Towards Understanding the Design of Bidirectional Interactions for Enriching the Human-Plant Relationship

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Figure 1: a. A breathing-driven MR experience to cultivate awareness of bidirectional interaction with plants. b. A bidirectional touch-based platform to enable communication with plants. c. A wearable bidirectional hydration system for human-plant mutual care.

Abstract

Engaging with plants offers many wellbeing benefits. Motivated by these benefits, human–plant interaction (HPI) research is emerging. However, current systems appear to focus on unidirectional interactions between plants and humans, in which humans act on plants or receive information from them. This research argues that such approaches overlook the potential to give back to nature. Hence, I propose bidirectional interactions in which technology mediates the mutual influence between humans and plants, which appears to have been largely overlooked. As a new form of interaction between humans and nature, which involves plants not as passive objects, but as responsive living entities, in order to enrich the human-plant relationship. To explore this space, I developed a series of bidirectional systems across four progressive stages based on perceptual distance: awareness of bidirectionality, fleeting bidirectional interaction, embodied bidirectional interaction, and transcendent bidirectional interaction. This work seeks to contribute to the design of future HPI systems that enrich the relationship between humans and nature, ultimately aiming to achieve a more integrated coexistence with the natural world.

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CCS Concepts

• **Human-centered computing** → **Interaction design**.

Keywords

Human-plant interaction, More-than-human, Bidirectional interaction

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1 Introduction

The field of human-computer interaction (HCI) has shown an interest in studying the relationship between people and nature mediated by interactive technologies [18, 27], often labeled "NatureHCI" [10]. For example, the NatureCHI workshop series envisioned mediated interactions with nature in outdoor environments [12], while design works have explored the use of interactive technology to enhance the benefits of interacting with nature, such as increased psychological wellbeing [3] and physical activity [32], cultivating environmental awareness [7], and expanding social value [17]. These works primarily take a human-centred stance, leading to the realization that they miss out on facilitating any potential benefits to nature when humans interact with it [6].

While NatureHCI has often focused on how nature benefits humans [1, 13, 25], recent studies have begun to explore how nature

might also benefit from human engagement [20–22]. For instance, researchers have proposed that design can encourage humans to care for plants [1]„ foster empathy for nature [45], and promote pro-environmental behavior [33]. The former are all aimed at influencing human behavior to benefit nature, while some studies argued for designing through a respectful lens of nature [11], such as some systems that help monitor [20], enhance [22], and sustain nature [21]. Yet this compensates for the fact that humans have unilaterally benefited from nature [5], such systems remain a traditional one-way interaction perspective. However, the perspective of collaborative relationships with nature was proposed [19], and we can see the opportunity for new forms of interaction between humans and nature. While this challenges the traditionally unidirectional focus of HCI, it remains unclear whether such systems truly deepen a human-nature relationship [5]. Hence, I began to think about how technology explores new forms of interaction in mediating the relationship between humans and nature.

Plants, broadly defined as sessile or rooted, non-motile organisms [43], are living beings that use photosynthesis to produce energy and respond to environmental stimuli through biochemical and bioelectrical mechanisms [37]. Among them, indoor plants occupy a unique space in human life, offering many wellbeing benefits [8], especially in urban settings where access to nature is limited. Prior human-plant interaction (HPI) research has started to explore bidirectional interactions [35], reflected in research "Project Florence" that exemplifies this approach by using plant biofeedback to create a bidirectional interaction, where both humans and plants influence each other by using plant biofeedback. This inspired me to explore new forms of interaction between humans and plants and their impact on nature relationships. In particular, I decided to focus on indoor plants as a promising context for studying bidirectional human-plant relationships, as prior HPI research has often focused on outdoor or garden contexts [32, 38], leaving a gap in our understanding of how indoor plants [39] can support meaningful bidirectional interactions [2].

2 Related work

With the advancement of HPI, there is a growing interest in how bidirectional interactive technologies can enrich the relationship between humans and plants [5]. I examined how bidirectional interaction has progressively been incorporated into human-plant relationships in the literature.

