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The IndaPlant Project: An Act of Trans-Species Giving

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Abstract

The IndaPlant Project: An Act of Trans-Species Giving is a generative artwork in which houseplants are robotically enabled to freely move in search of sunlight and water. This project has successfully constructed a floraborg, a term its creators coined to describe an entity that is part plant and part robot. Originally debuted at ISEA in 2012, the interdisciplinary collaboration now consists of a community of three light-sensing, robotic vehicles, each of which responds to the needs of a potted plant by moving it around in three-dimensional space. This paper presents an overview of current floraborg life and details the research in and across art, engineering, computer science and biology that makes self-sufficient, data-sharing IndaPlants possible. These initiatives include the creation of a self-monitoring computer vision system, a self-watering mechanism that utilizes plants' transpiration, and a cyber-physical interface to support plant-machine communication, and by extension, a new paradigm in plant-to-human interaction.

Keywords

IndaPlant, robotics, eco-robotics, mobile plant, plantbot, machine vision, floraborg, cyber-physical interface.

Introduction

The IndaPlant Project: An Act of Trans-Species Giving was conceived as an interactive installation in a domestic environment, where robotically enabled, autonomous houseplants could roam freely in search of sunlight and water.

Artist Elizabeth Demaray originally envisioned that the robotic supports for the IndaPlants would draw upon the work of the Italian/Australian cyberneticist Valentino Brattenberg. He designed Brattenberg vehicles, which are simple devices, based on the neuronal architecture of insects, that utilize basic schematics for attraction to and avoidance of stimuli. However, once the team began considering the possibilities inherent in the creation of a floraborg, we realized that we could instead wire the vehicle through an Arduino board. This configuration not only allows for species-specific programming, but can also support simple adaptive behavior in the form of machine learning.

Floraborg Configuration

The one floraborg featured at ISEA in 2013 has expanded into a population of three units, each of which performs sun- and water-seeking functions. The plant-carrying robot platforms are three-wheeled to enable movement in any direction. Each unit is equipped with six sonar sensors for motion planning and carries three solar panels that allow the robot to recharge its battery packs when the plant is sunning itself. These solar panels additionally function as the unit's light sensors, allowing it to find the brightest spot within a lit area. Created to map the space of a domestic environment, the community is designed to wirelessly share information concerning light and water sources.

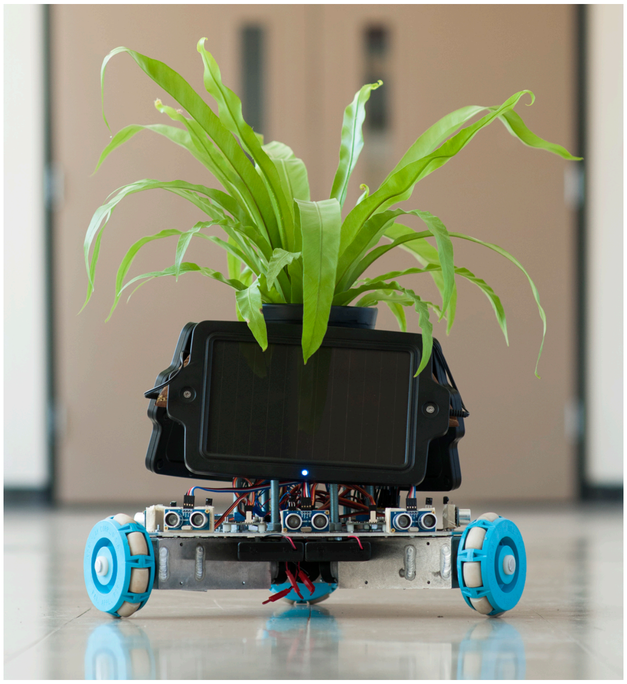

Figure 1. Single IndaPlant on three-wheeled platform. Each unit has six sonar sensors for motion planning and three solar panels for recharging its batteries. © David Gehosky 2014

