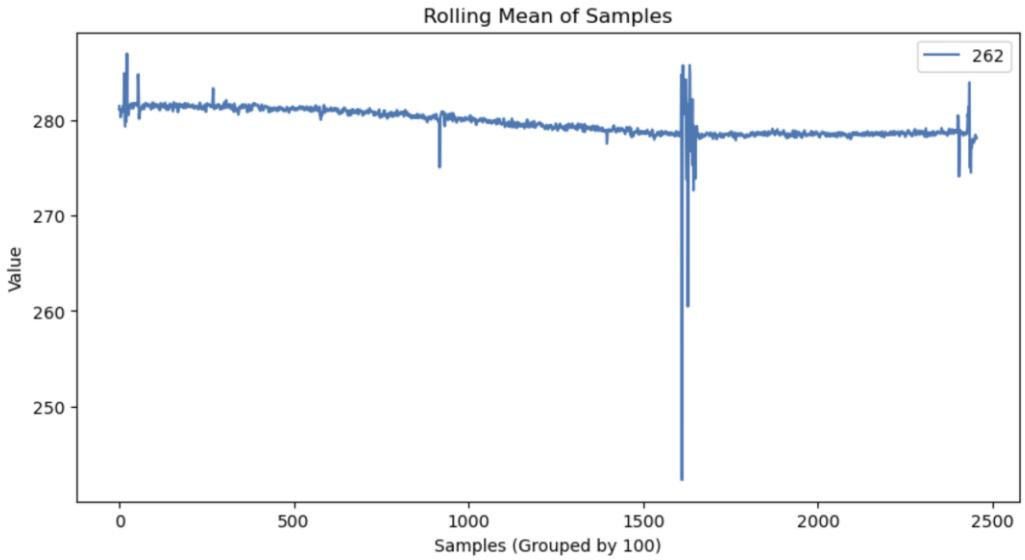
Before I could sonify the data, I first needed to understand its nature. As the data set is large, taking many samples per second I wanted to visualize the data graphically , so the flow of data can be understood better. To do this I needed the data form the serial port to be added to a csv file. Arduino can create and upload the data to a csv, however its much easier to directly read the data from the serial port on the pc. I used CoolTerm [8], to export the serial port data to csv. From the csv I plotted the basic data and found that there was a lot of noise within the data and that there was a major spike in activity when the light was turned off.

2.2.2 Noise Reduction

As the data is quite noisy but also prone to very few spikes, I wanted to keep quite a simple noise reduction algorithm. I went with a rolling mean algorithm[9]. Simple but effective, it smooths out the noise and the windows size can be adjusted to the desired effect.



Original Data



Rolling Mean Data (Peak at roughly 1700 is when light was turned off)

2.2.3 Data Analysis

Using the describe function simply shows where the data lays and the ranges I should be using to map. It also gives me an idea of the deviation in the data .

count	245405.00
mean	279.72
std	16.78
min	195.00
25%	263.00
50%	280.00
75%	296.00
max	326.00

2.3 Signal Processing

2.3.1 Serial Port – Input

When the Arduino reads the data form the two AD8232's it prints them to the serial port and places and A and B be after. This is for the ASSCII conversion (explained in next subsection). Originally, I use a new line to represent each line of data, however it became quite complex to determine when a newline was happening and if the data was slow to process the steams could get interlinked, with each other. This happened because there was no key for the data telling you where it was from. So instead, I used letters of the alphabet to represent the key for the data, when you come across a new key it's a new piece. This also made it incredibly easy to implement swap modes (explained later).

```
  Serial.print(analogRead(SENSOR_A_READ)); // Otherwise, read and send Sensor A value
}
Serial.print("a")

// Sensor B
if ((digitalRead(SENSOR_B_NEGATIVE) == 1) || (digitalRead(SENSOR_B_POSITIVE) == 1)) {
  Serial.print('!'); // If sensor B lead-off detected, send '!'
} else {
  Serial.print(analogRead(SENSOR_B_READ)); // Otherwise, read and send Sensor B value
}
Serial.print("b")
```

376b322a315b344a349bc347a344b314a318b374a379b292a283b398a407b2

a and b determine which sensor the data has come from, they are used as the “key” when c is pressed the mode changes it, this is skipped over when reading the data so can be placed as soon as possible.

2.3.2 ASCII Conversion

When super collider takes the data form the serial port it is in an ASCII format. This then has to be converted back into int values so they can be processed. Each digit is converted to an int, added to an array and combined to output the whole number. A new number is defined when an ASCII value is either “a” or “b”(65 or 66). Depending on whether it is a or b determines which plant it is coming from and which synth to send it to.

```
if(ascii.isDecDigit, {
    ~charArray = ~charArray.add(ascii); // Add digit to charArray if it's a decimal digit
});

if(ascii == $a, {
    ~valB = ~charArray.collect(_.digit).convertDigits; // Convert charArray to valB
    ("B: ").post; ~valB.postln;
    ~charArray = [ ]; // Reset charArray
});

if(ascii == $b, {
    ~valA = ~charArray.collect(_.digit).convertDigits; // Convert charArray to valA
    ("A: ").post; ~valA.postln;
    ~charArray = [ ]; // Reset charArray
});
```

2.3.3 Swapping Mode

To swap modes between sonification and audification, when the button is pressed it simply outputs an “c” to the serial port. This tells supercollider that it should swap modes. As this is a letter of the alphabet it is not read as data and will not mess up the ASCII conversion. It also has the benefit of being able to be placed anywhere in the data.

```
if(ascii == $c, {
    ~mode = ~mode.not; // Toggle mode between audification and sonification
    ("Mode toggled: ").post; ~mode.postln;
});
```

2.4 DATA SONIFICATION

2.4.1 Super Collider

I looked at a couple methods of sonification including, Midi Conversion[10], Pure Data[11] and Super Collider. I chose super collider because I wanted to gain experience using it and has the deepest level of customization.

