Cultivating a Green Interface: Exploring the Potential of Human-Product Interaction Based on Plant Plant Interfaces

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PAPER ABSTRACT: As humanity advances into an era of advanced technology, there has been a significant enhancement in our perception of the world and our interactions with it. This progress facilitates the discovery of novel modes of creative expression. This paper demonstrates the feasibility of employing plant interfaces to control everyday objects through the design of two cases: PlantMIDI and PlantLamp. The objective is to harness the sensory and expressive capabilities of plants as interaction devices. By integrating synthetic circuits with the physiological aspects of plants, it enables these life forms to interact responsively with humans. This approach has the potential for widespread and sustainable deployment, fostering a deeper connection between nature and humanity.

Keywords: Argument Plants; Biological Signals; Interface; Sound Design; Lamp Design.

1. INTRODUCTION

In an era characterized by a growing sense of disconnection from the natural world, there is a need for more immersive and mindful interactions within our living environments, as opposed to the sterile and impersonal experiences offered by conventional devices. Plants, with their inherent intelligence and ability to perceive their surroundings (DeFalco et al., 2010), and their capacity to generate electrical signals (Fromm & Lautner, 2007; Mousavi et al., 2014), have emerged as ideal companions that individuals are inclined to keep in their homes. This research aims to develop plant-controlled products that facilitate immersive and responsive experiences, fostering a profound connection between humans and plants while maintaining reverence for the natural world.

This paper presents two prototypes: PlantMIDI and PlantLamp. PlantMIDI is a sound interface designed to enhance people's awareness of and respect for nature, which enables a dialogue between humans and plants. This interface allows plants to express their significance through sound, strengthening their connection with humans in an increasingly urbanized and industrialized society. PlantLamp is a desk lamp that incorporates human-plant interaction and integrates a heart rate sensor for emotion regulation. It utilizes a plant as a medium for emotional support (Gonzalez et al., 2010), along with light and scent feedback to manage anxiety and stress, which are significant concerns for individuals dealing with complex tasks and responsibilities in their daily lives.

The contributions of this paper are: 1) Summarizing relevant research in the fields of art, design, and science related to plants. 2) Demonstrating the potential of plant interfaces in everyday objects through the design of two prototypes.

2. LITERATURE REVIEW

2.1 PLANT SIGNAL AND INTELLIGENCE

Greg Gage (2016) used an electrocardiogram (EKG) to detect electrical signals in Mimosa pudica and Venus flytrap plants after they closed their leaves in response to external stimuli. This offers a new perspective on plant intelligence and their ability to process and respond to environmental stimuli. In 1966, Cleve Backster, a polygraph expert, connected a dracaena plant in his lab to a polygraph machine and observed significant electronic signal changes when he thought about burning the plant's leaf, which indicated a possible electrochemical reaction to his thoughts. Botanicus Interacticus (Poupyrev, I. et al., 2012) is a technology that uses plants as input interfaces. A single electrode is placed in the soil with a frequency sweep program that detects when and where an individual is touching the plant. I/O Plants (Kuribayashi, S. et al., 2007) shows examples of multiple use patterns of interaction between people and plants, plants and plants, and plants and their environment. It introduced sensing/transducing kits such as water level sensors and photoresistors to detect the environment around plants.

2.2 INTERACTIVE ART INSTALLATION

Sonnengarten (Fastnacht, T. et al., 2016) is a media art installation for a festival that takes the form of light feedback as an urban spatial interface with plant interaction to trigger visitors' curiosity and their awareness of nature. Apart from reducing the heat island effect, the primary aim to use plants in a city is often aesthetic. And it is common to embed plants on walls for architectural or spatial design purposes. However, Kimura, T., & Kakehi, Y. (2014) designed MOSS-xels, an installation that utilized the morphological changes of plants in response to varying moisture conditions. This time-varying installation serves as a dynamic information display, showcasing the potential of plants as interfaces for providing information.

