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HydroMorph: Shape Changing Water Membrane for Display and Interaction

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Abstract

HydroMorph is an interactive display based on shapes formed by a stream of water. Inspired by the membrane formed when a water stream hits a smooth surface (e.g. a spoon), we developed a system that dynamically controls the shape of a water membrane. This paper describes the design and implementation of our system, explores a design space of interactions around water shapes, and proposes a set of user scenarios in applications across scales, from the faucet to the fountain. Through this work, we look to to enrich our interaction with water, an everyday material, with the added dimension of transformation.

Author Keywords

Water Membrane; Shape Changing Interface.

ACM Classification Keywords

H.5.2. [Information interfaces and presentation]: User Interfaces.

Introduction

Water is a common material with many interactions in everyday life. For example, we use the faucet to wash dishes and our hands, and fountains have been since antiquity a medium for public art and entertainment. Although water itself is malleable and continuously flowing, and occurs in various forms in nature, most of the water in daily use and interaction comes in the form of a single stream. We explore how to create dynamic

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shapes within the flow of water as well as how such dynamic shapes may have functional, informative, and aesthetic purposes.

HydroMorph transforms a single stream of water flow into a dynamic spatial water membrane, taking advantage of the phenomena that a water stream follows smooth surfaces (e.g. spoons) and extends into a “surface” of its own. We developed an interaction hardware system that changes the shape of a water membrane in response to our action (Figure 1).

This paper details our system to interact with shape changing water membranes. We first describe the mechanism of our implementation. We then explore the design space of interactions with the water stream and propose various applications scenarios across different scales such as faucets, interiors, and public fountains.

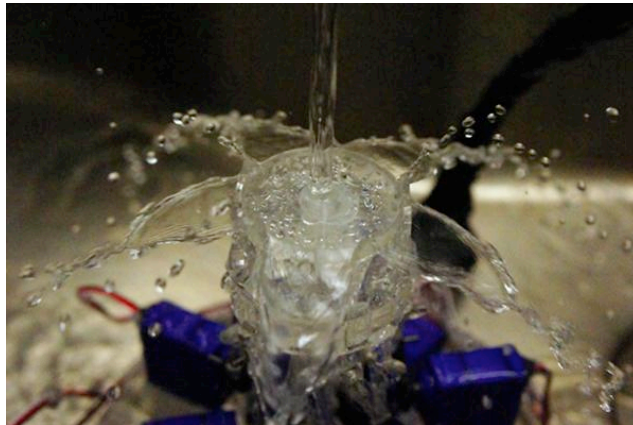


Figure 1: HydroMorph system dynamically changes the shape of a water membrane.

Related Work

Shaping and manipulation of water is a theme found in many projects in both kinetic arts and HCI. MOMENTum [6] and WATER LOGO '09 [1] are examples of kinetic art which controls the motion and shape of water droplets on water-repellent surfaces. Polka Dot [7] also explores the way to manipulate water drops to represent information by changing a shape of physical surface.

Some installations, such as bit.fall [5] and Water Room [10], manipulate water in mid-air, releasing hundreds of water drop from arrayed exhaust nozzles. Eitoku et al. proposed a type of 3D display using water particles, by projecting images on the falling droplets [3].

AquaTop Display [8] is a projection system that uses opaque water as a screen surface. This medium allows for interactions from both above and below the surface such as scooping up or poking fingers from underneath. Splash Controllers [4] is an interaction system with water using receptacles for gaming. Also, Mann has invented series of keyboard-based instruments, named Hydraulophone, using jet streams of water as keys [9].

Finally, Sugihara's Water Dome Project[11] is an art project which explores how to use water membranes as installations. We were strongly inspired by one of her works, The Water Membrane Creatures [2], which controls shapes of water hitting on a predefined static surface to create water membrane shapes expressing butterflies, spiders or flowers. We propose a system which can change the shape of water membrane dynamically by changing the shape of the surface which hits water on top.

HydroMorph

Implementation

The prototype of our system comprises a water-shaping device, a computer, a microcontroller, a camera, and a water source (Figure 2). As the stream of water from the source hits the water-shaping device, various shapes are created according to the actuation data sent from software on the computer through the microcontroller (Arduino UNO). The camera is mounted fixed above the system to overlook the entire device. The camera is used to detect physical objects and human hands around the device by distinguishing color of them. We developed the software on Processing.

