Mycorrhizal Networks, or How I Hack Plant Conversations

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Introduction

In this project, I introduce the idea of interaction between elements of different kinds, which includes transport of information passed during the interaction process. In one case, the interaction appears in a natural environment where fungi act as an interface between the interacting plants; in the other case, I introduce an electronic interface between organic elements and a computer to translate chemical activity into digital information, and vice versa. The idea of intermediary interfaces is that, while passing information, they act as proxy servers, being able to change the information that is passed and send it further to the target destination. The idea is represented within a kit that includes diverse organic and inorganic elements, along with tools to execute the experiments described (Fig. No. 6).

Within the scientific context, the kit introduces two discourses around communication. First of all, I refer to Claude Shanon's idea of a noise source being in between the transmitted and received signal. Secondly, I introduce the idea of allelopathy, a phenomenon by which an organism, while producing and signaling biochemicals, influences the growth of other organisms. In addition, although not directly introduced, other essential topics for discussion around fungi could come up while executing the experiments provided. These topics include the DIY production of antibiotics, such as penicillin (Inglis-Arkell 2013), the ability to use space radiation as a food source (Dadachova et al. 2007; Dadachova & Casadevall 2008), and the ability of fungi to biodegrade organic and inorganic elements, including slowly degrading elements such as cellulose, toxins, and heavy metals (Stamets 2005; Singh 2006).

The title Mycorrhizal Networks, or How I Hack Plant Conversations is a direct reference to the use of fungal mycelium for interaction between plants. This interaction is introduced through an electronic interface that translates chemical signals into electronic signals and vice versa, opening up a playground for the feedback loops between organic and inorganic elements – in this case, plants, mycelium, and a computing machine.

Related Artworks

There are a number of artists and artworks worth mentioning. Among other artists working with plants, fungi, and/or electronic interfaces, bridging these subjects are Martin Howse, Saša Spačal, Laura Popplow, Gediminas and Nomeda Urbonas, Leslie Garcia, and Miya Masaoka. For the sake of diversity, I have chosen to introduce four artworks: *Pieces for Plants* by Miya Masaoka, *Radio Mycelium* by Martin Howse, *Fungutopia* by Laura Popplow and *Life Box* by Paul Stamets.

Miya Masaoka, *Pieces for Plants*[1]

Because of the methods used, Miya Masaoka's *Pieces for Plants* project from 2007 is probably the most direct reference to *Mycorrhizal Networks, or How I Hack Plant Conversations*. In her piece, Masaoka uses electronic interfaces attached to the plants to generate sound (as well as text, appearing in a video performance) (Fig. No. 1). While changing her body position in relation to the plants (approaching, touching, retreating), Masaoka changes the physical properties of the space, which, in turn, affects the plants. Plants sense the changing environment and further transport the captured changes in the form of electrical signals to the electrodes attached to them. The electrical signals captured are then translated into digital signals and transferred into the computer for further manipulation.

Fig. No. 1. Miya Masaoka. *Pieces for Plant* (2007). Photo: Donald Swearington. Available at http://www.miyamasaoka.com/media_files/photos/ (Accessed 26 February 2017).

Using the measurements captured from the interaction between herself and the plants, Masaoka, on the one hand, acts as a performer and, on the other hand, lets the machine generate sounds. Here, the machine becomes an interface between the plants and the performer, while, at the same time, a collaborator for the artistic piece. The final performance could be described as a translation of physical environmental properties into sonic, visual and haptic experience.

*1. http://www.youtube.com/watch?v=1AHOEcAprc8 (Accessed 23 February 2017).

Martin Howse, *Radio Mycelium*[2]

As in Miya Masaoka's *Pieces for Plants*, Martin Howse's *Radio Mycelium* (2011) introduces interaction between the physical properties of an environment and living organisms. In both cases, living organisms and electronic elements are enclosed in a system. On the other hand, the artworks are of different approaches and narratives. While Masaoka explores, from a poetic perspective, the ability of plants to sense the environment, Howse examines connectivity and interaction between the physical properties of the environment and mycelium networks from a scientific, cultural and technical perspectives. Moreover, Masaoka "performs" her piece, whereas Howse holds a "workshop" (Fig. No. 2).

Fig. No. 2. Martin Howse, *Radio Mycelium* (2011). Photo: Nik Gaffney/foam (CC BY-SA 2.0). Available at https://www.flickr.com/photos/foam/6459095083/in/album-72157628288022139/ (Accessed 26 February 2017).