2.3 PROBLEM-SOLVING PRODUCTS

To help children perceive plants as living beings, Hwang, S., Lee, K., & Yeo, W. (2010) anthropomorphized plants and created different sounds in response to various user gestures. The plants emit sounds like sleeping and breathing when there is no interaction. Park, T., et al. (2016) used plants as game controlling interfaces and designed three electronic games to alleviate people's anxiety. Through testing, they verified that plant-based interfaces can, to some extent, enhance the emotional connection between humans and plants. Tang, T. Y. et al. (2015) developed a singing plant for autistic children. The plant can play different songs according to the position of touch and the intensity of pressure. This is the first attempt to use the plant interface as a therapeutic product for Autism Spectrum Disorder (ASD). EmotiPlant (Angelini, L., Caparrotta, S. et al., 2016) is designed to enhance the care of plants for the elderly, which simultaneously fosters an emotional connection between plants and them. By transforming plants into smart companions, the system aims to alleviate feelings of loneliness among users.

2.4 HUMAN-PLANT CONVERSATIONS

Project Florence (Steiner, H. et al., 2017) is a product that can convert human language into stimuli that plants can understand through Natural Language Processing. The plants will respond to it through means such as changes in light patterns or printed notes. Angelini, L. et al. (2016) propose three types of augmented plants designed for three different groups: the elderly, individuals with visual impairments, and those with smell disorders. In these scenarios, augmented plants serve as companions and sensory substitutes for these individuals. The TalkingPlant, among them, can even recognize simple language and engage in conversations with users.

2.5 SOUND INTERFACE

Pieces for Plants (Masaoka, M., 2013) is an interactive installation where people can hear the responsive sounds from plants when they approach them. Through this approach, it encourages participants to consider the possibilities and potential of plants having consciousness, communication abilities, and awareness. PlantWave (2011) is a commercial product that helps deepen meditation practice by generating ever-changing sounds when connected to plants. This product effectively showcases the commercial potential of plant-based interfaces.

In summary, the vision of this paper is to utilize the changes in plant data generated during the interaction between humans and plants as the interface to control the product instead of using sensors to monitor the plant's surrounding environment and display feedback through the plant as a medium, and extends plant interfaces into everyday products to increase people's awareness and appreciation of plants.

3. METHODS AND PROCESS

3.1 PLANTMIDI

From the dawn of time, humans and plants have been in constant communication, evolving together in an intricate dance of coexistence. This relationship, though often overlooked, remains a fundamental aspect of our existence. While many have forgotten how to reach out and speak to plants, plants have not forgotten us. They continue to provide us with essential resources, from food and shelter to flavor and beauty. At every moment, plants have something to say to us. But if they could speak, what would they say? And if we could converse with them, what would we tell them? PlantMIDI explores these questions through the creation of a sound interface that facilitates human-plant interaction. By combining biology, design, and engineering, PlantMIDI allows people to express themselves through electronic sound in collaboration with plants.

For the interaction logic of the interface, there is a sensor attached to the plant to measure its bioelectrical conductivity, and then converting the data into corresponding sounds that represent its characteristics. The plant itself functions as capacitive touch interface, allowing users to elicit different sounds by interacting with different leaves. These sounds are subsequently processed via various sound synthesis techniques, which enables users to collaborate with plants through the medium of electronic music. The interaction framework is shown in Figure 1. PlantMIDI is not only a controller based on plant interfaces for playing electronic sound, but also by giving plants a voice and the ability to respond and engage with us, it would lead to new forms of entertainment, enhance our lifestyles, and create a new environmental computational platform that can be used for education.

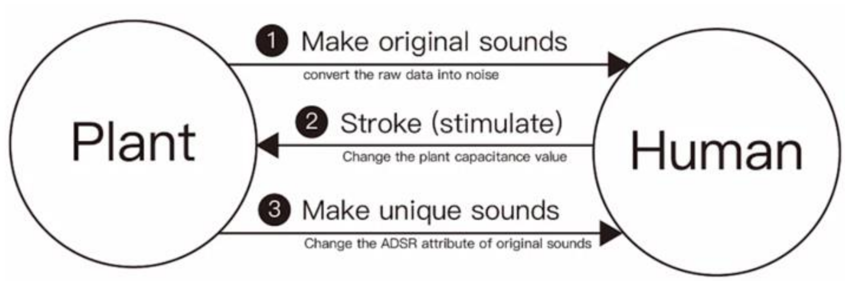

Figure 1. Through the step 2 and step 3, the communication between humans and plants is realized.