WATER-SHAPING DEVICE

The water-shaping device consists of a flat circular surface, and 10 blocking modules each composed with an actuated block, a linkage mechanism and a waterproof servomotor. As a stream of water hits the flat surface, a membrane is created and each module blocks the membrane to change the shape. Using the linkage mechanism to convert the rotary motion to linear motion, servomotors enable a vertical displacement of the blocks. The block has been designed to have an arrow-like profile so that it can slightly interfere with the membrane or completely obstruct it, according to the block's vertical position (Figure 3).

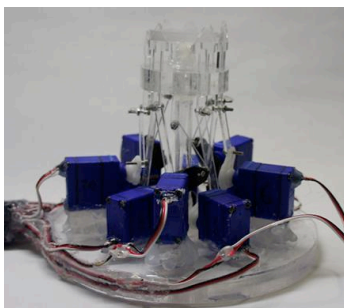


Figure 4. The appearance of the water-shaping device

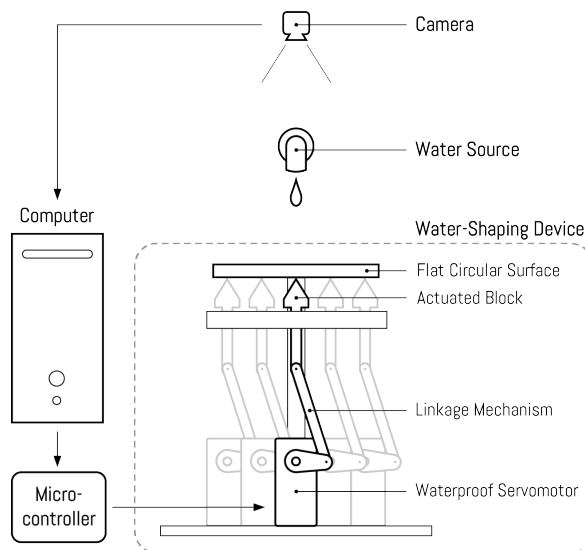


Figure 2. System Overview

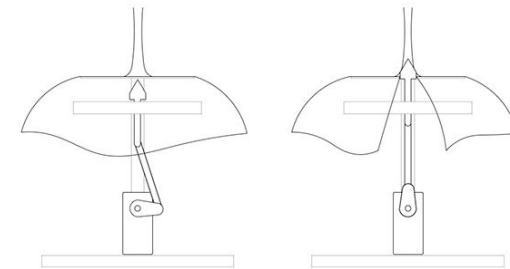


Figure 3. Changing the shape of a membrane with an arrow-shaped blocking module.

Figure 4 shows the actual device of our prototype. The total height is approximately 13.5 cm, and the diameter of flat circular surface is 4cm. For the waterproof servomotors, we used the Traxxas 2080 which actuates with a speed of 0.11 sec/60°. The blocks are actuated in a range of 1.5cm vertically.

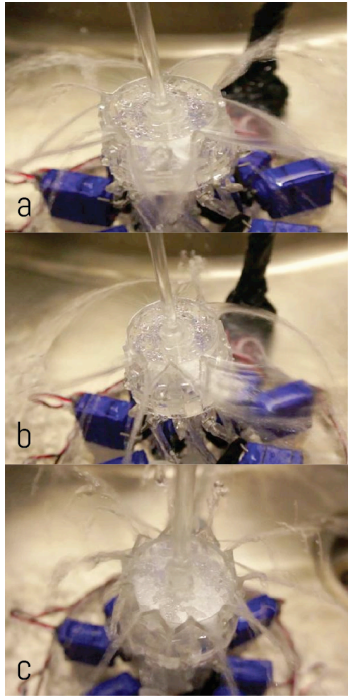


Figure 6. Creating iconic shapes (a: flower, b: bird, c: sun)

Design Space

Here we describe the design space of interaction for HydroMorph system along with a description of the actual shapes created with our prototype. We describe types of information that may be displayed by HydroMorph as well as basic user interactions.

DISPLAY

As a display, HydroMorph can create iconic forms from which a user may derive meaning easily. Our prototype can create simple shapes such as flower, birds, and sun (Figure 6). The system can provide information to users by creating these shapes according to certain context and data. It can also display abstract data with its circular shape, such as timer or pie chart. Figure 7 shows the countdown timer by changing the number of blocks activated.