Daily Routine

Currently housed in the Mechanical and Aerospace Department at Rutgers University, the floraborgs have become part of the daily routine (see Figure 4). When Zou comes to work in the morning, he is greeted by the three IndaPlants, which jostle one another to exit his office in search of sunlight in the adjacent hallway. When an IndaPlant is thirsty, a moisture sensor sends a signal through the unit's central processor that may decide that the plant needs water. If so, the unit will locate a water dispenser in the hallway via an infrared sensor. If a floraborg is in the immediate vicinity of a watering station, passers-by are invited to give it a drink. A three-minute video summarizing the project's inception, with footage from the IndaPlant community's daily routine, may be seen at https://vimeo.com/90457796.

Aims of Current IndaPlant Project

Due to their sessile nature, plants are often exposed to a variety of overlapping perturbations, including air pollution, temperature and light variations, drought, a deficiency or surplus of nutrients, and attacks by insects and pathogens, and they must therefore develop sensory mechanisms to protect themselves. Different stimuli evoke specific responses in living cells, which are in turn transmitted to the organism as signals. Consequently, plants generate various types of intra- and inter-cellular electrical impulses in the form of variation potentials. Moreover, since they lack motility, plants are naturally equipped with superior biological probing devices that detect, record and transmit information about environmental changes.

Given the unique characteristics of plants as sensors and actuators, the IndaPlant team aims to build the necessary computational and robotic infrastructure to support the health and self-sufficiency of these organisms while integrating them into a dynamic, mobile, cyber-physical system.

We currently seek to establish both a theoretical/computational and a cyber-physical framework that may sustain an IndaPlant community. Key to this effort is the creation of an interface that allows the robotic platform to acquire signals from the plant and to interpret these signals to infer gas interactions, metabolism and growth in its supported species. In response to this input, the robotic carriage will move the plant around to maximize its well-being. The platform's ability to navigate according to the plant's signals is essential to closing the control loop. This can be achieved by equipping the floraborg with the necessary support infrastructure, sensors, processing power and algorithmic ability to gather and interpret data. To this end, the team is exploring machine vision, a transporation watering system, and the creation of a floraborg cyber-physical interface.

Machine Vision

A fundamental challenge we are addressing is to capture a plant's visual cues. Ahmed Elgammal is using a Raspberry Pie camera board to record time-lapse video of the IndaPlant, which allows it to visually monitor its own state of health. We developed a computer vision algorithm to track the plant's growth and leaf wilting, which indicates the need for water.

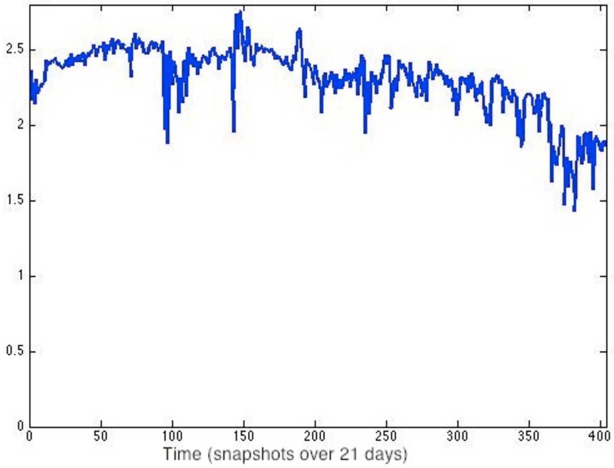

Figure 2. Measuring visual leaf wilting signal over a duration of 21 days. The decay in the signal corresponds to a period when the plant was not watered. © Ahmed Elgammal 2014

We plan to investigate the use of basic computer vision segmentation and shape description techniques to quantify the growth process and other visible cues. Figure 5 shows the preliminary results of measuring a plant's wilting motion via a single visible spectrum camera. They were obtained using 2D analysis of one view over a long duration. We will attempt to develop algorithms to measure and discriminate between several visible cues, including growth,

Figure 3. A Demaray-Kuchoni system gathers purified water after photosynthesis. © Elizabeth Demaray 2014

wilting, phototropism, and different types of nastic movements. We will also investigate the use of multiple cameras that can obtain depth information from various views to provide a dynamic 3D reconstruction of the plant.