This is how he describes his Radio Mycelium:
The Radio Mycelium workshop aims to actively examine the cross-spore-germination between two parallel wide area networks; between radio-based communication technologies and the single organism network of the mycelium. Fungal transceivers sprouting mycelial antennas form an imaginary underground network. Diversity of human networks is mapped across fungal diversity in the urban environment. The influence of electromagnetic carrier wave on the mycelial network is to be examined.[3]

Proposing the workshop format as artistic means, Howse also proposes research and educational frameworks. Howse and the participants seek understanding of how the environment functions, how species interact with their surroundings, how much cultural charge there is in what is being approached (Howse gives references to Terence McKenna, Paul Stamets, Charles Darwin) and how science and cultural charge complement each other. Through research, doing, sharing, and envisioning, Howse's artwork becomes multilayered.

*2. http://libarynth.org/parn/radio_mycelium (Accessed 23 February 2017).
*3. http://www.psychogeophysics.org/wiki/doku.php?id=mycelial (Accessed 25 February 2017).

Laura Popplow, *Fungutopia*[4]

Laura Poplow's *Fungutopia* from 2011 is an installation, a workshop, a prototype kit and a community project (Fig. No. 3). Being a multifaceted artwork, it also serves as an educational platform. The artist herself describes the project in the following way:

> *As an installation fungutopia shows the different possibilities that mushrooms offer to help to make the world a better place: Mushrooms are open source medicine, food, fertilizer and soil-recovery-method. They can be cultivated quite simply even indoor and are perfect for urban fungiculture. The workshop shows simple techniques to grow mushrooms in cities, whereas the prototype MUSHroom tries to combine Open Source Electronics with Biology to grow even more rare medicinal species year round indoor. As a community-project fungutopia tries to bring together people for urban fungiculture and share knowledge and experience. The Online Community grow.fungutopia.org is the web equivalent of the f2f experience.*[5]

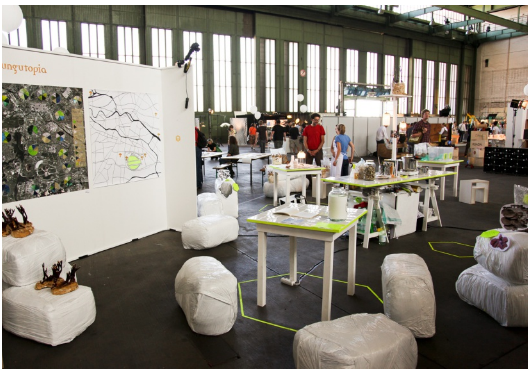

Fig. No. 3. Laura Popplow, *Fungutopia*, 2011. Photo: Martin Schlecht. Available at http://www.fungutopia.org/index.php?/ppp/test/ (Accessed 26 February 2017).

As a very complex project, *Fungutopia* becomes a platform to discuss a variety of topics related to posthuman aesthetics. Along with the reference topics covered by Paul Stamets, *Fungutopia* is also about cooking, DIY electronics, open-source initiatives, sustainability, social practices and, of course, contemporary aesthetics.

*4. http://www.fungutopia.org/ (Accessed 23 February 2017).
*5. http://www.fungutopia.org/index.php?/about/ (Accessed 23 February 2017).

Paul Stamets, *Life Box*[6]

Related to *Mycorrhizal Networks, or How I Hack Plant Conversations* is the project *Life Box*, by mycologist Paul Stamets, started in 2010. Although not exactly an artwork, but rather a commercial product, the project deserves to be listed among other related artworks. First of all, Stamets' ideas regarding mycelium and fungi are often referred to by artists working with fungi (Gediminas and Nomeda Urbonas, Laura Popplow, Martin Howse, TARO). Furthermore, the idea behind the project is well shaped conceptually.

In 2010, Stamets came up with the idea of producing cardboard boxes that could be used for at least two purposes: as packaging material and for the collection of plant seeds. Cardboard boxes of different sizes (Fig. No. 4) can be purchased and used for shipping goods. At the same time, these boxes also serve to combat deforestation and climate change.

The idea behind the *Life Box* is simple: Cardboard, which is made of cellulose, is a good source of nutrients for mycelium and fungi. Through biodegrading processes, the cardboard will turn into soil, and soil containing decomposed chemical elements will, in turn, become a basis for plant growth. The cardboard from the *Life Box* is filled up with plant seeds and fungal spores, so, if watered, they would start interacting with the cardboard and would likely grow into trees.