2.4.2 Audification

For the Audification a simple saw wave is used, simply maps the frequency and then plays it. I panned the signals, right and left to give each signal a speaker. I would have used a different channel however I had issues getting it to work. The signal similarly couldn’t be muted so I used

gates to remove.

```
SynthDef(\saw, {
    |freq = 440, cutoff = 1000, gate = 1, pan = 0| // Saw synth with frequency and panning
    var sig, env;
    env = EnvGen.kr(Env.asr(0.01, 1, 0.5), gate); // Envelope generation
    sig = Saw.ar([freq, freq * 1.01]);
    sig = RLPF.ar(sig, cutoff.lag(0.02), 0.25, 0.2); // Resonant low-pass filter
    sig = sig * env; // Apply envelope
    sig = Pan2.ar(sig, pan); // Apply panning
    Out.ar(0, sig); // Output audio
}).add;
)
```

2.4.3 Sonification

For the sonification I created a simple piano that maps the value. I wanted to use mdaPiano[12] however I had issues with installing the plugin. The notes are then played at random intervals to make it sound more natural and musical. Sonification was kept far more simple and originally intended to, however this will be covered in evaluation.

```
SynthDef(\simplePiano, {
    |freq = 440, amp = 0.2, gate = 1, reverbMix = 0.3| // Simple piano synth with reverb
    var env, sig, reverb;
    env = EnvGen.kr(Env.perc(0.01, 1.2), gate, doneAction: 2); // Envelope generation so synth can be muted
    sig = Mix.new([
        SinOsc.ar(freq, 0, 0.5), // Sine oscillator
        Saw.ar(freq * 2, 0.3) // Sawtooth oscillator
    ]);
    sig = LPF.ar(sig, freq * 3); // Low-pass filter
    sig = sig * env * amp; // Apply envelope and amplitude
    reverb = FreeVerb.ar(sig, 0.9, 0.5, reverbMix); // Reverb effect
    Out.ar(0, reverb.dup); // Output audio
}).add;
```

2.5 Degree Show

The project concludes with an exhibition as part of the degree showcase where I intend to demonstrate the live sonification of plants. Throught the development of my project it has gradually shifter from being primarily an artistic project to being more of an exploration. It has served as a valuable opportunity to expand my knowledge within signal processing and data representation.

When it comes to the presentation within the exhibition, I plan to keep the physical setup intentionally minimal. Similar to Plant machete[13] so that the physical is not distracting from the auditory experience. The display will feature plants and headphones for individual listening. This decision was made to, so the exhibition is immersive and personal, without contributing to the ambient noise levels of the wider exhibition space. By creating a quieter, more introspective experience, I hope to encourage visitors to engage more attentively with the subtle nuances of the variation and patterns of the sonified data.

3 Evaluation

3.1 Success Criteria

To determine the success of my project, my evaluation focuses on the three main areas: the ability of the installation to raise awareness of bioelectric activity, the emotional and sensory engagement of the participants and the contrast of between the healthy and wilting plants. I designed a survey to ask participants their options and experience of the installation, I hoped to gain clarity on of their sound experience and the overall aesthetic of the installation. I chose to

use a survey because it allowed me to gather both quantitative ratings and open-ended feedback, helping me understand not just what participants thought, but also how the piece made them feel and reflect. To make the survey accessible to a wider audience beyond those who could physically visit the installation, I recorded a video walkthrough of the installation and shared it alongside the survey, allowing participants to experience the work remotely before giving their feedback.

3.1.1 Data Collection

The participant must have completed Participant information sheet (see appendix). This states that personal information about the user is not collected, and data collected will only be kept and used for a specified period of time. This is done for the privacy and protection of survey participants.

3.1.2 Data Evaluation

The survey data collected for the plant sonification project, while derived from a relatively small sample size, provides valuable insights into user perceptions and engagement. Participants were encouraged to approach the survey with an unbiased perspective, allowing for more authentic responses. Despite the limited sample size, the feedback gathered offers a foundational understanding of how users relate to and interpret the sonification of plant signals, which will help inform further development of the project.

3.2 Data Analysis

Key Findings

The project appears to have influence people's perceptions of plants. With the majority expressing a change or development of the viewpoint. This shit in opinion suggest that the project successful engages the individual in a deep way. It expands their appreciation for plants and highlights their often overlooked importance.

