Figure 1: The assembled *Overgrown* prototype. Using an endoskelton, a climbing plant can be actuated to, for example, perform a waving motion.

Overgrown: Supporting Plant Growth with an Endoskeleton for Ambient Notifications

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ABSTRACT

Ambient notifications are an essential element to support users in their daily activities. Designing effective and aesthetic notifications that balance the alert level while maintaining an unobtrusive dialog, require them to be seamlessly integrated into the user's environment. In an attempt to employ the living environment around us, we designed *Overgrown*, an actuated robotic structure capable of supporting a plant to grow over itself. As a plant endoskeleton, *Overgrown* aims to engage human empathy towards living creatures to increase effectiveness of ambient notifications while ensuring better integration with the environment. In a focus group, *Overgrown* was identified with having personality, showed potential as a user's ambient avatar, and was suited for social experiments.

CCS CONCEPTS

• **Human-centered computing** → **Ubiquitous computing**; **Ubiquitous and mobile computing systems and tools**.

Figure 2: *Overgrown*'s endoskeleton in its neutral position. The central spine consisting of a bendable plastic rod with supporting discs is actuated by 4 servo motors adjusting tension of individual fishing lines.

KEYWORDS

Ambient interfaces; ambient notifications; empathic living media; focus group.

INTRODUCTION

Ambient notification systems play an essential role in supporting users' daily activities in smart environments. By informing users of relevant events, they provide awareness of the system's state and serve as a first course of action. A key aspect of ambient notifications is the unobtrusive manner in which information needs to be provided. In order to promote calm computing, users need to be perpetually informed of what is happening around them without being overburdened [12].

While research has considered different techniques, designing consistent and aesthetic notification environments still remains challenging [13]. To form an informative dialog to the user, ambient notifications require a meaningful and unambiguous representation desirable to the user's context. In many such contexts, typical audible, visual and haptic cues are prone to distracting the user. To provide seamlessly integrated ambient notifications, we envision employing the living environment around us. Specifically, we focus on designing a framework which supports the aesthetic value of the plant kingdom while integrating them into the dialog of the smart environment.

In a first approach, we designed *Overgrown*, a remotely controllable robotic structure, shown in Figure 2. While *Overgrown*'s freedom of movement allows it to act as an ambient interface, its design is specifically focused on supporting a plant to grow over its structure, shown in Figure 3. Our technique differs from existing plant displays as we aim to not impede or alter, but support the growth of the plant. To gain insights into future directions for our concept, both as an ambient interface and as an assistant in a smart home environment, we organized a focus group and detail on the conclusions.

RELATED WORK

The concept of *Overgrown* intersects established literature on empathic living media with ambient interfaces for ambient notification environments.

Ambient Notification Environments

In an age of increasing complexity, managing events occuring in smart environments grows increasingly difficult. While visual, auditory or tactile alerts are generally efficient at communicating the message,

they tend to draw the attention away from the user's task [13]. Designing appropriate notifications requires finding a balance between the detail of information and the alert level while maintaining an unobtrusive dialog. To support the user in their context, ambient notification systems aim for *calm computing* by informing the user of what is happening around them while not overburdening [12].

Early research on presenting information in the user's periphery considered ambient display media using different modalities such as light, sound, airflow, and water movement [4]. Since then, a large design space of different ambient information systems has been uncovered [8]. Our *Overgrown* prototype functions as an ambient display using movement and orientation to notify the user.
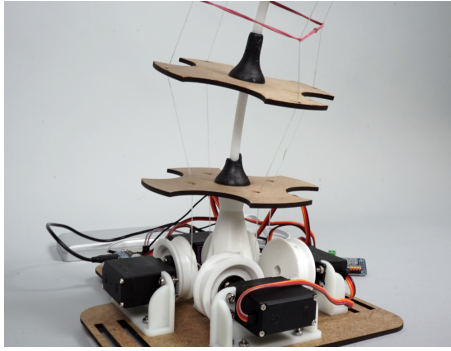
Plants as Ambient Interfaces

Plants are ubiquitous members of our environment living as silent, prevalent lifeforms in their own timeline. Interest is growing in understanding them as active beings rather than overlooked objects [1].

