An evaluation of human-plant interaction approaches for artistic live performances

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Abstract

The increasing effects of the climate crisis has shifted society's focus towards nature and its relationship to it. Plants in particular are fundamental part of nature but our understanding of them is still limited. The field of Human-Plant Interaction, as part of HCI, searches to broaden communication with plants through technology. However, we are in need of intermediaries like artists who use these technologies and foster empathy with nature within society. In order to support artists' explorations in this area, this paper presents an overview and evaluation of common approaches. For this I focused on the context of live artistic performances, where the interaction with a living plant occurs in the moment through either performers or audience and is immediately perceivable. Through this, I hope to lower the barrier for artists to incorporate plants into their work and expand the boundaries of what has been done so far.

1. Introduction

With growing awareness of the climate crisis, the extinction of species and decay of natural habitats, ever bigger parts of society are focusing on nature. Exploring ways to work sustainably, preserving ecosystems and their inhabitants, as well as researching the relationships within them are becoming increasingly important and urgent as they are at risk of extinction.

A big part of these explorations is dedicated to plant life. Plants are an essential part in our perception of nature and yet we know comparatively little about them. The rich communication system that trees and fungi use to support each other, for example, has only been recently become a topic of interest. Even though forests play major roles in balancing local and global climate, energy companies still cut them down despite protests. On one hand people work towards this shift and make great progress, many on the other hand refuse to acknowledge the problem and do not change their behavior within capitalist structures. This refusal is blocking major economical and political decisions that are needed to free resources for climate and environmental research.

In order to feel the need to act, people not only need to know about the problem, more than anything, people need to feel empathy for the situation and the actors involved. While the sciences work on the factual knowledge for understanding the problem, the role of growing empathy falls onto the arts and humanities. The combination of arts and science is especially effective for this purpose. In this research, I focus on the intersection of a subcategory of HCI, namely Human-Plant Interaction (HPI) and how artists can use its research in their own works to foster more empathy for plant life.

Interaction with a medium, as it has been a focus in video game studies for quite some time, is a powerful factor for empathy building. When we interact with plants they act as a stand in for nature at large. It emphasizes our connectedness to our environment. Furthermore I chose the specific artistic context of live performances to investigate HPI in. For one, the live aspect of it goes well with the theme of direct interaction as it happens in the moment. Additionally, the live-ness enhances the physical experience and makes it more memorable for the audience.

HPI provides the means to interact with plants, artists provide interpretations to make these means worthwhile for a wider audience. There is however a knowledge gap between the pure research and how approachable the results are for people outside the field. This is the target question I want to address: which approaches to plant-interaction exist that are suitable for artists? What do they entail and what preexisting skills are necessary to incorporate them? For this I collected and evaluated approaches from the field of HPI and looked at their implementation and suitability for the context of live performances and finally categorized them by skill and experience level.

2. Related Work

The ways in which we can interact with plants or other non-human actors is a recurring topic in HCI research. For plant interfaces specifically Chang et al established the subcategory Human-Plant-Interaction (HPI) [Cha+22]. Many publications present a single artifact or approach, a few focus on giving overviews over the methods used in the field.

For the former category I want to highlight Akousmaflore

[AG22] which pioneered interactive sonification with plants. The installation Botanicus Interacticus [Pou+12] together with the underlying project Touché [SPH12] show how to derive more meaning from simple touch and how to apply machine learning sensibly to the field. Pulsu(m) Plantae stands out for demonstrating DIY approaches that not only read plant reactions to touch, but also to surrounding noise and light fluctuations [Gar16].

Aside from projects that are interesting from a technical perspective, it is also relevant to look at the artistic side. Arlander explores how plants perform for, as or with humans in a theatrical setting, without involvement of HPI [Arl20]. The dramaturgy of Evergreen [Pek24] builds on sonification of prepared plants, but also invites the audience to bring their own house plants, and their stories, to be integrated into the soundscape of the performance. Wright and Howden integrated life plant interaction data into a VR experience [WH20] inviting investigations on plant interactions in virtual or hybrid performance spaces.

In the category of state-of-the-art reports, I want to go into Chang et al and Weil specifically. Chang et al define HPI and give the broadest and most in-depth overview of the field as of now [Cha+22]. Their resulting framework for categorizing HPI helped in the research of this paper and provides a great starting point for similar endeavors and the way I structured my results. However, since they looks at the entire field of HPI, some of the approaches presented are simply out of reach for artistic context as they require professional grade laboratories and equipment and are very experimental. They do however offer exciting glimpses into the future of HPI.

On the other side of the overview-spectrum is Weil's "Artistic Human Plant Interfaces", as its main focus is, as the title suggests, the artistic side [Wei]. The artworks presented here however don't necessarily deal with interactions, live plants or performances. They also show great examples of projection mappings on plants or fine art with plant matter, only a small part is relevant for this paper. I still find it a great inspirational resource and also shows how much my paper's definition is not covering.