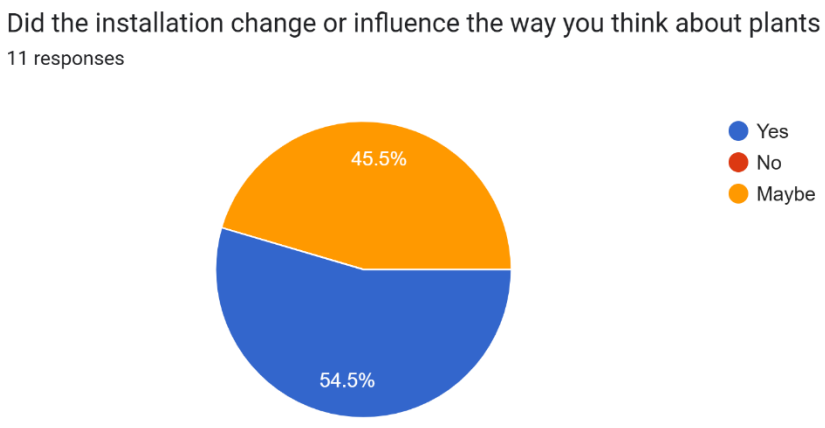


Figure 1

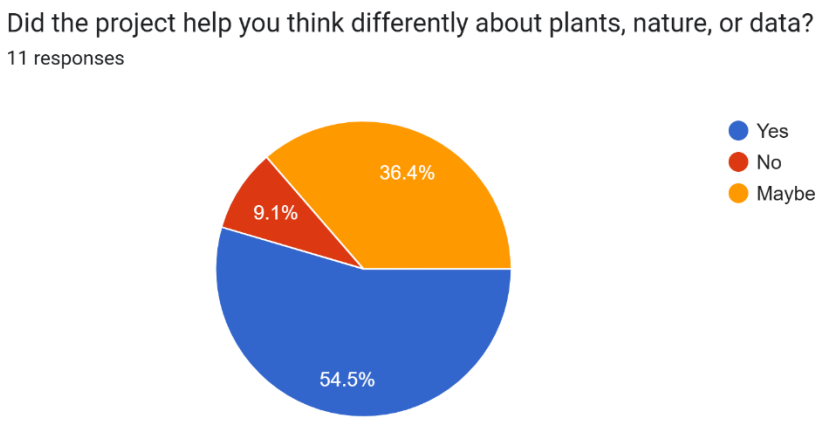


Figure 2

Figure 1 shows that all the users either felt that information changes or potentially had an effect on their understanding of plant communication. This is significant because positive or negatively their perspective changed, which is a key focus for the project.

Figure 2 suggest a similar finding, this question was more generalised to the project how it support a similar notion that the project changes opinion or is impactful to the audience.

While the project successfully engaged the participants in many aspects, the sonfication did not evoke the emotion response I had hoped for. The sound was designed to evoke a feeling of sadness or pain, with on of the main themes of the project focusing on loneliness.