- **S1: Absence of bidirectional interaction in HPI**. At this stage, HPI works have primarily focused on interactive plant interfaces [29]. These systems have mainly employed one-way interactions [20, 40], positioning plants as input or output interfaces. Plants have often been positioned as passive recipients or tools, ignoring the potential for bidirectional influence [5]. This absence has resulted in missed opportunities to enrich interactive experiences by effectively integrating plant characteristics.
- **S2: Bidirectional engagement in HPI.** Chang et al. [5] have highlighted the potential of incorporating bidirectional communication between plants and humans into HPI designs. Steiner et al. [34] have defined bidirectional interaction as a form of communication that enables humans to influence plants and, in turn, allows plants to influence the human experience. Such systems have highlighted how technology can mediate plants as active subjects and achieve bidirectional engagement in real time. Yet they have not addressed whether such experiences cultivate a deeper relationship with nature.
- **S3: Fostering collaboration in HPI.** The perspective of collaborative relationships with nature through interaction with fungi has been proposed [19], highlighting opportunities for new forms of interaction between humans and nature. In HPI research, some researchers have begun to utilize plant biofeedback to create bidirectional interactions [34]. However, the exploration of cooperative relationships between humans and plants has remained limited.
- **S4: Developing mutualism in HPI.** "Mutualism" describes the ecological interaction between two or more species in which each species has gained a net benefit [4]. Wilson et al. [44] have emphasized the importance of mutualism in human-plant relationships. Although HPI research has revealed potential to enrich human-plant relationships, it has continued to face the challenge of seamlessly integrating interactive technologies into long-term mutualistic relationships with plants.

The review of the role of technology in advancing human-nature relationships guided my exploration of bidirectional interactive systems. I gained two major insights. Firstly, most previous work can be categorized as falling into the first and second stages (S1 and S2). Secondly, previous research on HPI work has fallen short of exploring human-plant integration as collaboration (S3) and mutualism (S4). Consequently, there exists a gap in knowledge of how to design for such opportunities. Therefore, the gap in our current understanding is how to design bidirectional interactive systems between humans and plants. To start filling this gap in knowledge, this PhD aims to begin understanding the research question: ***How do we design bidirectional interactions to enrich the human-plant relationship?***

3 Research Objectives and Methods

I define "bidirectional interaction" as a dynamic exchange in which both humans and plants can sense [45], respond to [35], and influence each other's states or behaviours [19], fuelled by interactive technology. As a new form of interaction between humans and plants, it involves plants not as passive objects, but as responsive living entities, thereby achieving bidirectional interaction.

This PhD project aims to deepen our understanding of how to design such bidirectional interactions for enriching human-plant relationships. I intend to develop a design framework for the design of bidirectional human-plant interactions. To arrive at this design framework, I chose a "Research through Design" (RtD) approach where I developed a series of systems organised across four progressive stages based on perceptual distance [41] with time and space. Perceptual distance is the different ways in which an object might be removed from that point—in time, in space, in social distance—constitute different distance dimensions. It will do so through the design of four interactive systems that demonstrate

bidirectional interactions between humans and plants, thereby enriching the human-plant relationship, ultimately aiming to support a more integrated coexistence with the natural world.

4 Current Progress

Currently, I have just started my third year in the 3.5-year doctoral program, and have successfully passed the research ability test and obtained doctoral candidate status. Two projects have been completed, and the CHI paper [23] and DIS paper [24] on related work have been published, and two other long papers have been submitted. The prototype of case study 3 has completed the pilot study and is in the prototype iteration stage.

4.1 Respireal

Breathing is both involuntarily regulated by the autonomic nervous system and voluntarily controlled through conscious effort [14, 16]. This speaks to interactions with nature, which are inherently dynamic, uncertain, and not fully predictable [9]. As a result, this project proposes that breathing could be a promising control mechanism for mediating engagement with nature that remains responsive to the body while respecting the indeterminacy of nature. Even though interactive technologies have shown the potential to support engaging experiences with nature [12, 18, 42], such as mixed reality (MR), the relationship between humans and plants has remained relatively large. This case study helps answer the first sub-RQ of how to cultivate people's awareness and represents the first stage of doctoral research. I designed a playful, breathing-driven MR experience that transitions participants between virtual and real nature, serving as a playful way to enrich engagement with nature (Figures 2). I have considered that the appropriate use of bidirectional interaction has the potential to reduce device dependence that draws users away from nature, and to cultivate awareness of bidirectional interaction with plants.

4.2 PlantMate

Touching a plant not only calms the mind but also allows people to sense its response to the environment, forming a subtle and tangible connection with nature. Based on this, I built on the interaction model proposed by Rasmussen et al. [31], which identified direct interaction in human-plant projects, such as humans providing input directly to plants through touch, gesture, sound, or remote networked entities. Accordingly, this project proposed that touch could serve as a control mechanism for enabling communication with plants. I designed a novel bidirectional touch-based platform to enable communication with plants (Figures 3). The initial focus was on electrical muscle stimulation (EMS) [26], which enables the body to function as output [28]. In this system, a user's fleeting touch stimulated plant growth by translating touch into electrical signals. In return, the plant's hidden electrical signals were converted into fleeting electrical muscle stimulation for the user, allowing people to feel the "touch" from plants. This bidirectional touch-based approach offers a novel communication channel with plants, helps address the second sub-research question of how to enable communication with plants, and represents the second stage of the doctoral research.