The listed resources provide a lot of information for people new to HPI, from overviews to concrete implementations. But there is space for evaluating and clearly communicating the feasibility of the methods for artists.

3. Investigating plant interaction options

To achieve the goal of a comprehensible list and evaluation of plant interactions for artistic life performances I will first describe my process of collecting and categorizing said approaches and then present the results. Before that I want to provide the definitions of terms that I used. For plant interaction I only consider interactions with live plants valid. This excludes mushrooms and other fungi and anything that is only a part of a plant, like tree barks or fruits. The interactions must be purposefully carried out by a human actor. Most likely this will mean approaching or touching the plants, but is not limited to it as Pulsu(m) Plantae demonstrates [Gar16]. This excludes approaches that measure environmental properties, like soil moisture or oxygen content.

An artistic live performance I define as follows: It is artistic if an artist thought of concept and interprets the plant interaction and its results according to their artistic vision. It has no economic or scientific purpose. A performance is an event that follows such an artistic concept and includes either the artist or performers (as opposed to an installation), as well as an audience to be present in the moment. Additionally, performers, plants and audience share the same physical space (which could in theory include a virtual or hybrid space). By this definition Akousmaflore [AG22] does not qualify because of the lack of performers, whereas Baumarktmusik when performed in front of an audience [MSH11] does.

Note though that I do consider approaches that are suitable for performances even if they are presented or first thought of as installations. Careful readers will spot where there is empty space to be filled with potential new ideas.

Another set of definitions comes from Chang et al's framework that also helps placing this paper within a broader HPI context. In terms of interfacing with plants, I'm moving exclusively in the "traditional computing", meaning physical computing, space. The type of interaction is always "direct interaction", specifically the subcategory "human input generating plant output". Everything is happening on a "human to plant" scale, as opposed to a forest or ecosystem scale [Cha+22].

3.1. Method

The outlined definitions already narrow down the possibilities for plant interaction drastically, but they also make identify suitable ideas easy.

I started out with collecting projects and approaches directly from Chang et al.'s research [Cha+22]. From there I followed the references and used search engines until I found Weil's thesis [Wei] which complemented my list nicely. Only Evergreen [Pek24] was added because of a personal recommendation. More time and resources for scraping different social media platforms could have lead to interesting results as to how artists interpret plant data. But as far as HPI approaches go my findings seemed more than sufficient.

As next step I looked at the underlying methods to single out the unique approaches. Once again Weil [Wei] provided great inside and basically already the desired list. I did however remove "The electric field measurement approach" as is has not been mentioned in any of the other references and it proved difficult to find more information about it. Thus I ended up with five different approaches that I'll present in more detail in the results section.

For these five approaches I researched DIY implementations using micro-controllers and other electronics popularized through the Arduino electronics ecosystem. Through this I wanted to make sure that all approaches are in fact and not just theoretically reproducible by artists and regular people.

With these insights I could deduce the technical skills needed to implement each approach and group them into experience levels for easy self-identification.

Interfacing technique	Physical property	Type of interaction
Plant as resistor	Electrical resistance	touch, pressure
Contact microphones	Surface vibration	touch
Capacitive sensing	Capacitance	touch, proximity
Swept Frequency Capacitive Sensing	Capacitance	touch, proximity, touch location, touch gestures
Electrodes	Bioelectrical current	touch, light, sound

Table 1: *Plant interaction approaches*

Interfacing technique	Resistors	Other
Plant as resistor	1 M	
Contact microphones		piezoelectronic Sensor
Capacitive sensing	1 – 40 M	
Swept Frequency Capacitive Sensing	10k, 1M, 3,3k	100pf, 10nf capacitors, 1N4148 diode, 10mH inductor
Electrodes		Electrode leads (3.5mm Jack), electrode pads, Jack socket, amplifier

Table 2: *Hardware requirements*

3.2. Results

Through the data collection and evaluation process I ended up with three tables roughly corresponding to each step in the process and to the research questions posed in the introduction.

3.2.1. Interaction options

The first result shown in Table 1 is a list of technical plant interfacing options. I have listed them with the physical property that is measured, as well as the interaction we can deduce from it. All of them offer continuous readings of analog signals that can be mapped and interpreted to the artist's liking, the interactions themselves happen as spikes in the readings.

Swept Frequency Capacitive Sensing (SFCS) is introduced by Sato et al. [SPH12] and is not so easily categorized. While just the technical setup in theory allows for the identification of touch location and other touch-based gestures, they have have trained a classifier model to make the finer distinctions presented in Botanicus Interacticus [Pou+12]. I decided to include SFCS as its own approach but its benefits over regular capacitive sensing only really show in combination with a classifier.