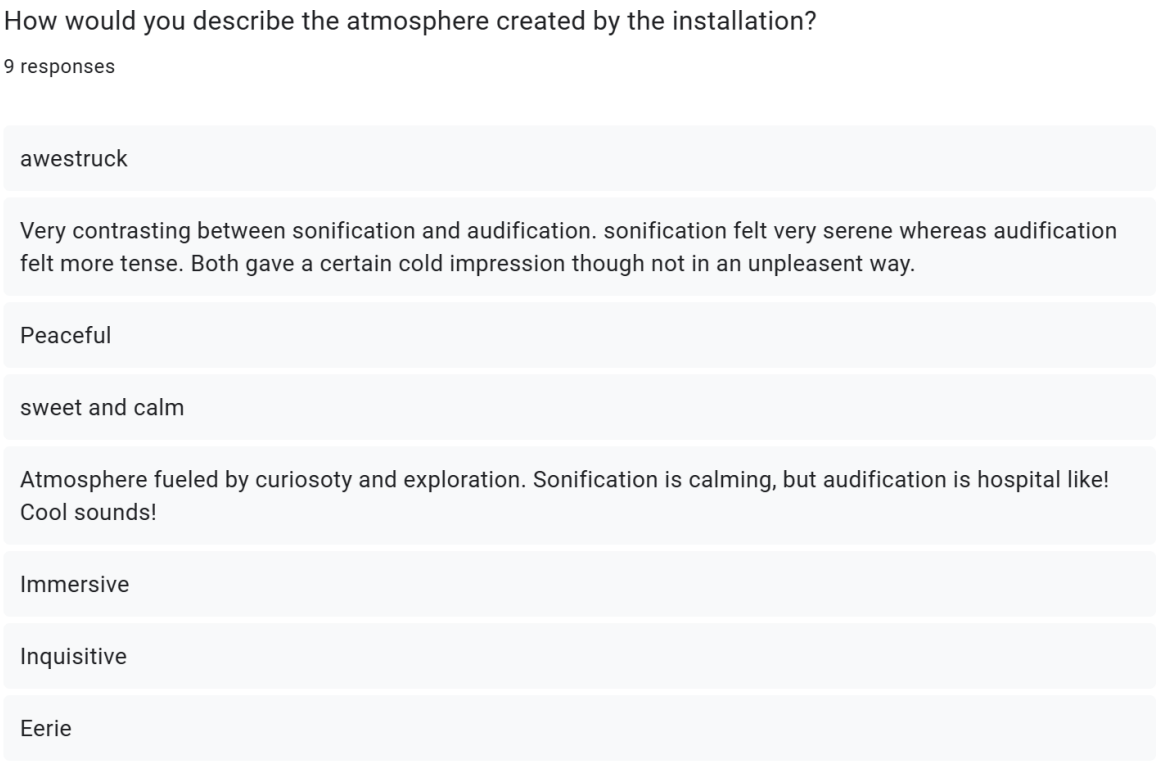


Figure 3

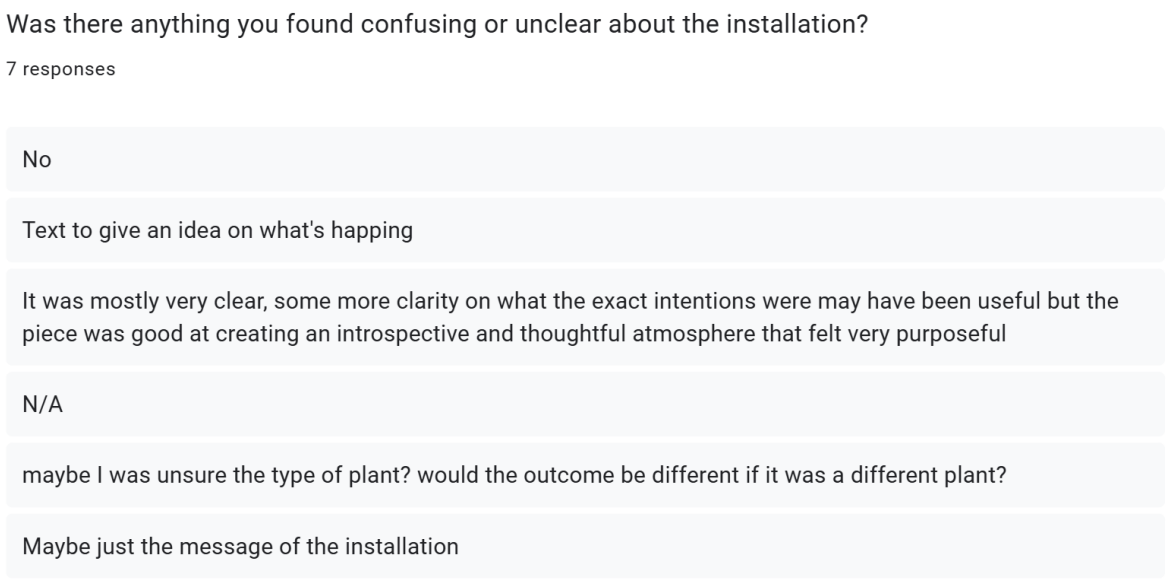


Figure 4

Figure 3 shows some of responses, they suggest that the project seemed to create an atmosphere of peace rather than one of loneliness or sadness. It may be necessary to better align the auditory experience with the desired response in future version. Figure 4 suggest that the projects intension could be conserved as unclear, partly due to the lack of responses. For the exhibition I hope to provide a deeper explanation about what the people means and the artistic intent.

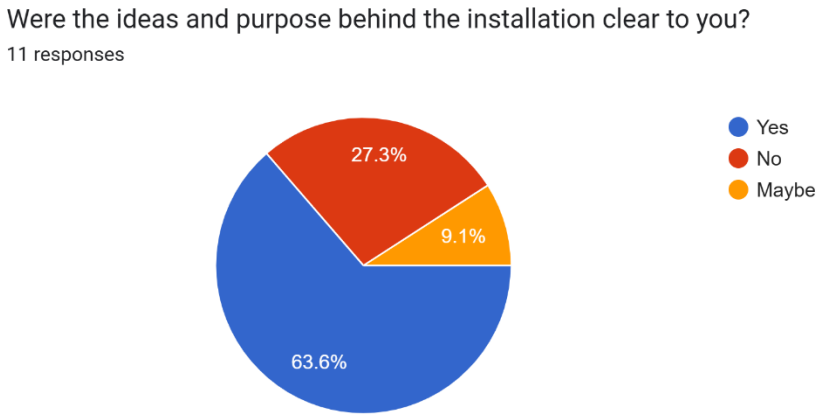


Figure 5

Figure 5 seems to contradict this notion, as it shows that the audience interpreted the project in a variety of ways. This suggests that while the intended emotional response may not have been universally evoked, the sonification still allowed room for personal reflection and interpretation. Many participants expressed different views on what the project represented to them, with some finding the atmosphere calming or meditative, while others described it as thought-provoking or reflective.