Interesting in this project is the process of learning how plants grow. The project also involves taking care of living organisms – in this case, fungi and plants. Finally, if trees are nurtured and continue to grow, they could grow into a forest, consuming carbon dioxide and producing oxygen, and, in such a way, again making the environment user-friendly.

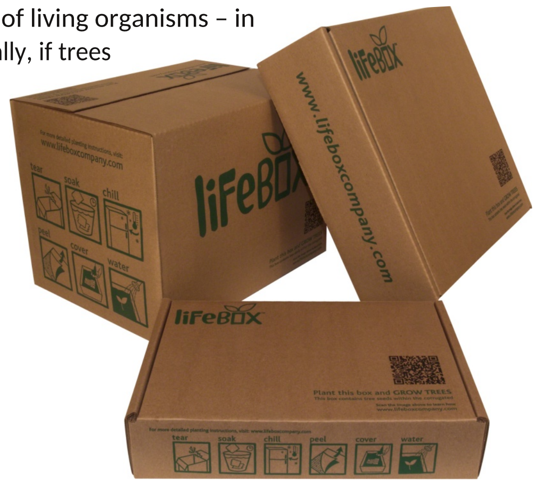

Fig. No. 4. Paul Stamets, *Life Box*, 2010. Courtesy: Life Box Company. Available at http://www.thalo.com/thumbnail/040212_1efa29d-586244594-4f79e58e-a7f0-b1c6d6db/o.jpg (Accessed 26 February 2017).

*6. https://www.youtube.com/watch?v=Q8CMsB4jLLc (Accessed 23 February 2017).

Concept

One of the scientific terms defining plant interaction is allelopathy, a phenomenon wherein compounds produced by one plant affect the growth of surrounding plants. The compounds produced are released into the soils or taken in by symbiotic fungi and further transported over mycorrhizal networks to the target plants within the same community in order to resist invasive species. Why would fungi and plants interact with each other? How would that happen? And what further picture could be drawn from this interaction?

Using allelopathy as a metaphor for plant interaction, this project suggests interference in this interaction by adding an electronic interface to plants that captures biochemical signals and translates them into digital values and vice versa. The electronic interface acts as a proxy server, able to change the information passed and influence the target destination.

Interaction Between Elements of Different Kinds

This chapter provides an introduction to methods for transmitting information between elements of different kinds, in particular, fungi, plants, and electronic parts, which might impact the information transmitted.

Fungi, Plants and the Transport of Chemicals Between Different Species

Fungi and plant kingdoms belong to the Eukariota domain and have an eukaryotic-type of cells that differs from prokaryotic cells (bacteria and archaea) in membrane-bound organelles, which contain genetic material enclosed by a nuclear envelope. According to Nic Fleming, around 90% of land plants are in mutually-beneficial relationships with fungi. These partnerships are usually described as “mycorrhiza”, where the fungus colonizes the roots of the plant (Fleming 2014). The colonization is either intracellular (arbuscular mycorrhizal fungi) or extracellular (ectomycorrhizal fungi), where both sides interact with each other, exchanging chemical elements as well as differently charged protons and electrons.

Most fungi grow as mycelium, consisting of a mass of branching, thread-like hyphae, which are cylindrical, thread-like structures 2–10 µm in diameter and up to several centimeters in length. Together, hyphae may form extremely large organisms, such as, for example, *Armillaria ostoyae*, which occupies 965 hectares of soil found in Oregon's Blue Mountains in the US (Casselman 2007). While able to form net-like structures, this fungus has been called “Earth's natural internet” (Stamets 2008). Fungi expert Paul Stamens has even compared mycelium to ARPANET, the US Department of Defense's early version of the internet (Stamets 2008).

On the other hand, allelopathy, the exchange of chemicals within mycorrhizal networks has been explored by Kathryn Morris, formerly Kathryn Barto (Barto et al. 2011), Nancy Stamp (2003), and Rick Willis (2010). Morris and her team tested, for example, the soil for two compounds made by the marigolds. In the samples where the fungi were allowed to grow, levels of the two compounds were two-to-three times higher than in samples without fungi (Barto et al. 2011). That suggests that the mycelia transport chemical compounds.