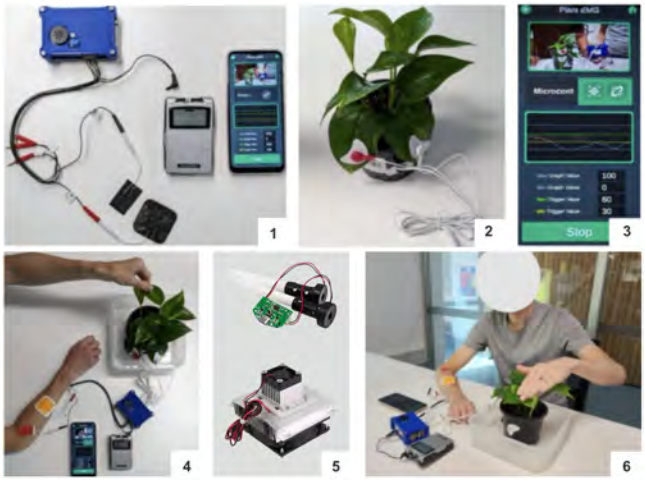

Figure 3: PlantMate, a novel prototype in the form of a bidirectional system between humans and plants.

5 Next Steps

In this ongoing project, I plan to explore a bidirectional interaction in the care process [46] through embodied interaction [36]. This perspective advocates acknowledging the materiality [30] and temporality [15] of plants. This case study aims to help answer the third research question regarding perceptual distance across the entire doctoral research. As I am working on the final iteration of my project, I am reflecting on how my case studies connect through the theoretical lenses and what they contribute to the theoretical frameworks of my dissertation. Participating in the DIS Doctoral Consortium would be a timely opportunity at this stage. I look forward to hearing diverse perspectives that will help me sharpen my focus and better articulate how my research contributes to the HCI and design communities.

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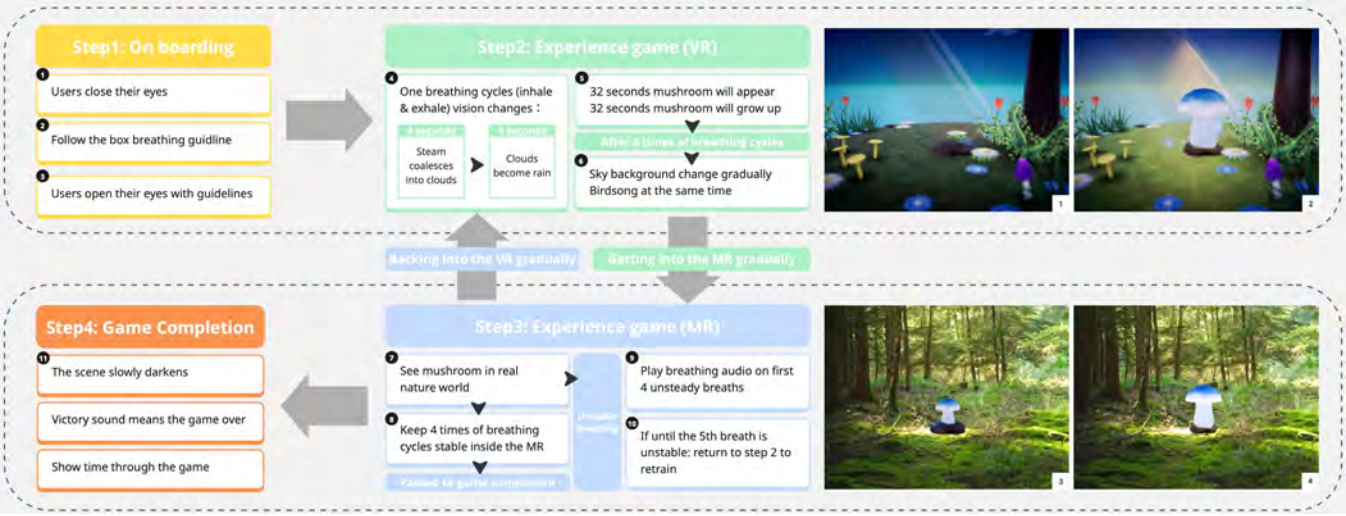

Figure 2: Respireal, a mixed reality breathing game.

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