Water-Jet Printer: Sprinkler with Watering-Position Control

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Abstract
Sprinklers with a rotating nozzle that is driven by a water current are commonly used in gardens. Many of these sprinklers sprinkle water over a circular or fan-shaped area in a garden. For common gardens that are not circular or fan-shaped, these sprinklers cannot sprinkle water over the entire garden area without sprinkling the immediate surroundings, such as the neighboring properties or public pavements. In this study, we developed a computer-controlled sprinkler and a web application that allow users to specify the watering locations easily.

Author Keywords
Water-Jet Printer, Sprinkler, Water Display

ACM Classification Keywords
H.4.m [Information systems applications]: Miscellaneous

Introduction
Many commonly used garden sprinklers are designed to sprinkle water uniformly in a circular or fan-shaped area using an automatic rotating nozzle driven by a water current. However, the watering area in gardens and parks is not always circular or fan-shaped. Moreover, a garden may contain various plants, some of which require more water than others. People may also have objects such as tables or chairs in a garden. Although these objects are

likely designed to be waterproof, it is often undesirable to spray them with water. However, conventional sprinklers are designed to water evenly, making it impossible to allocate extra water to specific plants or avoid specific objects in the garden.

We attempted to solve the aforementioned problems by developing a computer-controlled sprinkler that waters the locations specified by a user. By ignoring the locations that do not require water, the novel sprinkler can reduce the water consumption compared with conventional sprinklers that water evenly over the target area.

This paper describes a novel computer-controlled sprinkler that effectively sprinkles water only to specified locations. We also developed a web application running on a computer embedded in the sprinkler, enabling users to specify the watering location easily. By connecting a smartphone or a personal computer (PC) to a webpage, a user can "draw" the watering areas on a display showing a sketch of the garden.

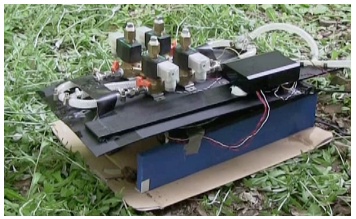

Figure 1: Overview of the water-jet printer.

Related work

Researchers have conducted studies and developed products based on computer-assisted watering. Pearce investigated gardening methods with twenty gardeners and developed software tools that proposed the proper watering schedule and the amount of water [4]. Edyn [1] informs the user of the condition of the garden by using data from a soil-diagnosis sensor, and Farmboat [2] is an open-source robot that realizes precision farming. Numerous studies have focused on interactions using water. Jansen developed an interactive input device with water pipes having several drain holes [2]. The user can make sounds by closing one of the holes of this device. Jansen developed Garden Aqua[1] , which can cause a ball to rotate in the air by placing the ball on water ejected from a nozzle. Koike developed an interactive water surface. They placed a projector and a Kinect sensor over a bathtub, allowing users to interact with the projected contents by performing hand-gestures on the surface of the water in the bathtub [3].

Watering hardware

Our sprinkler device waters the specified locations by controlling the flying distance and the horizontal angle of the sprayed water. An overview of the system is shown in Figs. 1, 2 and 3. The desired flying distance is achieved by adjusting the water pressure at the nozzle, and the horizontal direction is adjusted by rotating the turntable on which the nozzle is mounted.

The waterway from a faucet is split into four paths. In each path, a regulating valve is connected to adjust the pressure, followed by an electric valve[3] . The power lines of the electric valves are driven by a microcomputer embedded under the valve part, and each valve can be opened or closed by a program running on the computer. After passing the regulating and electric valves, the four paths rejoin and connect to the nozzle. When the regulating valves are set at different positions, various water pressures are achieved at the nozzle by opening or closing the electric valves. For example, if the four regulating valves are set to yield water pressures with the ratio of 1:2:4:8, we can induce 15 levels of linear water pressure by opening or closing the four electric valves. By this mechanism, the sprinkler device sprays water to the specified distances according to the 15 levels.

The entire waterway part, including the regulating valves,

[1] https://www.kickstarter.com/projects/edyn/edyn-welcome-to-the-connected-garden

[2] http://go.farmbot.it/

[3] CKD, Direct Electronic ValveAG41-03-2

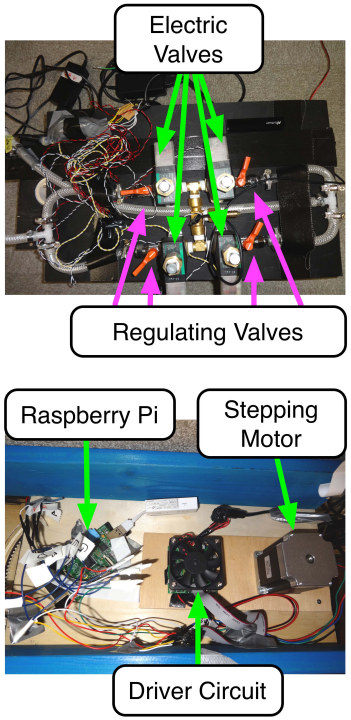

Figure 2: Top and bottom views of the water-jet printer.

electric valves, and injection nozzle, is mounted on a turntable. The turntable is connected to a stepping motor[4] and rotated according to the control signal from the computer to adjust the horizontal angle of the nozzle.