3.2.2. Hardware

Table 2 shows the hardware needed to recreate the respective setups. The hardware list only shows the parts special to each approach and assumes the availability of an Arduino Uno or similar microcontroller, Arduino IDE or equivalent to program said microcontroller, as well as basic electronic components such as breadboards and cables. The overview should also help estimating necessary budgets.

Note that for the setup of the SFCS I rely on the adapted Arduino version outlined by Hobye and DZL [MD12] as the original implementation is outside a hobbyist's scope. Arner [Nic17] used this adapted version and also succeeded in training a classifier on the data.

Another note on the electrode approach. There is very little documentation on barebones bioelectric readings with the Arduino and therefore it requires some experience with signal processing and general programming. An alternative here is Cusumano's Biodata Sonification [Sam21] that offers a solution that directly converts readings to MIDI data to be directly used in a DAW. This requires more electronic parts in a slightly more advanced technical setup but he provides easy to follow, throughout documentation.

3.2.3. Skills and level

Having a better understanding of what takes to implement the different approaches I assigned necessary skills. Also knowing how difficult they are to complete and well they are documented, I assessed the experience levels. Table 3 shows the result.

For skills I chose the descriptors basic and advanced physical computing. Physical computing itself entails programming skills but also an understanding of electronics. "Basic" includes understanding of simple circuitry and being able to read a wiring diagram, as well as copying code and making smaller adjustments if necessary. "Advanced" builds up and that but requires a firm understanding of electrical components, and proficiency to change circuits and code independently.

Further I introduced "signal processing" as a skill for approaches where interpreting and processing the readings as audio signals makes sense based in their natural fluctuation. They are however optional in their respective approaches. "Machine learning" was added for the training of the classifier in the SFCS approach and is optional as well.

A direct consequence of the skill descriptors are the levels. "Beginner" marks a project that can easily be accomplished by someone completely new or with very little experience in physical computing. "Advanced" marks the levels where more experience, skill and time are needed to implement the approach.

With this information an artist can now chose which approach is suitable for their level and skillset or search for helping hands with this skillset.

4. Evaluation & Discussion

I compiled a list of DIY approaches to plant interaction for artistic live performance settings. Additionally, I inspected for what types of interaction the measurements of the physical properties are suitable, what hardware is needed to enable them, and gave a final rating on necessary skills and experience level to complete them.

Interfacing technique	Skills	Level
Plant as resistor	basic physical computing	beginner
Contact microphones	basic physical computing, signal processing	beginner
Capacitive sensing	basic physical computing	beginner
Swept Frequency Capacitive Sensing	advanced physical computing, machine learning	advanced
Electrodes	Advanced physical computing, signal processing	advanced

Table 3: *Skill and level assessment*

Overall it is a simple method which heavily draws from own experience in physical computing. However, I tried to keep the categorizations and assumptions about skillsets as objective as possible. I set out to make a small part of HPI more approachable for beginners and people with little experience in the field, like artists and hobbyists, and I think I succeeded. However I don't offer full on implementation guides, so artists still have to find these materials for themselves which can still be a huge barrier. (The reference list should give decent pointers though).

While my sample size of projects is rather small and I did not search for more contemporary projects on social media for example, it quickly became clear that there are only so many ways to talk to plants without professional equipment and they have all been done multiple times.

What makes plant based projects interesting in the end is the artist's vision and what they do with the tools they have. So I do hope to encourage more artists to try it for themselves.

5. Future Work

To follow up on this work I'd like to provide step by step tutorials and code under open source licenses to further lower the barrier of incorporating direct plant interaction in artistic work. Seeing as some approaches have very little to no documentation on how to work with them, this could really make an impact. As accompanying material I could also imagine a list of suitable houseplants with example readings.

Aside from digging deeper into the interaction interfaces I can also imagine looking into how artists interpret the data they receive. What software and algorithms do they use? To which different actuators do they map them in performances? Pure Data and Max/MSP are already used in some projects, as they provide nice interfacing to lower and higher level APIs, so there are lots of possibilities to look at.

6. Conclusion

Working on interspecies empathy is an important step to sensitize people for the needs of the environment. It brings awareness to one's own actions and how one can adjust them. This will be an integral part of fighting the climate crisis, protecting ecosystems and the life they are housing.

Art plays an important role in building empathy as it shows us perspectives outside our own and make us think and feel. Combining this power together with technological approaches learned from HPI, artists can build fantastic pieces that can make the difference.

For this paper I chose a small segment from both HPI and the arts, namely human-plant interaction and life performances with the aim to lower the barrier for artists to use these approaches. The result provides easy to understand information about kinds of interactions with plants are possible in a performance context and hardware and skill is needed for realize them.

I hope this encourages and inspires artists and others to explore human-plant interaction for their work and help grow more empathy for nature.

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