I/O Plant: A Tool Kit for Designing Augmented Human-Plant Interactions

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Abstract
In this paper, we introduce the versatile creative tool called "I/O Plant" which generates new-style interactions among humans, plants and computers. It enables designers to manipulate plants as modules by attaching actuators and sensors to plants. It has been designed to create original hybrid circuits. We report not only our tool, but also use patterns and several examples. I/O Plant cultivates new creativity toward the interaction design.

Keywords
plants, interaction, ambient interface, biological signal.

ACM Classification Keywords
B.4.2 [Input/Output Devices], H5.2 [Information interfaces and presentation]

Introduction
There are abundant interactions between plants and their surroundings in our living world. Plants accumulate and display an effect of stimuli in forms and motions. For example, photosynthesis combines CO2 and water to turn into energy which grows plants. Tropisms change a plants' growth direction according to the stimulations such as light, contact, gravity and

water. Furthermore, biopotentials of plants instantaneously react to changes of their surroundings.

In the field of Computer-Human Interactions, researchers have tried to utilize plants as information interfaces [1-3]. However, there are serious limitations to utilize plants. It is not easy to perceive plants' reactions because biopotential response is invisible and growing response takes a lot of time to display. In addition, every plant produces diverse reactions by differences in species and surroundings. Therefore, the former researches took a lot of effort to utilize plants' behavior.

The purpose of this paper is to support designers who develop a dynamic interactive system using plants' ecosystems. We present a tool kit to design the human-plant interactions, an experiment of plants' reactions, several use patterns and application examples.

I/O Plant

Design

I/O Plant is designed as a hardware kit and software for connecting plants and electronic circuits.

The hardware consists of two different sets- sensing/-transducing parts and induction/growing parts (figure 1). The former is composed of needle-type solid electrodes, conductive frogs for flower arrangement, amplifiers, sensors, cables and wireless modules. The latter is composed of the full-color LED lights, water pumps, and audio speakers.

The software is developed by MAX/MSP and it has two transduction functions (figure 2). First, it executes actuators (i.e., light and water pump) to stimulate

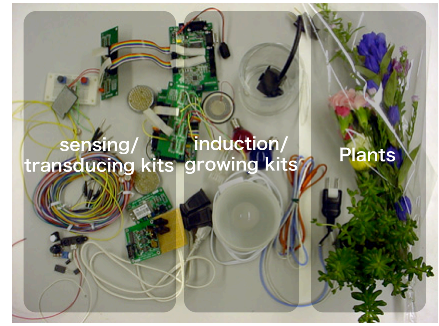


figure 1: I/O devices.

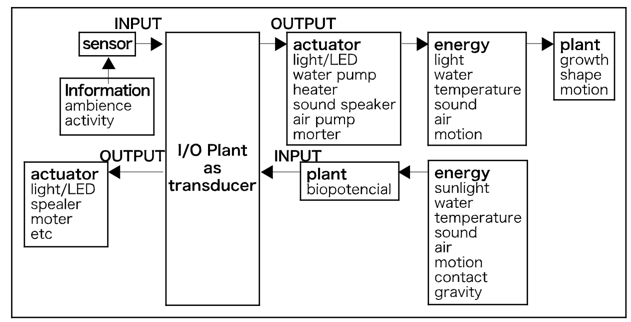


figure 2: Plant as transducer.

plants. The actuators manipulate growth, shapes and motions of plants. Secondly, the software can convert biopotential responses into numeral values, and control actuators. By the software, we can observe various aspects of plants' reactions (figure 3). It is shown that the biopotentials change according to stimulus, surroundings and plant species. Plants adapt themselves to the change in different stimulation such as motion, touch, approach, vibration, sound and water (i.e., the pattern 1 and 2). They discriminate differences of surroundings such as place and clock

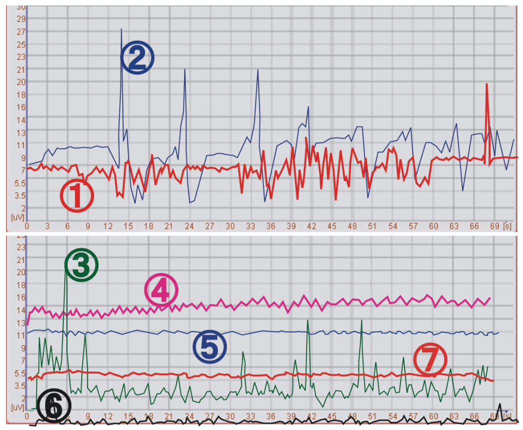


figure 3. The potential variation: (1) Changes by motion. (2) Changes by touch. (3) Place A, outside, night (4) Place B, inside, bright, night. (5) Place B, inside, bright, daytime. (6) Place C, inside, dim, night. (7) The other plant: Place B, inside, bright, daytime.

time (i.e., the pattern 3,4,5 and 6). They have a different waveform by plant variety and individual specificity (i.e., the pattern 7).