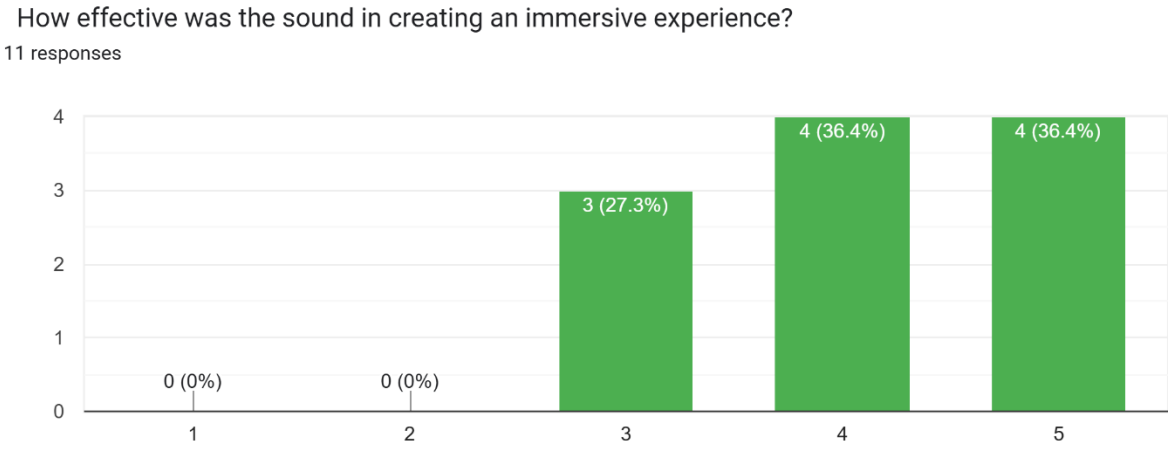


Figure 6

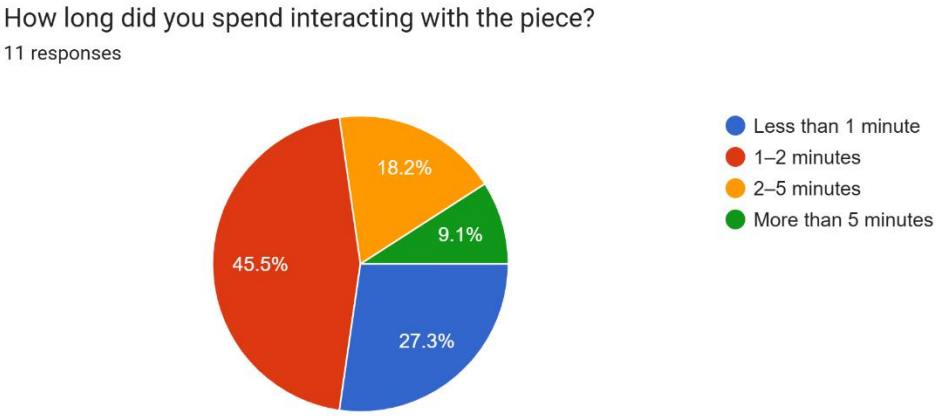


Figure 7

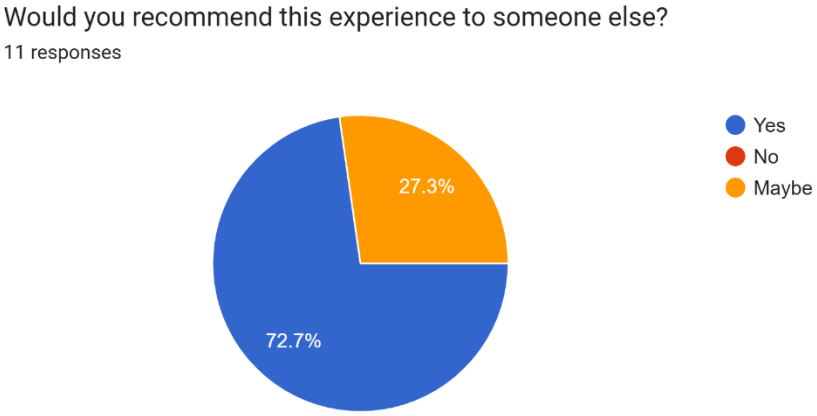


Figure 8

The Overall project seemed to be positively perceived with a high with an average rating of 4.1/ 5, shown in figure 6. This is somewhat contradicted by the short interaction timing stated in figure 7. The majority of users spent less than 2 minutes viewing the piece. However I believe this is because the survey was based on short videos (roughly 20sec) rather than the physical expedition planned for the future. This makes this data quite unrealistic. In Figure 8, almost everyone would recommend the installation to someone else, so it suggests that, despite the brief interaction time, the overall experience was still engaging and positively received. This could indicate that while the duration of engagement was shorter than expected, the impact of the installation left a strong, favourable impression, leading to a high level of recommendation. Throughout the survey many people suggest more visual elements rather than just auditory.

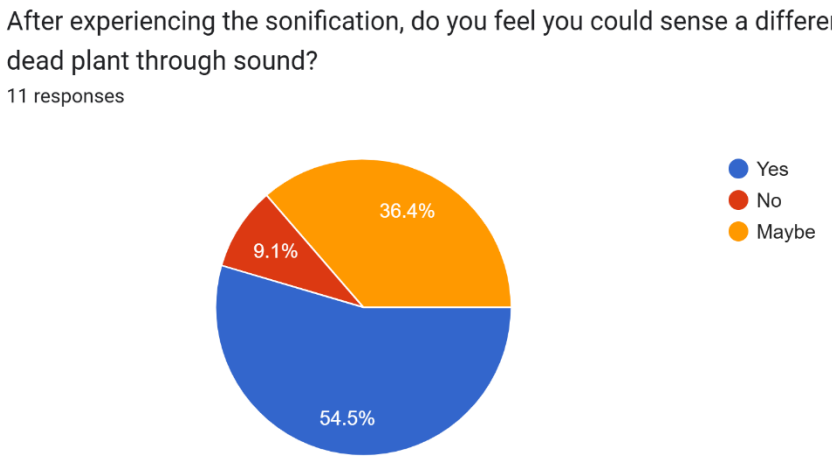


Figure 9

Figure 9 tell us that the project meets the requirement for audience members to sense the difference between the living and the dead plant. The audience members felt the could hear the difference between the plants and it help meaning them.