For the hardware design, Arduino Mega 2560 is used as the microcontroller for the PlantMIDI. The Galvanic Skin Response sensor (Model: Seeed Studio Grove GSR Sensor Module) is connected to the stem of the plant to collect the plant's conductivity, which will be used as representative data for the plant's sound. The Arduino CapacitiveSensor Library is used for touch-sensing logic. Four capacitive sensors are connected to four individual leaves of the plant, which will be used to collect data from humans when they interact with the plant. The image of the prototype is shown in Figure 2.

Figure 2. Display of PlantMIDI. The plant depicted in the image is a soil-grown Pothos plant. The product incorporates the use of a WS2812B LED strip, specifically chosen in green color (RGB:0,255,0) to enhance the aesthetic appeal and resemble plants. The casing is made from resin material and it is 3D printed.

The collecting speed of both sensors is 10 data points per millisecond. After obtaining the raw data, both types of data will be fed into Max/MSP, a software that will do the data processing and mapping. Figure 3 showcases the framework for data mapping and the methods for sound synthesis. Firstly, the plant's electrical conductance value is mapped to the range of digital audio sound, with an amplitude range of -1 to 1. This mapped data is then stored in a buffer. The sound generated from this date represents the plant sound. Secondly, the date generated from the capacitive sensors will be input to multiple sound synthesizers such as Frequency Modulation (FM) and Amplitude Modulation (AM). Finally, through the effects of these synthesizers, the initial sound of the plant will be altered. (When humans touch the plant, the plant's electrical conductivity will change, which means the raw sound will also be changed a little bit.) This variation in sound creates a cycle of communication between humans and plants.

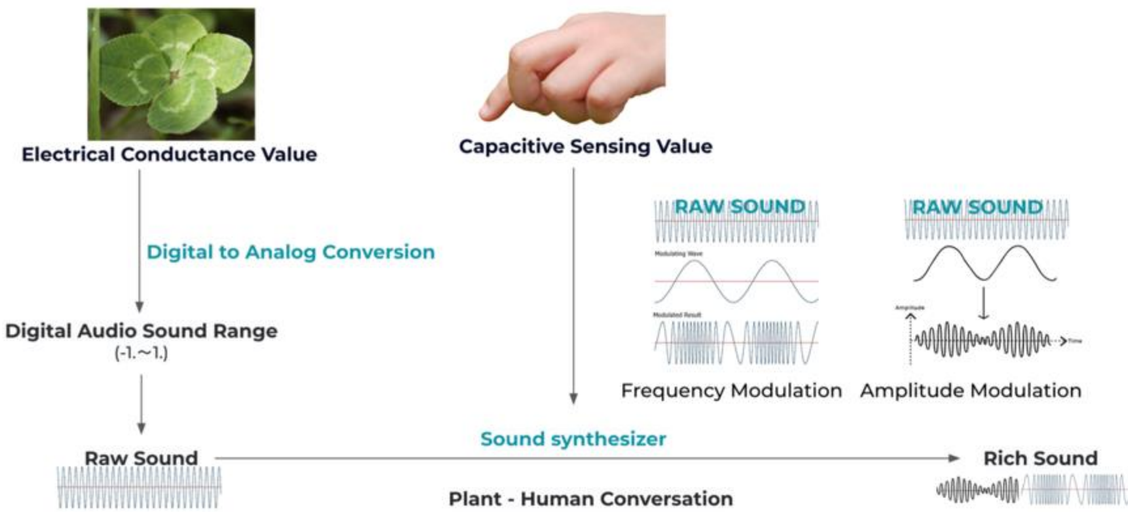

Figure 3. Plant data mapping framework.

3.2 PLANTLAMP

37% Americans rated their mental health as only fair or poor in 2023 (American Psychological Association, 2022). One promising avenue for providing emotional support is through plants. Caring for plants has long been recognized as a source of calmness and tranquility, with gardening activities known to reduce depression and stress (Gonzalez, M. T. et al., 2010; Park, T. et al., 2016; Tang, T. Y. Et al., 2015). Furthermore, a recent study demonstrated that touching plant foliage unconsciously evoked calming responses in individuals (Koga, K., & Iwasaki, Y., 2013). However, the potential of using plants as lamp controller interfaces, particularly for anxiety reduction, remains relatively unexplored in research. Therefore, PlantLamp is an exploration of a more interactive mode of intervention for promoting health and well-being in this emerging field.