As a result of this growing body of evidence describing the communication services that fungi provide to plants and other organisms, many biologists have started using the term “wood wide web” as a reference to the World Wide Web, or simply the internet (Fleming 2014).

Communication Systems and the Source Noise

The visual similarity of mycorrhizal networks to computer networks and proofs that mycorrhizal networks are able to transport chemicals brings us to Claude Shannon's communication theory. The communication theory could be symbolically represented through the information source that selects a desired message, a transmitter that changes the message into a signal to be sent through a communication channel, a noise that interferes with it, a receiver that converts the signal into a message, and a destination (Shannon 1948) (Fig. No. 5).

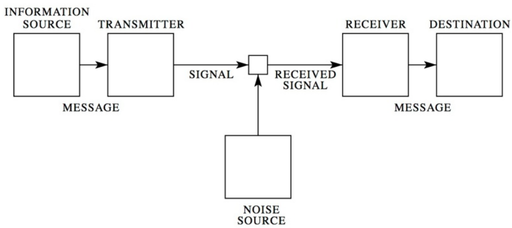

Fig. No. 5. Schematic diagram of a general communication system (Shannon 1948).

Related to this project is the source noise as part of a communication system, which always impacts it. While Shannon has proposed a way to reduce the source noise in order to have the least possible impact on the transmitted signal, the interest in source noise in this project lies elsewhere. Say, if we "employ" the source noise to generate false signals, the ability to impact the transmitted signal becomes higher, and, in turn, the message received at its destination point could have a higher impact. This higher impact is often seen, for example, in translated texts, because of the mismatch of languages used at their source and destination points, and the translator, who acts as a noise source in the setting.

While offering an electronic interface attached to a mycorrhizal network, the impact of the transmitted signal in a mycorrhizal network could be manipulated by the different electric potentials provided.

Electrical Potentials in Living Organisms

As in all matter, the differently charged protons, neutrons and electrons of atoms generate electrical potentials. Electrical signals, according to Nick Lane, are the basis for all living organisms and life forms (Lane 2015, Szechyńska-Hebda et al 2017). How does that work?

The cytoplasm of plants has, among other chemical elements, potassium (K) salts, which provide the correct ionic environment for metabolic processes and, as such, function as regulators of various processes, including growth regulation. Potassium ions (K+) provide protein synthesis and interaction with the external environment, for example, the exchange of gas or nutrition (Leigh et al. 1984). For example, in animals, positively charged sodium (Na+) and potassium (K+) ions are generated by interacting with negatively charged chlorine (Cl-) ions in neural cells (Davies 2006). Differently from animals, in plants, electric potentials are generated by potassium (K+), calcium (Ca2+), and chloride (Cl-) ions, which are passed through the cell membranes and ion channels (Fromm & Lautner 2007; Davies 2006; Lane 2015).

Electric potentials are usually measured with the help of a weak electric current, which is passed through the organism between two electrodes. The difference of the electric signal is compared with the third electrode, which is attached to the ground or further away from the electrodes, through which the electric current passes (Davies 2006).

Electrical charges could be captured by intracellular or extracellular measurements. Both methods have their positive and negative sides. For example, the intracellular measurements are localized and can perform measurements within one cell. At the same time, intracellular methods wound the plant. Extracellular measurements sum up the total of bioelectrical activity in large groups of cells at the surface of a leaf or stem and do not wound the plant (Fromm & Lautner 2007). Within this project, the use of extracellular measurements is suggested because the experiment can be performed for a longer period of time. Meanwhile, the plant will not be damaged by invasive electrodes.

To sum up, the interaction between symbiotic fungi and plants is an exchange of electrical signals and chemical elements between different species. The next question concerns the interpretation of the signals as forms legible to humans, and further manipulation of electric signals that might, for example, impact the growth of the plants and fungi.

Interfaces Between Plants and Computing Machines

Noting that differently charged protons, neutrons, and electrons of atoms within organisms generate electrical signals, and knowing that electronic

Fig. No. 6. The interface between plants and computing machine. Photo: Brigita Kasperaitė.

circuits and computing machines operate on electrical signals as well, the next step is to combine organisms with electronic elements into an interface and to translate electrical signals passed into digital signals or humanly perceptible sonic, visual and haptic outputs.

The interface between plants and machines within this project consists of electrode pads for capturing extracellular activity, an electrical circuit for high accuracy, an instrumentation amplifier AD620 for amplifying the electrical signals captured, and an Arduino[7] microcontroller for the conversion of electrical signals into digital information. The endpoint of the interface is a Windows, Mac or Linux computer.