A first approach to engage plants as ambient interfaces is to augment them with actuators to generate movement for ambient output. One of the earliest works is Office Plant #1 [2], a robotic sculpture mimicking a plant which changes its configuration based on the user's email activity. Although not a real plant, their concept of *intimate technology* brought awareness by provoking personal attachment through movement and light. Flona [10] builds upon this by adding actuators to a domestic plant to implement lifelike behaviors. Similarly, the actuation of our *Overgrown* prototype allows it to act as an ambient interface to the user while supporting the growth of the plant to ensure a more natural integration into the user's smart environment.

Empathetic Living Media

To create more desirable interfaces, empathic living media utilizes human's empathy for living creatures [3]. In the case of plants, human affect towards them is connected to the ability to recognize their state of wellbeing. Plant Display uses this affect to reflect inter-human relationships by influencing the light and water plants receive, turning them into social ambient displays [6]. Authors build upon this with I/O Plant, a tool kit for designing augmented human-plant interactions [5].

A similar approach considers phototropism, the growth of an organism which responds to a light stimulus. As plants adapt to the environment around them, the property of phototropism allows us to vary a plant's growth direction by manipulating light around them. Applied in a family environment, authors use this concept to bring awareness of family member communication [14]. Similarly, a plant-like object was used as reactive displays to bring awareness of trash recycling in shared environments [11]. While again not real plants, authors state the use of things from nature in the displays contributed to more engaging and compelling awareness. While *Overgrown* does not influence growth or wellbeing, we aim to improve ambient notifications by considering human affect and empathy towards its living properties.

Figure 3: *Overgrown*'s skeleton "overgrown" with artificial ivy. By supporting plant growth, our concept aims for better integration into the environment while eliciting human empathy for living media.

Figure 4: *Overgrown*'s actuation mechanics. Four servo motors tighten individual fishing lines to bend the spine.
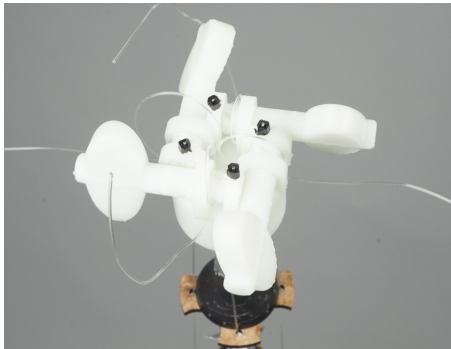
Figure 5: *Overgrown*'s tension mechanism. Inspired by the tuning pegs on a guitar, this mechanism allows to easily adjust the tension on the individual fishing lines.

[1]Animatronic Tail by Circuito.io
https://www.hackster.io/circuito-io-team/animatronic-tail-by-circuito-io-e40ba1

[2]WEMOS D1 Mini
https://wiki.wemos.cc/products:d1:d1_mini

[3]Adafruit PCA9685
https://www.adafruit.com/product/815

CONCEPT

An important aspect of devices for ambient notifications in ubiquitous environments is to have a technological aesthetic design. Even though efforts have been made to integrate them into the environment, this process is usually static and does not consider the change in the environment over time. We propose to have devices not only support the need for ambient notifications, but support living things in the room. As ambient living media promotes human empathy, we aim to make notifications more desirable. In our concept, a plant in the room overgrows the technology, making integration within the environment a continous process, serving as a living ambient interface.