Figure 4. PlantLamp prototype. Left) back view. Right) front view.

PlantLamp is a table lamp that leverages a plant as a control interface that enables the basic light operation. By using the plant's leaves as touch interfaces, users can activate the lamp and toggle between different lighting modes simply by touching the leaves. A prototype of the PlantLamp can be seen in figure 4. The lamp also incorporates a heart rate sensor to detect changes in the user's heart rate, as the resting heart rate is typically higher than normal (90 bpm) when a person is anxious. When the user's heart rate exceeds the normal range, the lamp emits pulsating light at a frequency reminiscent of breathing, guiding the user to relax. Additionally, the lamp releases fragrances to create an more immersive atmosphere, as scents have been found to have a positive impact on emotions and cognitive performance (Amores, J., & Maes, P., 2017). With the addition of the inherent healing properties (Therapeutic garden, 2023) of the plant itself, this design lends the lamp to emotion regulation, contributing to the well-being of individuals. A summary of the PlantLamp interaction framework can be seen in Figure 5.

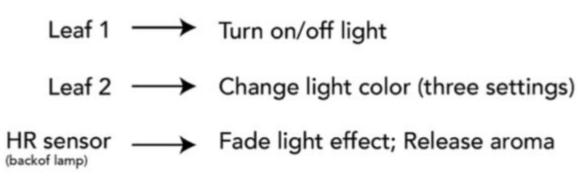

Figure 5. Interaction framework.

The prototype of the PlantLamp is printed using a Fused Deposition Modeling (FDM) 3D printer (Model: Anycubic Kobra) . The plants in the prototype are 4-inch indoor plants bought from The Home Depot. To enhance light diffusion, Two layers of textured Japanese paper are added to the outer surface of the printed shell. The structure of the lamp is depicted in Figure 6. The Lamp has a container for water or soil beacuse it needs to fulfill the requirements for plant survival while providing illumination.