Transpiration Collection

Transpiration is the process that plants use to secrete purified H_2O on the undersides of their leaves—trading water for atmospheric gas (CO_2)—during and after photosynthesis. This collected water is a way to measure plant metabolism. The IndaPlant team is designing a system that may use collected transpired water to allow each floraborg to hydrate itself. This research and design work has also resulted in a Demaray-Kuchoni collection system that lets humans draw on the potential of plants to produce purified water, as seen in Figure 3.

Plant/Robot/Human Communication

The IndaPlant team also aims to create a cyber-physical interface that can close the positive feedback loop between the plant and its robotic support. Functioning as a conduit to signal and then digitize information about environmental perturbations from plant to machine, this interface will, by extension, allow for a new paradigm in plant-to-human communication.

The immediate goal of this interface is to create an instrument that utilizes the sensory powers of sessile organisms to detect and map hazardous gasses within a mobile framework. While still in its infancy, the floraborg system may pave the way for a wide variety of environmental exploration, manipulation, data mining and modeling applications. By utilizing whole plants, we hope to devise a way to leverage the information they can gather on ecosystem health, the effects of climate change, and air pollution. In this capacity, the IndaPlant interface may provide foundational capabilities that will allow us to model and support environments that can sustain humans and plants alike. In settings that are unsafe for humans, the autonomous mobility of an IndaPlant may be used to detect pathogens, poisonous gasses and weapons. It may be able to sense toxic chemicals on the battlefield. In geologically unstable terrains, it may be able to analyze the fumes from volcanoes. Current research using biosensors in space [1] highlights the importance of bioinformatics in the success of human missions to Mars. Hence, this cyber-physical system may be used extraterrestrially to model how living organisms adapt to non-earth conditions.

Resolution 640*480
Mode 60 HZ
Brightness 13
Contrast 6
Preset 1

Figure 5. Two IndaPlants on a live webcam feed at "Welcome to the Anthropocene," the Association of Environmental Science Studies 2014 symposium in New York City. © David Gehosky 2014

While the field of biosensing is still young [1], there are already indications that different plant species excel at different types of sensing and remediation [2]. Our project maintains that focusing on the abilities of heterogeneous plant species is timely and important. Scientists believe that the earth is in the midst of a sixth great extinction, an event characterized by the loss of between 17,000 and 100,000 species each year [3]. According to Stephen Hopper, director of the Royal Botanic Gardens in Kew, England, "Recent work on plant assessments suggests that around one in five plants are threatened" [4]. While new species do eventually evolve to replace those that are lost, after each of the last great extinctions, evolution required about ten million years to restore the pre-disaster levels of diversity [5]. With each extinct plant species representing a loss of genetic information in the form of ten million years of evolutionary adaptation in both the sensing and remediation of harmful conditions, the IndaPlant group aims to create the cross-cutting, multi-disciplinary framework required to support studies on the abilities of the plants that are still available.

Broader Impact

We anticipate that our research will have a broad impact in robotics, biology, bioengineering, and system controls. The paradigm shifts involved in mobilizing a sessile organism, in creating a two-way plant robotic interface (allowing greater communication among plants, computers, and by extension, humans), and in utilizing plants as mobile biosensors, will open the door to new studies in the biology of the biosensing and remediation capacities of diverse plant populations; bioengineering and systems control; and advances in computational science as plant signaling becomes more integrated into the plant/computer interface. These research activities may even foreshadow the creation of EcoRobotics, which may become a field in its own right.

IndaPlant Project Updates

Videos, project information and updates on the *IndaPlant Project: An Act of Trans-Species Giving* can be found at http://elizbethdemaray.org.

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Figure 4. Floraborgs in the hallway at Rutgers University. © David Gehosky 2014.