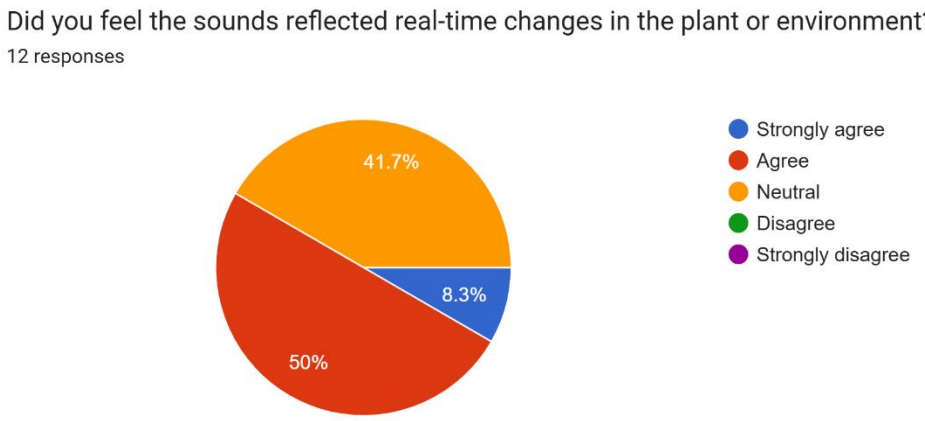


Figure 10

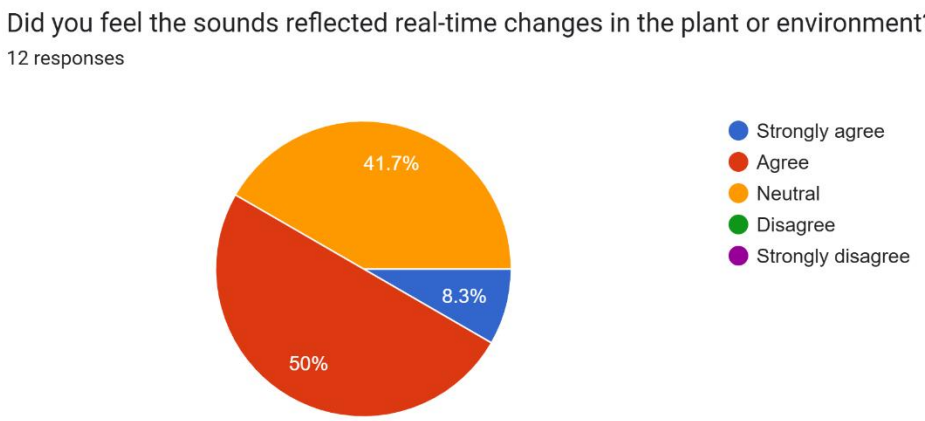


Figure 11

Figures 10 and 11 both showcases how the audience seem to have little understanding of the electrical signals of plant and then understood how the response to real life stimuli can be presented. This shift in understanding indicates that the project not only engaged people on an emotional level but also introduced them to a novel scientific concept in a way that was accessible and thought-provoking.

3.3 Reflection

To improve the project, I have a few points from the survey and some self-reflection on the project.