A Raspberry Pi microcomputer is used to control all the aforementioned mechanisms in order to water the specified locations. On the Raspberry Pi, we installed a Linux OS, web server, and Wi-Fi module. The web server provides a webpage where a user can specify the watering areas, as explained in the software section.

To supply sufficient power to the electric valves and the stepping motor, we placed driver circuits between these parts and the Raspberry Pi. Four electric valves are connected to the Raspberry Pi's digital output pins via driver circuits. Each electric valve opens or closes when a program running on the Raspberry Pi outputs high or low signals, respectively, to the digital pins. The stepping motor is connected to the Raspberry Pi via a stepping-motor controller[5] . The controller has SPI (serial peripheral interface) pins, which are connected to the digital I/O pins of the Raspberry Pi. When a program running on the Raspberry Pi sends commands via the SPI, the controller supplies the proper pulses to the stepping motor for the corresponding precise rotation in the appropriate direction.

We tested the garden spray mechanism in our experimental house[6] . To check the flying-distance control, we configured the regulating valves with the proper settings and confirmed that the sprinkler watered at 15 levels of distance. The maximum flying distance was 10 m. After 1 s of spraying, the watering area was approximately 20 cm in width and 50 cm in length. The sprayed area was longer than expected,

[4]Mercury Motor ST-57BYG076-3004D
[5]Strawberry LinuxïijŇL6480 Stepping Motor and Driver Kit
[6]http://ochahouse.com/

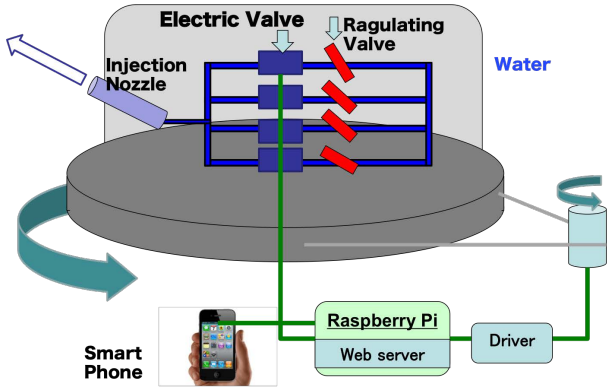

Figure 3: Schematic diagram.

mainly because of the insufficient response time of the electric valves, as we observed small amounts of water drip before reaching the target pressure at the beginning and end of each spray period. In a future prototype, we plan to fix this dripping problem.

Watering Software

We developed an easy-to-use web application allowing a user to specify the watering locations and start the sprinkler. A webpage written in HTML5, PHP, and JavaScript was developed and is hosted by the web server running on the Raspberry Pi. When a user connects to the webpage using a smartphone or PC, a sketch of the garden is displayed. On the sketch, the user specifies the areas to be watered and the amount of water in the manner of a drawing application; that is, the user draws each watering area with different colors to indicate the amounts of water, as shown in Fig. 4. Figure 5 shows the part of the garden corresponding to the screenshot.

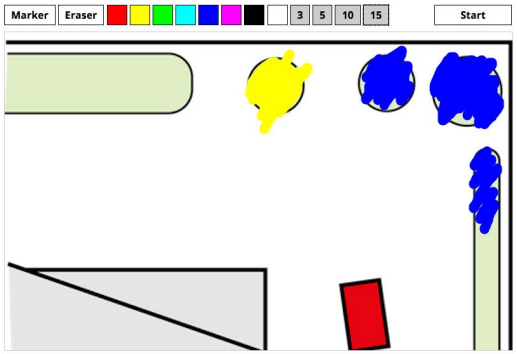

Figure 4: Screenshot example.

When the user presses the "Start" button on the page, the drawn image is saved, and a watering control program written in C is executed on the Raspberry Pi. The control program converts the drawn image into a list of watering subtasks, each of which involves spraying a certain amount of water to the specified location. The location is specified by the distance according to 15 levels, and the horizontal angle is specified with steps of 5°. After the watering task is determined, the control program starts the watering by controlling the valves and motor.

Figure 5: Actual setup in the garden.

Summary and future plan

We developed a sprinkler allowing users to specify the watering positions using an easy-to-use application with a drawing-tool-like user interface. We plan to improve the precision of the spraying mechanism and consider other applications in addition to plant-watering. For example, we plan to use the device to display information, such as characters or images, by spraying water on the ground.

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