The electrical signals captured with electrodes are further directed to an electrical circuit in order to amplify those signals and to further deliver them for conversion into digital information. The digital data received by the computer is further manipulated with a Pure Data programming environment for audio, video, and graphical processing[8]. While converting digital data back into an electric current, and sending the electric current further to the plant, the proposed interface is completed. It is ready to be used as a source noise for the plant-to-plant, plant-to-fungi, or similar interactive setting.

*7. https://www.arduino.cc (Accessed 5 March 2019).
*8. https://puredata.info/ (Accessed 25 February 2017).

Fig. No. 7. A kit for the interaction between elements of different kinds. Photo: Christian Döller

Toolkit

The kit (Fig. No. 7) contains tools to experience interaction between interconnected elements of different natures. It includes: electronic components for building a sensor and a radio transmitter, both developed by Martin Howse, a petri dish full of coffee grounds, a few dowels with dried samples of oyster mycelium, different plant seeds, a digital microscope, an Arduino microcontroller, and software to bring the tools into action. The experiments introduced in the toolkit will give an idea of how to grow mycelium, how to make electronic tools and attach them to living organisms, and how to use the tools for audiovisual expression.

The use of the kit is divided into an array of different phases. The first phase introduces the cultivation of mycorrhizal networks and plants using the provided mycelia samples and plant seeds, and some coffee grounds. This phase should last for some weeks, until the mycelia have grown on the coffee grounds. The next phase is to grow plants next to the mycelia. Depending on the plant seeds used, the phase could take months or years, until the plants are big enough to attach to the electrodes provided. During the third phase, the user is invited to build an electronic interface and bridge it with the plants, the mycorrhizal fungi, and the computer in order to hack the interaction between them.

The first experiment introduces how to grow mycelia on coffee grounds. The second experiment shows how to sense electric potentials in living organisms. The third experiment explains how to assemble and test the mycelial radio transmitter. The fourth experiment explains how to use built tools and the Pd patch provided for audiovisual expression and electric-current manipulation.

Experiment No. 1. Growing Mycelium on Coffee Grounds

In this experiment we will begin to grow mycelium (Fig. No. 8.). The grown mycelium will be used for connecting electronic components to sense electric potentials among different organisms in the habitat. For the experiment we will use coffee grounds, and dowels with mycelium. In case different amounts of ingredients are needed, purchase mycelium dowels online from a commercial mushroom supplier. Coffee grounds can be collected at home. For the experiment we will need:

Tools
- A petri dish;
- A strainer;
- A small pot;
- An electric hot plate.

Components
- Coffee grounds;
- Oyster mushroom dowels;
- Water.

Fig. No. 8. Dowels with mycelium on coffee grounds.
Photo: Brigita Kasperaitė.

- Put coffee grounds into a pot and pour water on top so it covers them.
- Sterilize the coffee grounds by cooking them for ten minutes on a hot plate.
- Strain the coffee grounds. Leave them for a couple of minutes to cool down.
- Put the coffee grounds into the petri dish and wait until they reach room temperature.
- Add dowels with oyster mycelium inside the coffee grounds and cover the petri dish.
- Place the petri dish in a dark place.
- Inspect your coffee grounds after a couple of days. In two-to-three weeks, you should have your coffee grounds colonized by mycelium.

For further experimentation: grow larger amounts of mycelium, plant the seeds provided, and connect the grown plants to electronics. Also experiment with different substrates for growing mycelium, for example, wood chips, cardboard, and so on (Gapševičius & Howse, 2018).

Experiment No. 2. Sensing Electric Potentials in Living Organisms

Once the mycelium has reached a level you are happy with, we will build an electronic interface in order to bridge the mycelium with a computer and measure small electrical impulses in the mycelium (Fig. No. 9). For the experiment we will need:

Tools
- A breadboard;
- A 100 µF capacitor;
- 1 kΩ resistors – 3 units;
- An Arduino microcontroller with software;
- Jumper wires;
- An A-B USB cable;
- Electrode patches – 2 units;
- Computer.

Components
- A mushroom and mycelium;
- Plants.