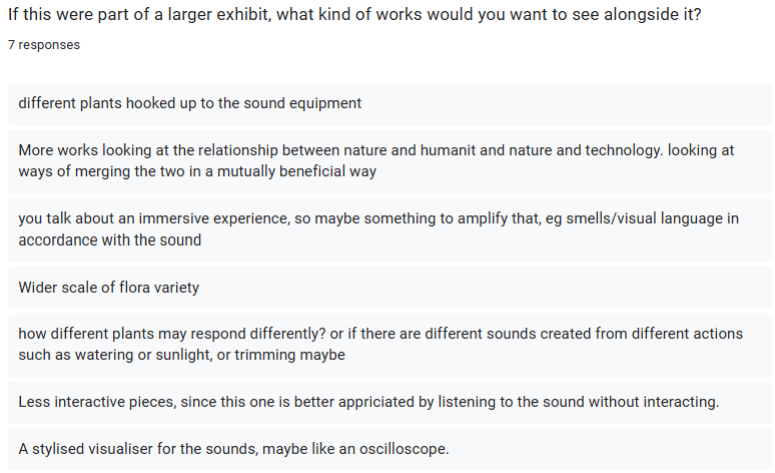


Figure 13

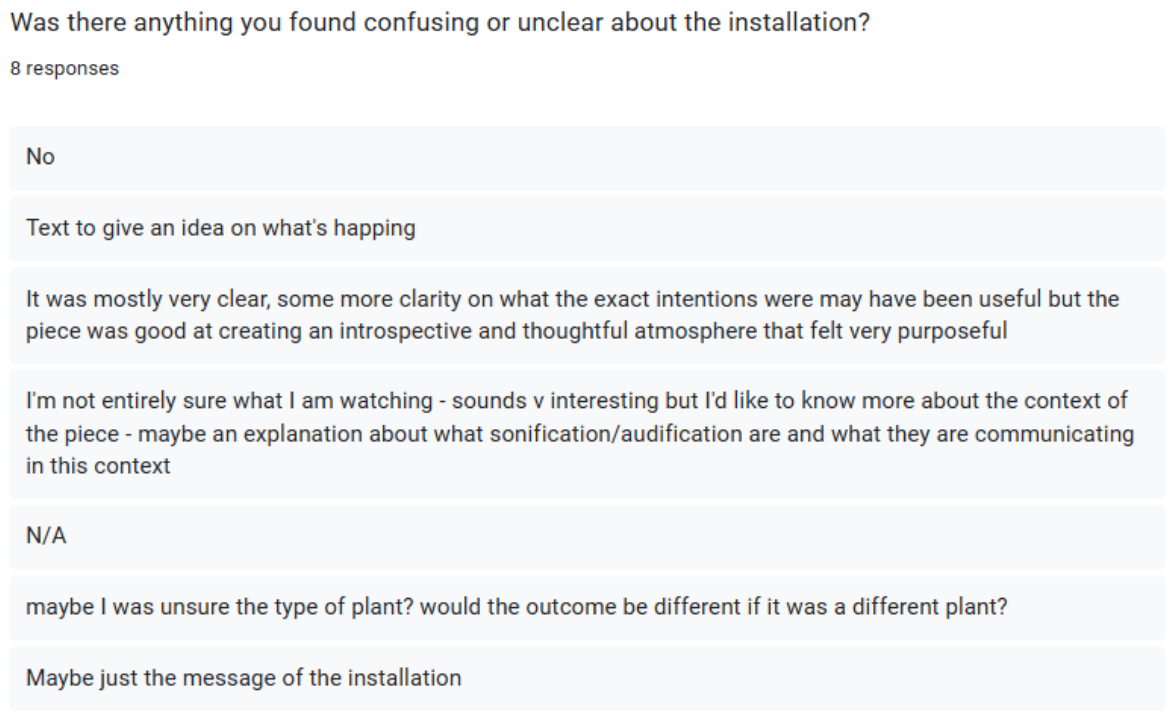


Figure 14

There are 3 key reflection points from the survey (Figure 13 & 14). Firstly type of plants, many of the participants stated that using different plants or plant that have a more defined reaction to stimuli such as mimosa plant[14] could be more interesting and impactful. I feel when it comes to the exhibition it may be a good idea to create a small echo system with many plants where the sensors can be moved around. This would make the piece more interactive and interesting, which from the feedback is an area that could be improved.

Secondly clarity on the intensions of the piece, similarly with the gallery exhibition information and someway to inform viewers of the intensions of the piece would be useful. As stated in the overview of the project this is an exploration, artistic piece rather than research so it would be useful to present it in this form.

Finally, although not demonstrated in the video, SuperCollider can generate a default oscilloscope, it may be a useful way to demonstrate and better understand the data. This was also a point that was made during the project spec. Making the piece inclusive for all users regardless of auditory capabilities. The only consideration is to make sure the visuals don't take away from the auditory experience.

Personal Reflection

Overall, I am pleased with how the project turned out, especially considering the technical challenges I faced throughout the process. The concept of using plant data for sonification was something I found really exciting, and seeing it come to life, even in a simple form, was very rewarding. However, there are aspects that I know could be improved. The sonification itself ended up being far too simple compared to what I had originally envisioned. I had hoped for a more complex and dynamic output, but limitations in both the software and my experience meant that the final version was quite basic.

Another major issue was the sensitivity of the sensor and its accuracy. I would explore different options further for sensor in the hopes to reduce noise and have less problems with hardware. I would also be interested in exploring different plants and more artistic versions of the project. Despite this the outcome reached my mvp and I achieved my goal of exploring sonification and reading plant signals.

4 CONCLUSION

Overall, the project has been a success, meeting the Minimum Viable Product (MVP) goals and successfully achieving real-time sonification of plant data. Throughout the development process, I gained a significant amount of personal experience, particularly in building custom hardware and working with SuperCollider for sonification. However, the project turned out to be much more challenging than initially expected causing the scope seemed to grow substantially. I understand better the importance of clearly defining and containing a project's goals early on. Having a more tightly scoped and well-articulated plan would have helped maintain focus and allowed more time to be spent refining the sonification itself, rather than being caught up on hardware and technical hurdles.

There are a few key improvements that must be made for future development Firstly, I would invest in a different, more reliable sensor, one that provides consistent and accurate readings, to reduce time spent troubleshooting hardware issues. Secondly, I would split the project into two phases that focus solely on hardware and sonfication so more time could be dedicated to each. In this current version majority of the time was taken up by building and debugging hardware rather than the complexity / improvement of the sonfication.

Additionally, I encountered a major problem when defining the project. It seemed to oscillate between a technic exploration and an artistic installation. This lack of clarity slowed development and meant the project lacked design direction. I would commit to one earlier rather than trying to both and balancing it.

