Creating an Ultrasonic Automated Watering System
Decoding Plant Communication and Interconnectedness

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By
Alex Morris

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Technical Team Members:
Audrey Swart
Kate Van Meter
Sophia DeCleene

On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

ADVISORS
Joshua Earl Department of Engineering and Society
Adam Barnes, Department of Electrical and Computer Engineering

Prospectus Introduction

My research question for this technical project is: "How can we design an efficient and responsive automatic watering system that uses ultrasonic sensors?" This project was inspired by a research article highlighting how plants emit ultrasonic popping sounds when stressed outside the human hearing range. This inspired my capstone team and I to begin exploring how this knowledge could enhance plant care, especially for forgetful or busy plant owners. The central focus of this research is the integration of ultrasonic sensors to create a watering system that alerts plant owners when their plants require hydration.

When I commenced this research, I reviewed existing literature in the fields of plant communication and sensor technology. This initial phase was critical for understanding the foundations of automatic watering systems and the science behind plant stress. Additionally, my group and I delved into the process of constructing an ultrasonic sensor capable of detecting the specific sound frequencies emitted by dehydrated plants. For clarification, an ultrasonic sensor detects vibration of frequencies greater than the audible range for humans. The functional prototype of the automatic watering system incorporates an ultrasonic sensor, microcontroller, and water delivery mechanism consisting of components that have datasheets to help understand the configuration and operation. Microcontrollers are components that make it easy to control indicators like LEDs based on a sensor input like temperature or light. Subsequently, we conducted experiments to collect data on the plant sounds and evaluate the sensor's accuracy. Finally, we fine-tune the system's algorithms and control mechanisms to ensure it responds efficiently to the plant hydration needs.

In my STS paper I plan to answer "How does the emergence of plant communication technology challenge our understanding of ethical responsibilities in addressing climate change and gaining insights into plant stress?" This question offers a comprehensive examination of the societal and environmental implications of adopting an ultrasonic sensor-based automatic watering system for plant care. By knowing these answers, I explored potential benefits, such as water conservation and improved plant health, while also addressing ethical concerns. I used a Utilitarian perspective to provide a more comprehensive understanding of the ethical implications associated with plant communication technology. Use of such technology can enhance agricultural practices, contributing to increased efficiency and sustainability which will reduce damage to plants. This communication device aligns with the goal of developing tools that facilitate interaction with the ecosystems, emphasizing positive implications for both plants and human societies.

Overall, this paper attempts to shed light on the ethical considerations associated with integrating advanced technology into everyday activities like gardening and agriculture; while talking about how the technical project bridges the fields of botany, sensor technology, and automation to address the crucial issue of plant hydration. My goal was not only to contribute to the development of an innovative plant care system but also to promote a deeper understanding of the intricate relationship between technology, nature, and society.

Creating an Ultrasonic Automated Watering System

The technical side of this project went into the design and implementation of an automated plant watering system utilizing an ultrasonic microphone for precise and efficient plant hydration to improve plant care. Conventional plant care methods often struggle to strike the right balance between under and overwatering, leading to resource wastage and plant health issues. The primary goal of this system is to revolutionize plant care by creating a solution capable of assessing the hydration needs of various plant species. The project's centerpiece is an ultrasonic microphone sensor unlike strict automated watering systems, this approach focuses on detecting plant distress signals to determine when watering is needed. These signals are emitted when plant capillaries "pop" due to dehydration, typically in the 40kHz to 80kHz range. By using a peristaltic dosing pump and moisture sensor the device delivers precise water amounts, eliminating overwatering and underwatering risks. This project has several environmental benefits including water conservation and reducing waste from replacing dead plants.