- Place the operational amplifier provided on the breadboard with its legs bridging the middle gap in the breadboard.
- Connect the 100 micro-farad capacitor between pin 4 and pin 7. The capacitor smooths the power supply from the Arduino.
- Place the 1 kilo-Ohm resistor between pin 1 and pin 8. This resistor sets the amplification of the organism's signal to a factor of 50.
- Add the two other resistors at pin 5 with one ending at pin 7, which is the power, and the other at pin 4, which is the ground.
- Connect pin 7 to the power source and pin 4 to the ground of the Arduino microcontroller.

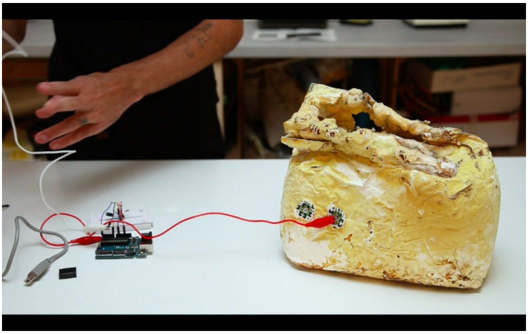

Fig. No. 9. Building an electronic interface to capture impulses in the mycelium. Photo: Brigita Kasperaitė.

- Connect pin 6 to the analogue input A0 of the Arduino.
- Pins 2 and 3 of the operational amplifier are then connected to the electrode patches, which are then attached to the grown mycelium.
- Connect pin 5, the reference, to the grown mycelium. The pin sets the ground reference for the amp.
- Connect the Arduino microcontroller to the computer using the USB cable provided.
- Open the Arduino application and set the port and the board in the preferences.
- Open the sketch by going to File, then Examples, then Basics, then click AnalogReadSerial. In the window, click the right-pointing arrow to upload it onto the microcontroller.
- Go to Tools, open the Arduino Serial Plotter, set the signal rate to 9600, and see the variation of electric potential in mycelium in action.

For further experimentation use different mycelium, sorts of plants and/or other organisms, including yourself (Gapševičius & Howse, 2018).

Experiment No 3. Assembling and Testing the Mycelial Radio Transmitter

In this experiment, we will build a very simple FM (frequency modulation) radio transmitter, which will use a mushroom and mycelium as part of its transmission circuit (Fig. No. 10). The transmitter will respond subtly to changes in the mushroom body, signals in the room, and the proximity of human and other bodies. The circuit we are assembling re-purposes a logic chip and a few components, and the signal can be received on the simplest FM/AM radio receiver, which you can find easily. We will need the following electronic parts and components:

Electronic parts
- A diagram of the circuit;
- The operational amplifier provided;
- Two 10 pico-farad capacitors;
- A 33 pico-farad capacitor;
- A 100 nano-farad capacitor;
- A 1 kilo-Ohm resistor;
- A printed circuit board;
- A battery pack and three AAA batteries;
- Stiff copper wire for antennas and the mushroom connection.

Components
- A mushroom and mycelium;
- A diagram of the circuit;
- A soldering iron & solder;
- A wire cutter;
- An FM radio receiver.

- Orient the printed circuit board according to the diagram (the view is from the top down). You will place parts from the top and solder them from the bottom.
- Place the operational amp chip provided (the 14-legged item) from the top onto the board. Pin 1, which is just underneath the notch, should be as in

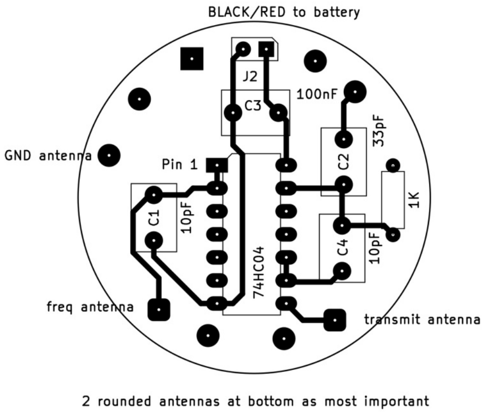

Fig. No. 10. Circuit diagram of the mycelial radio transmitter. Sketch: Martin Howse.

the diagram. Turn over and solder each leg in turn.
- Place and solder the four capacitors (of differing values) and the one resistor as indicated.
- The long leads on the bottom can now be clipped after you have soldered everything.
- Solder the battery holder with the red lead right, black lead to the left.
- Solder one thick 10cm-long bare wire to the "frequency antenna" spot and one to the "transmit antenna" spot.
- Insert the "frequency antenna" wire into the mushroom body.
- Put batteries in (and switch on if the battery holder has a switch option).
- Switch on the radio, place it about one meter from the mushroom, and make sure it is set to FM with the switch. Tune the dial until you hear the sound change.