To conclude, although I had many difficulties, the project overall successfully demonstrated the core concepts and provided me with new insights and skills. With more refined planning and clearer project definitions, being a key learning outcome.

5 APPENDIX

5.1 PARTICIPANT INFORMATION SHEET

Declaration by Participant
Please tick to confirm:

☐ I have read the **Participant Information Sheet** (PR/002), overleaf, and consent to take part in Plant Sonification

If you are happy to be identified in materials (see PR/002) relating to you participation, please tick each of the options that you agree to:

☐ I consent to being **referred to by name**

☐ I consent to being **referred to by my place of work**

☐ I consent to being **referred to by my position / title**

If you **wish to be fully anonymised** in any such materials, please instead tick here only: ☐

Name of Participant (please print): _____

Contact details of the Participant: Email _____ Phone _____

Date (DD/MM/YYYY): _____

Declaration by Researcher

I have provided the above participant with "Participant Information Sheet (PR/002)", given the participant the opportunity to ask further questions, and believe that the participant has understood the process.

Name of the Researcher (please print): _____

Date (DD/MM/YYYY): _____

Participant Information Sheet (PR/002): Plant Sonification

Thank you for your interest in this research project. Your participation is very much appreciated. This Participant Information Sheet explains what will happen if you choose to take part in this evaluation study.

My name is George Biffin. This survey is for my plant sonification project, the data will be used to evaluate the success of the project. This is for my final year project at Goldsmiths, University of London.

You will complete a singular survey, with a range of questions on the aesthetic and technical implementation of the project. You may complete this after seeing a video or the project in person. All questions will be entirely voluntary, and you may refuse or refrain from answering any questions. You have the right to withdraw from the study at any time.

You can clarify on the Participant Consent form (PR/001) whether you consent to your identifiable information (name / organisation / position) to be included in the project report.

This identifiable information (your “personal data”) will be stored securely by the principal project researcher.

Your data will be held for up to six months after the end of the project (expected Oct 2025), and then securely destroyed. You can request a copy of your data at any time before this date.

What if I have any questions relating to my data or want to withdraw my personal data?

You can send any questions relating to the processing of your data or request to withdraw your personal data by contacting [george.biffin@gmail.com].

If you have any concerns about the processing of your personal data or your information rights, please see the University’s data protection web pages. Or contact the Data Protection Officer: dp@gold.ac.uk

You can also contact the Information Commissioners’ Office – https://ico.org.uk – in relation to any concerns or issue you may have with the processing of your personal information.

6 REFERENCES

[1] ‘ad8232.pdf’. Accessed: Apr. 28, 2025. [Online]. Available: https://www.analog.com/media/en/technical-documentation/data-sheets/ad8232.pdf

[2] ‘Arduino - Home’. Accessed: Apr. 28, 2025. [Online]. Available: https://www.arduino.cc/

[3] ‘index’, SuperCollider. Accessed: Apr. 28, 2025. [Online]. Available: https://supercollider.github.io/

[4] I. A. http://www.injosoft.se, ‘ASCII table - Table of ASCII codes, characters and symbols’. Accessed: Apr. 28, 2025. [Online]. Available: https://www.ascii-code.com/

[5] ‘ad623.pdf’. Accessed: Apr. 28, 2025. [Online]. Available: https://www.analog.com/media/en/technical-documentation/data-sheets/ad623.pdf

[6] ‘Create beautiful interaction.’, Bela.io. Accessed: Apr. 28, 2025. [Online]. Available: https://bela.io/

[7] R. P. Foundation, ‘Teach, learn, and make with the Raspberry Pi Foundation’, Raspberry Pi Foundation. Accessed: Apr. 28, 2025. [Online]. Available: https://www.raspberrypi.org/

[8] ‘CoolTerm’, LO4D.com. Accessed: Apr. 28, 2025. [Online]. Available: https://coolterm.en.lo4d.com/windows

[9] H. Amit, ‘What is Rolling Mean and How to Use It with NumPy?’, Medium. Accessed: Apr. 28, 2025. [Online]. Available: https://medium.com/@heyamit10/what-is-rolling-mean-and-how-to-use-it-with-numpy-d4ff4c85ceb9

[10] SYSTEM Sounds, *Sonification with Python - How to Turn Data Into Music w Matt Russo (Part 1)*, (May 02, 2022). Accessed: Apr. 28, 2025. [Online Video]. Available: https://www.youtube.com/watch?v=DUdLRy8i9qI

[11] ‘Pure Data — Pd Community Site’. Accessed: Apr. 28, 2025. [Online]. Available: https://puredata.info/

[12] ‘MdaPiano | SuperCollider 3.12.2 Help’. Accessed: Apr. 28, 2025. [Online]. Available: https://doc.sccode.org/Classes/MdaPiano.html
[13] ‘plant machete’, David Bowen. Accessed: Apr. 28, 2025. [Online]. Available: https://www.dwbowen.com/plant-machete
[14] A. G. Volkov, J. C. Foster, K. D. Baker, and V. S. Markin, ‘Mechanical and electrical anisotropy in Mimosa pudica pulvini’, *Plant Signal. Behav.*, vol. 5, no. 10, pp. 1211–1221, Oct. 2010, doi: 10.4161/psb.5.10.12658.