Our project aims to achieve optimal plant care by using ultrasonic sounds as indicators of plant distress and a user interface accessible through a web portal that enables remote monitoring and control. When the ultrasonic sensor detects these sounds, a notification is sent to the user. The user can then decide to water the plant manually using a water button on the webpage or to water it automatically where the system detects the sound and water the plant on its own. Both options will ensure accurate water delivery by monitoring soil moisture levels using the moisture sensor data. An ultrasonic microphone captures the sounds and processes the data using an myRIO microcontroller that is a portable device that can be easily be used for embedded Wifi solutions. The main challenge was filtering out unwanted noise to isolate plant sounds accurately. This involved using passive bandwidth filters, amplifiers, and an analog-to-digital converter as well as Digital Signal Processing algorithms to distinguish plant distress signals from other sources. In order to test the microphone we used an ultrasonic pest repeller and distance sensor to stimulate a sound at the same range as the plant. This all sounds nice in theory but comes with its challenges.

Some other challenges included power management, integration of multiple components and addressing failure. When working with various components that require different power supplies we needed to know how to effectively distribute our power source to each component. Additionally, we had to figure out how to interface software with the hardware. We needed to find a way to integrate the microcontroller programming, signal processing libraries, push notification services, embedded software and web development tools. The myRIO microcontroller incorporated the plant environment monitoring sensors while applying Digital Signal Processing algorithms to take the digital signal from the microphone. In order to water the plant remotely we hosted a web server through the myRIO that allows us to store and visualize the sensor readings from anywhere. Some constraints included part availability, manufacturability, and production costs. High-quality ultrasonic sensors can be expensive, impacting the prototype's cost so we attempted to replicate them. The complexity of assembly, safety compliance, and energy efficiency was our biggest challenge.

Overall success would be if everything works out, which means we successfully synched the ultrasonic microphone to the water pump system, so that when the plant makes enough sounds to be classified as dehydrated, the device immediately detects it and sends a notification to the user using sms which will then notify the water pump to water the plant. If we are able to pull off the entire system working then we would be able to commercialize the project. We know that our goal might be overly ambitious, so we said that we would also consider our project successful if we were able to build the ultrasonic microphone and have it successfully detect the sound made by the plant because that is the main focus of our project.

Decoding Plant Communication and Interconnectedness

Plant communication technology has significantly transformed our understanding of plant life, introducing new possibilities for addressing climate change and gaining insights into plant stress. Plant communication devices refer to mechanisms through which plants exchange information. These devices allow plants to transmit signals related to environmental conditions, stress, or threats, enabling them to coordinate responses such as defense mechanisms, growth adjustments, and interactions with other organisms. I explored the ethical responsibilities associated with this technology, focusing on two key aspects: the development of plant communication devices and the interconnectedness of plants to society, then how these advancements can contribute to improved agricultural practices and environmental resilience through a Utilitarian perspective. Utilitarianism assesses actions based on their overall consequences and seeks the greatest good for the greatest number. Applying utilitarian principles to plant communication technologies involves evaluating the benefits and consequences to plants, humans, and the environment.

Over the years, captivated scientists have discovered chemical signals, volatile organic compounds, and even ultrasonic emissions that enable plants to interact with their environment and neighboring organisms. Plants have been known to alert neighboring plants about threats by using a signaling system to share information about potential dangers. This information was pertinent to the project as it provided insights into natural plant communication mechanisms, informing the design of communication devices that align with the existing ways in which plants interact and warn each other. For instance, in a study about *Sound Perception and its Effects in Plants and Algae* (Frongia et al., 2020) it delved into how plants and algae respond to acoustic stimuli, shedding light on the mechanisms and potential effects of sound perception on plant behavior. Utilitarianism utilizes this knowledge to develop communication devices that enhance plant well-being. The analysis considers the benefits of knowledge acquisition and improved plant care against potential threats, such as intrusion into plant autonomy. Advancements in sensor technology, enabling the eavesdropping on plant communication, raises ethical questions about the damage being done to plants. In the past, scientists injected electrodes into the stem of plants in order to read the electrical signals produced by the plant when threatened and consequently this method hurt the plant - ultimately killing them. Over time scientists have come up with less invasive ways to measure the electricity by making a gel-like electrode that can be attached to the surface of the stem (Keller et al., 2016). By understanding the harm done to plants, We can start to develop smart devices to enhance monitoring and ensure optimal conditions for plant growth for places like greenhouses environments, agriculture, and house plants. Effective plant communication can help create an environment that will help plants coexist with humans as fellow co-inhabitants without mistreating them.