For further experimentation: try soldering wires to other nodes on the outside of the circuit board; insert them into different parts of the mushroom, connect more transmitters to other mushrooms in the same space, take the headphone jack out of the radio, and use it with PD patches or an Arduino sketch (Gapševičius & Howse, 2018).

Experiment No 4. Using Built Tools for Feedback Loops Between Plants and Computing Machines

In this experiment, we will use the built tools to set feedback loops between the electric potentials sensed in the grown plants and rewired with electric potentials in the Pd patch provided (Fig. No. 11). The idea is to influence the growth of plants and mycelium with the electric potentials generated in response to the sensed electric potentials. Finally, we will use the generated signal for the audiovisual expression. We will need:

Tools
- An Arduino microcontroller with software;
- Pd software with the provided pduino libraries;
- Previously assembled sensor for sensing electric potentials;
- An A-B USB cable;
- Additional electrode patches – 2 units;
- Jumper wires and alligator clips.

Components
- Previously grown mycelium;
- Previously grown plants.

- Attach pin #9 of the Arduino microcontroller to an electrode and place it next to one of the electrode patches of the sensor connected to the plants;

- Attach the “ground” of the Arduino microcontroller to another electrode patch and place it next to the second electrode patch connected to the plant in such a way that both electrode patches appear in between the electrode patches of the sensor.
- Open the Arduino sketch by going to Finder, then the USB memory stick provided, then the Arduino-analog-to-PWM folder, then open the Arduino-analog-to-PWM file.

- In the window, click the right-pointing arrow to upload it onto the microcontroller.
- From the Finder window, open the analog-to-PWM patch with the “extended” version of Pure Data.
- Open the active port of the Arduino microcontroller by clicking on the object [devices] followed by clicking on one of the numbers bellow corresponding to the active port. Activate the [on/off] object of the PD patch so that the patch updates the values captured on the object, turns on the speakers, and activates the window for visuals. If everything is done correctly, the scale of the slider in the patch should start moving left and right and you should hear sound and see visuals. Additionally the sensed input from the plants will be converted into electrical voltage and sent to the Arduino port #9.

For further experimentation: add new objects to the Pd patch and change the audiovisual performance. Also, try to change the electrical voltage supply by editing the Pd patch. You might also want to let the setup run for a longer time and see how the feedback loops influence the growth of the plant (Gapševičius & Howse, 2018).

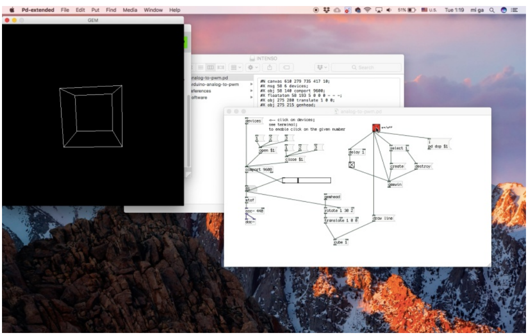

Fig. No. 11. Pd patch.

Conclusions

While providing a set of organic elements (plants, mycelia, coffee grounds) and inorganic elements (electronic elements to bridge the organic elements with the computer), I have laid the practical foundation to work with the interactive setting of plants and computing machines. Along with the practical experiments, I have briefly introduced the discourse in relation to the interaction between elements of different kinds and the idea of transport of information between these elements. Biochemical processes happening within living organisms could be altered and manipulated digitally by picking up an electric signal at its source location, translating it into a digital signal, altering it, and sending it to the destination. In so doing, the growth of the plants, for example, could be altered by themselves through the electronic interface. Furthermore, the signal captured could be sonified or visualized with software such as Pd.

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This paper is part of a broader body of research within the *Introduction to Posthuman Aesthetics* project, initiated in 2016. The discourse introduced in the paper and the Toolkit invite the reader and Toolkit user to think about the interaction between elements of different kinds, for example, different species or organic and inorganic entities. The paper is organized in four parts. The first part introduces related artworks and the contexts where the interaction emerges. The second part introduces the concept of this project. The third part brings the reader deeper into the discourse of the project. The last part is about the Toolkit, which comes along with a manual and a video tutorial for practical experiments related to the discourse introduced.

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