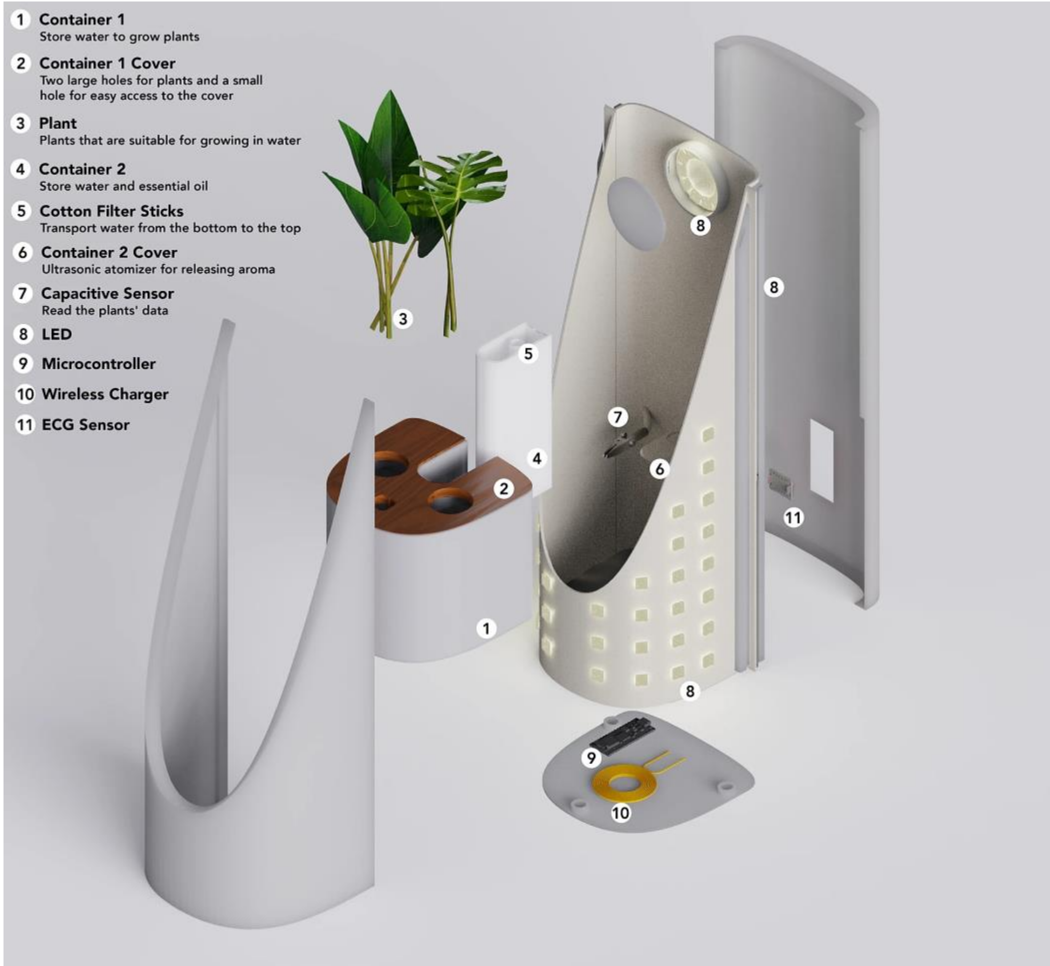

Figure 6. PlantLamp Structure. 1) Container 1: Store water to grow plants. 2) Container 1 Cover: Two large holes for plants and a small hole for easy access to the cover. 3) Plants. 4) Container 2: Store water and essential oil. 5) Cotton Filter Sticks: Transport water from the bottom to the top. 6) Container 2 Cover: Ultrasonic atomizer for releasing aroma. 7) Capacitive Sensor: Read the plants' data. 8) LED strips: WS2812b. 9) Microcontroller: Arduino Nano. 10) Wireless Charger: 5v, 1A. 11) Heart Rate Sensor Module: MAX30102.

The design of PlantLamp provides a reference for incorporating plants into the lamp. In terms of hardware programming, the Arduino CapacitiveSensor Library is used to enable touch interaction between humans and the plant interface, the Arduino SparkFun MAX3010x Pulse and Proximity Sensor Library are used to recognize heart rate, and the Arduino FastLED Library is used to program the lighting effects.

4. RESULTS

PlantMIDI and PlantLamp are two design explorations based on the plant interface. They have implemented the set functions and received positive feedback in the initial user experience tests. Eight participants (5 women, 3 men, with an average age of 25) rated the product highly in terms of functionality, creativity, and usability, with scores of 4.6/5, 4.4/5, and 4.0/5, respectively. However, more extensive quantitative user testing is needed. There are concerns arising regarding the potential harm to plants from excessive touch and the application of low electrical currents, as well as the possibility of attracting insects due to the presence of plants. Health concerns regarding plants are quite common in Plant Interfaces research. However, PlantMIDI and PlantLamp has been in operation for a year, and thus far, the connection between the plants and sensors has remained intact as well as the plant grows well.

5. DISCUSSION

Further extensive testing is necessary to address these concerns in a more professional manner. With regard to the attachment of sensors, it is preferable to attach them close to the stem of the plant rather than at the tip of the leaf, thus reducing the negative effect of bending the leaf due to the gravity of the sensor. For plant interface products, it is ideal to choose indoor plants that are easy to cultivate, small size (about 4 in), and have relatively fewer and thinner leaves. Some recommended plants include the Monstera Deliciosa, Pothos (Devil's Ivy), Bird of Paradise, and various California tropical plants.

The most common technology for using plants as interactive interfaces is Capacitive Sensing. Figure 7 shows the data changes after human-plant interaction using Arduino CapacitiveSensor Library. This experiment demonstrates the possibility of identifying each leaf of the plant. However, due to the variations among individual plants, the data obtained through sensors also varies. Therefore, algorithm optimization is required to handle noise and ensure data stability.