In a first approach, we propose a structure to support an upwards growing living plant, see Figure 2. We constructed the endoskelton by extending an open source sketch for an animatronic tail[1]. The basic design consists of four servo motors controlling the tension of four fishing lines, shown in Figure 4. Additional tuning pegs on the top of the spine allow to easily adjust and align the structure's neutral stance, shown in Figure 5. The fishing lines are threaded through laser-cut wooden 3mm thick vertebras that are equally spaced and tapered from the base to the top of the skeleton. A 5mm wide, 1m long, flexible polyoxymethylene rod serves as backbone of the endoskeleton. We used a Wemos D1 Mini[2] and a 16 channel PWM driver board[3] which allowed us to wirelessly control the servos and with this the skeleton, using a small python script and a gamepad. In our prototype we weaved an artificial ivy plant around the skeleton in a natural manner, shown in Figure 3.

FOCUS GROUP

Overgrown's concept as an ambient interface supporting plant growth was explored in a focus group which consisted of a total of 5 participants with backgrounds in Computer Science and Biology. Participants were aged 26 to 33 years old ($M = 29.4$, $SD = 2.6$) and were recruited from the University's campus. One observer carfully noted responses, while another observer actively engaged in discussion with the participants. The main task of the group was to collect ideas of how they would envision ambient plant based notifications to take place in a smart environment.

Participants were introduced to our prototype and its capabilities. A moderator used a gamepad to give an initial introduction in how the plant is able to move. During the session, participants were encouraged to actuate the plant to their liking. The discussion started with the question *What could the plant convey?*. Further discussion inquired as to where participants would place *Overgrown* and how they would use it in different contexts. The session lasted for roughly one hour. The collected data was processed and the most prevalent ideas were more deeply elaborated on.

Figure 6: *Overgrown* in a bended configuration. Besides acting as a pointing motion, human affect for the plant would evoke contemplation for its wellbeing.

RESULTS

As expected, the focus group produced a myriad of ideas and concepts. Here we detail on the three most promising themes that were discussed in more elaborately.

Plants with a Personality. When seeing the plant move, one of the first ideas that arose was to human-plant communication. This discussion later evolved into the concept of living media with a personality. Participants speculated that the plant could convey happiness when the owner returns home from a long day of working by waving its 'body', depicted in Figure 1. This behavior was seen similar to convey similar affect to the act of a dog wagging its tail. It was thought to be especially beneficial for older people living in a retirement home where having a pet was not allowed. Staying with the concept of supporting the elderly, participants devised the idea that the plant could provide subtle reminders, e.g. a leaning towards the door could mean that now would be good time for a walk (see Figure 6). A more obvious application of the plants' movement would be an indication of its wellbeing. While the lack of hydration would result in (irreversible) wilt of the plant, a leaning towards the floor could remind the owner of the plant to water it.

Plants as an Avatar. Similar to [7], human affect towards the plant could purpose it to act as an avatar of the owner. Combined with a sport- or food-tracking app, movements of the plant could mirror the physiological state of the owner. Here, the owner's heart rate could be visualized through swinging movements of the plant. Alternatively, not drinking enough water would result in the same behaviour meantioned before, i.e. a leaning towards the floor to notify the owner that it is time to drink some water. Designing a plant avatar considered beneficial for creating awareness of oneself and one's behaviour, essentially creating an object for empathy [15].

Plants for Social Experiments. One of the more surprising ideas consisted of using the plant for social experiments. Since the plant could be controlled remotely, the participants discussed attaching a camera to the top of the plant and placing it in a public space while controlling it remotely. In this context, participants were interested in investigating both sides of the interaction, i.e. the side controlling the plant and the side interacting with the moving plant. Expanding on this, public live streams of the given remote control interface could be used to enable a gamified, collaborative plant control system [9].

CONCLUSION & FUTURE WORK

In this work we presented our *Overgrown* concept, an actuated endoskeleton for ambient notifications which allows a plant to grow over its structure. We conducted a focus group to explore application scenarios and plan to further elaborate on these findings. While we used an artificial plant for our working prototype, we are looking forward to grow our own, living ambient notification system.

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