Usage

In this paper, we introduce implementation of the function that transforms biological reactions into data for computer processing.

HARDWARE

1. Connect to a plant.
2. Measure bioelectrical potentials.
3. Amplify miniature potentials.
4. Input to ordinary personal computers as sound waves (through the microphone terminal port).

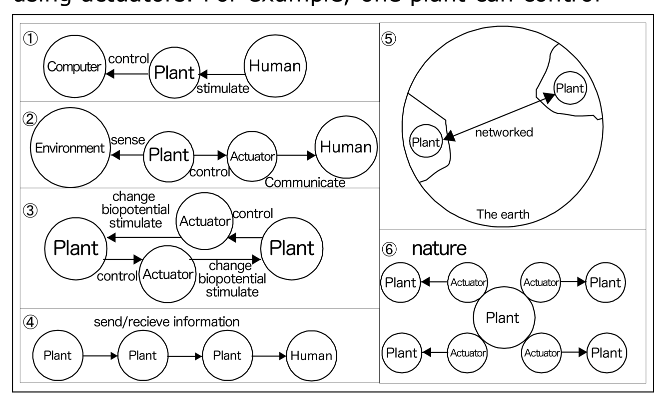
SOFTWARE

1. Convert analog to digital.
2. Register self-active biopotential changes as a standard value.
3. Discriminate the self-active biopotential change.
4. Discriminate the registered potential changes. Register it when it is an unregistered potential.
5. Control devices depending on the standard value and differences with the value. Set output processing by a detection order of stimulation.

Pattern for utilizing

Figure 4 shows pattern for utilizing designed by the kit.

- Pattern 1: Users control computers by intentional stimulation (i.e., touch, light, talk, nutrition and breath) to plants. In other words, plants become an interface between human and computers.
- Pattern 2: Plants represent environmental variations to human through controlling some actuators (i.e., light and sound).
- Pattern 3: Several plants stimulate each other using actuators. For example, one plant can control



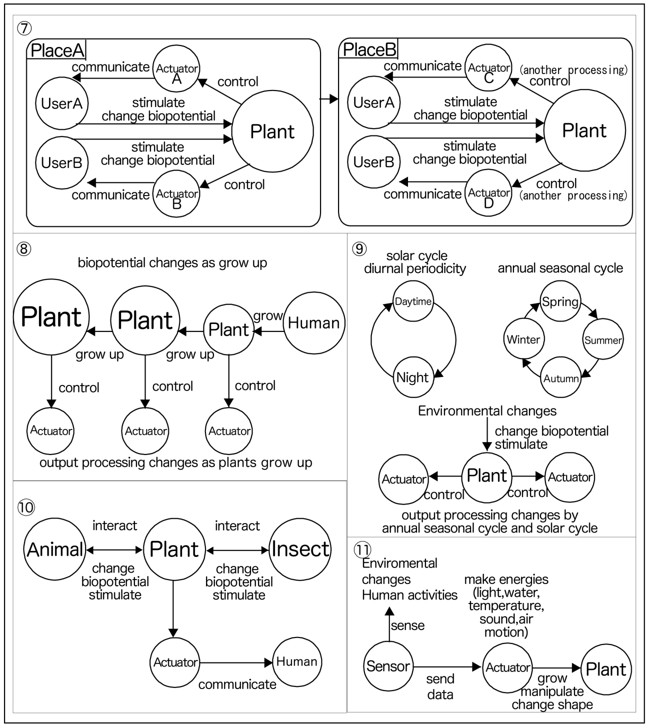


figure 4: Pattern for utilizing.

light devices according to own biopotential, in order to feed other plants (and vice versa). In this way, it looks as if plants are collaborating.