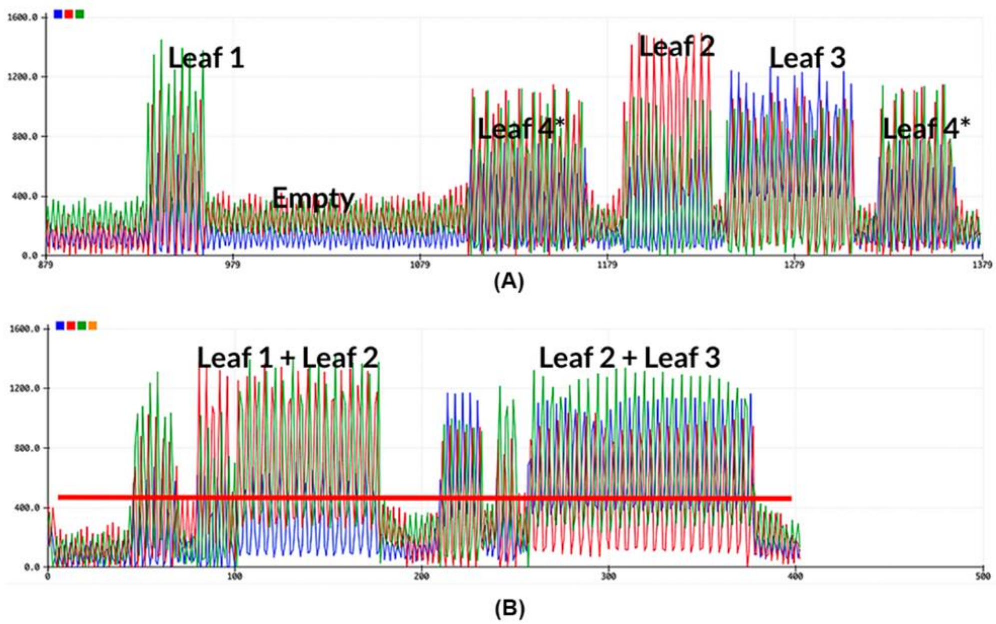

Figure 7. The plant used has four leaves but only three are used as capacitance sensors. A) When one leaf is touched (one of the three that act as capacitive sensors), although all the values will increase, the values of the touched will be significantly higher than the others (green color). When touching the Leaf 4 that had no capacitive sensor attached, all the values increased compared to the quiet condition, and the values of the two capacitive sensors close to the Leaf 4 are nearly equal (red and green color). B) It shows the data change when two leaves are touched at the same time. The data from these two sensors is increasing and approaching each other.

Today, the Internet of Things (IoT) represents a burgeoning trend that heralds a future where our lifestyles are seamlessly integrated with our devices, fostering a world intelligently interconnected. Products based on plant interfaces would like to expand on this concept of connection and transfer this into the natural world by leveraging the pervasiveness of sensing technology. Plant interfaces can connect our everyday objects just like the Internet. For instance, placing a plant in the living room at home, humans can use touch the plant's leaves to adjust indoor lighting, move curtains, play music, and switch TV channels. In addition to the sound interface and lamps introduced in this paper, there is a need to explore a broader range of products based on the plant interface that cater to different user needs.

6. CONCLUSION

The exploration of plant interfaces through the development of PlantMIDI and PlantLamp highlights the significant potential for integrating these natural elements into interactive, everyday products. These case studies demonstrate not only the technical feasibility of using plant signals for human-product interaction but also the profound impact such interfaces can have on fostering a deeper connection between humans and the natural world. By allowing plants to serve as interactive interfaces, these designs challenge conventional perceptions of plant functionality and open up new avenues for sustainable and mindful design practices.

The successful implementation of these prototypes underscores the relevance of this research in the field of industrial design, particularly in the context of creating innovative, nature-integrated products. The positive initial feedback from users suggests a strong interest and appreciation for the unique sensory and emotional experiences facilitated by these interfaces. Moreover, the potential applications of plant-based interfaces extend beyond the prototypes presented, offering opportunities for further investigation into a wide range of products that leverage the inherent properties of plants for enhanced human-plant interaction.

In conclusion, the findings from this research emphasize the importance of continuing to explore and refine plant interfaces. Such advancements could lead to more sustainable, engaging, and health-promoting designs that bridge the gap between technology and nature. The integration of plant interfaces into industrial design holds promise for enriching our interaction with the environment, ultimately contributing to a more harmonious and connected world.

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