It is important to understand the interconnectedness between human-plant interactions. This perspective views plants as more-than-human entities and co-inhabitants (Loh et al., 2024) . Utilitarian ethics supports this holistic approach, emphasizing the well-being of all sentient beings. By incorporating a respectful design approach, communication devices can be developed to consider the autonomy and well-being of plants, fostering a well balanced coexistence. To back my claims In the reading, *Finding the Mother Tree* (Griggs, 2022) Grigg's work explores the interconnectedness and communication among trees in a forest ecosystem, emphasizing the communal nature of plant interactions. Utilitarianism encourages recognizing and respecting these natural communication processes. Insights from this source can inform the design of communication tools that consider the communal aspects of plant communities, contributing to overall ecosystem health.

In conclusion, the emergence of plant communication technology challenges us to consider our ethical responsibilities to the ecosystem through the lens of Utilitarianism. Plant communication detectors, within the utilitarian framework, are viewed as instruments that can contribute to the well-being of both plants and humans. Understanding and developing communication devices that align with natural plant behaviors, respecting the interconnectedness of plants, and leveraging technological advancements responsibly can contribute to improved agricultural practices and enhanced environmental resilience. By prioritizing overall well-being, these advancements in plant communication technology hold the potential to create a more harmonious relationship between humanity and the plant kingdom, addressing climate change challenges with empathy and efficiency. This paper shows that these technologies can serve as a lens through which we perceive the harm and damage inflicted upon plant ecosystems in the wake of climate change-induced stress and migration. By making audible the "screams" of distressed plants, technology can compel us to confront the ethical imperative of addressing environmental crises.

Key Texts

My primary source for this technical project stems from the Article "*Plants Make Noises When Stressed, Study Finds*" (Sullivan, 2023). This study reveals that plants emit sounds when stressed, providing concrete evidence of their response to environmental conditions. It sheds light on the acoustic dimension of plant communication and stress. The text is highly relevant to the project as it showcased the feasibility of using technology to detect plant stress through sound emissions. They were able to detect the sound using CM16 ultrasonic sensors and machine learning algorithms.

Another resource I used to explain the harm of plant communication detectors comes from the article "*Engineers Create Device That Can Communicate with Plants*" (Ozdemir, 2021). This article discussed the development of a device that can communicate with plants by monitoring electrical signals in their leaves. It highlighted the potential for technology to bridge the communication gap between humans and plants. This text is essential for understanding the current state of technology in plant communication and how it aligns with the project's goals of using technology to understand and address plant needs.

To understand the STS perspective I used the following article "T*he Value of Nature: Utilitarian Perspective*" (Udoudom, 2021) provides a framework that underscores the practical benefits nature offers to human well-being. This perspective emphasizes the instrumental role of natural entities and their contribution to human utility. In the context of an essay exploring the ethical implications of plant communication technology in addressing climate change and understanding plant stress, Udoudom's utilitarian viewpoint can be a valuable reference.

Lastly, I referenced my STS project based on the concepts read in the text " *Plants can talk: a new era in plant acoustics"* (Hussain et al., 2023) This was relevant to the project as it provided insights into the sensory capabilities of plants, particularly in relation to sound, which may contribute to the overall understanding of how plants interact with their environment and potentially respond to communication devices.

These primary texts collectively provide a comprehensive understanding of the current state of research and technology in plant communication and stress detection. They informed the project's context by highlighting the significance of using technology to facilitate communication with plants and address their needs. Moreover, they emphasized the ethical dimensions of such technological interventions and their role in addressing climate change and understanding plant stress.

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