- Pattern 4: Plants transmit information to the other plants like a relay circuit by forming sensor networks.
- Pattern 5: A plant in a place communicates with the other plants in remote places through the Internet. For instance, a plant feeds other plants in different countries by reproducing the similar environment. Several remote plants become close partners.
- Pattern 6: A tree can feed other small plants near to it by providing heat and light through devices. The using actuators. For example, one plant can control light devices according to biopotential of itself, in order whole of a tree and surrounded plants propagates like a surrealistic botanical garden.
- Pattern 7: When the users or the environments change, the same circuit executes other processing. Consequently, the system produces various interactions in the differences of human, plants and environmental settings.
- Pattern 8: A plant changes output processing according to plants' growth.
- Pattern 9: A plant produces a different output processing depending on annual seasonal cycles and solar cycles. The device generates various reactions to different climate.
- Pattern 10: A plant represents own potential reactions by controlling actuators when it interacts with other creatures.
- Pattern 11: A plant is manipulated by actuator processing based on data of environmental changes or human activities.

Application

Ambient Plant interface

This is a platform that turns plants into ambient interface to control electrical equipments. This belongs to pattern 1. Figure 5-a shows an example in which a light is illuminated when users stimulate a plant. The lights' color change according to biopotential variation. Since actuators and plants are removable, the plant can be a music generator when a speaker is attached. These examples assist space design and interior design.

(a) (b) (c)

figure 5: (a) Ambient Plant Interface (b) Interactive Flower Arrangement (c) Grafted Illumination

Interactive Flower Arrangement

This is an appliance that can dynamically transform a style of traditional flower arrangement (Figure 5-b). This belongs to pattern 1 and 2. The whole of flowers turn into sensors by arranging on a frog which works as an electrode. Biopotential changes converted into various colors of full-colored LEDs set in a vase. LEDs dynamically changes by environmental variations and interaction with humans. Moreover, this representation makes audiences feel biorhythms of flowers. As a result, this communication with flowers creates new experiences as if a visitor can talk with plants.

Grafted Illumination

This is an illumination that can connect with trees. This belongs to pattern 1, 2, 4, 5, 9, and 10. This realizes variable illuminations by interaction among trees, people and surroundings (figure 5-c). For instance, electric changes by time, temperature, and other creatures produce various colors of lights. If a tree senses a drastic transformation by unintended stimulation, it transmits the information to the surrounding trees. This signal produces spreads of illuminations from a tree to a tree.

Related works

Infotropism [2] and Spore [3] are examples using plants as an actuator. Infotropism is an interactive display that utilizes phototropism. Spore is a self-sustaining ecosystem to visualize flow of stock prices. These works utilize only the function that converts environmental energies into plants' behavior. Moreover, these are too simple compared to our tool that covers a wider range for applying plants as information displays.

Plantron [4] and PLANTS DEMO [5] are works that use plants as sensors. Plantron is a bioelectric interface that converts biopotential changes into sounds. PLANTS DEMO is a system that will allow plants to control their own environments. These systems are different from our system in following points. These utilize only the function that utilizes biological reactions. These limit output processing and emphasize measurements.

Telegarden [6] and HERBARIUM [7] are computer systems for gardening. Their concept and our research are in same direction because these treat plants as a subject of an interaction. Telegarden is a device which allows users to seed and grow plants in a remote garden through a web-based interface. HERBARIUM is a product that characterizes growth conditions for each individual plants by strength of light. However, these mainly aim at cultivation of plants.

We would emphasize a decisive difference with these works is that our contribution is a tool. Although PLANT SYSTEM [8] is in a same direction as our research, their creative environments are limited to software and network architecture. Also, applications are far from interactive media. Our research covers hardware kits and a wider range for creations of interactive media.

Conclusion and future works

In this paper, we have demonstrated I/O Plant through the practical examinations. As a result, the tool and the use patterns supported us to construct interfaces with plants easily. Furthermore, we found that it can acquire plural information with one plant whereas current sensors have to be prepared by every data. Compared to previous works, the tool enabled us to distinguish each biopotential reactions different in surroundings and species. In conclusion, the results show that our research is effective to utilize plants' behavior for the interaction design.

We describe further study of applications using I/O Plant. We cannot effectively use the biopotential data that changes minutely because the applications limit actuator expression. Thus, we investigate rich representation and dynamic interactions through authoring various works by the use pattern. We especially consider utilization of timescale such as environmental changes in a year. Furthermore, we plan to develop a pet-like application which plants change their responses by place, growing phase, cycles (This belongs to pattern 3, 7, 8, and 9).

Further work of the tool kit is underway to develop a creative environment and an experimental environment for augmented human-plant interactions. We plan to develop software to analyze a wave pattern and a database system as well as I/O Plant. Those three enable everyone to test and create interactive system. Our software will be designed to analyze biopotential signals with multiple windows and filter with mathematical algorithms. The database record signals and store feature vector matrices for the long-time observations. Furthermore, we plan to hold the workshops for interaction designers. We etherealize our tool kit through practices.

Acknowledgments

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