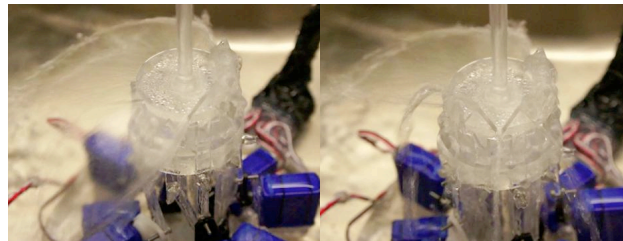


Figure 7. Representing countdown timer

INTERACTION

As for interaction, the water membrane can be transformed according to our actions detected by the camera. It can respond directly to our hands for either making water hit our hands or prevent from hitting (Figure 8). By scaling up, it can react to our whole body as well. We can also interact with the water membrane through other materials. The system can change the

shape of water membrane according to how we touch the membrane with tools (Figure 9 Left). It can detect objects around the device and interact with them; for cups, it guides the water to be poured to them (Figure 9 Right), and for toothbrushes it supports children to wash them.

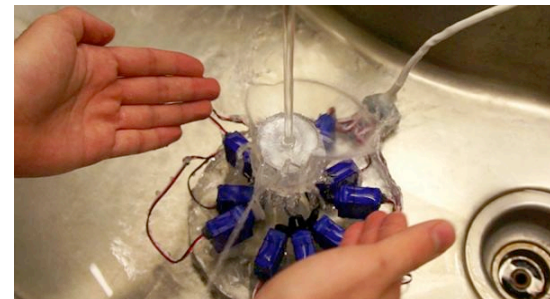


Figure 8. Preventing hands from hitting by water

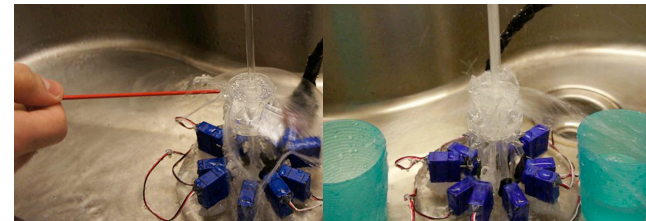
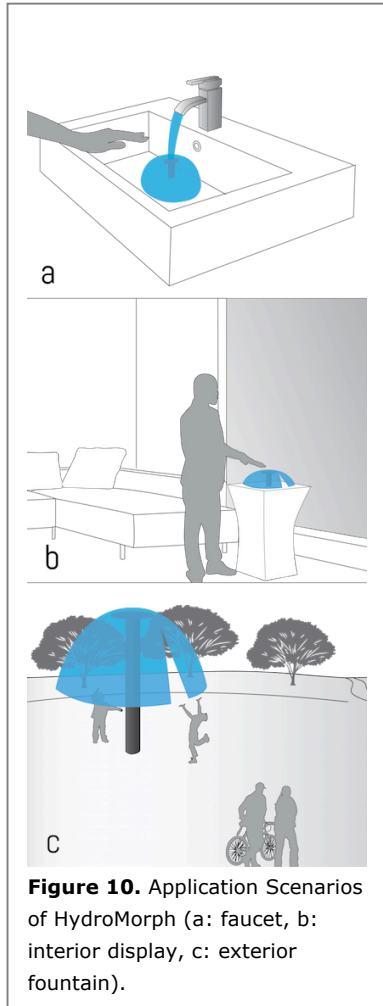


Figure 9. Inter-material interaction with HydroMorph (left: tools, right: cups)

Application Scenarios

Extending proposed system and our prototype, we define possible scenarios in which HydroMorph could be used. We envisioned mainly three contexts that demonstrate the variety of possible applications and scales: faucet, interior display and exterior fountain (Figure 10).



Faucet

A primary scenario is for a faucet. By placing the water-shaping device under faucet either in a sink or a bathtub, the HydroMorph can be used in daily life (Figure 10 a). With the capability of displaying information through iconic shapes, it may inform users the invisible properties of water such as temperatures and nutrients using additional sensors. For example, the system could notify users that the water is safe to drink by creating a shape of full-bloomed flower, or alert not to drink with a shape of a faded flower. Similarly, users may be informed to turn off the faucet by making a radical motion representing a rage. By understanding users' action, this notification could guide users to stop the action so that children can learn the appropriate time to wash hands and to prevent wasting water.

HydroMorph might also be used to extend the functionality of the faucet by interacting with surrounding objects, such as utensils or hands. By detecting the position of a cup, the HydroMorph can redirect the stream of the water into the cup, stopping the stream once the cup is filled. Adding multiple cups will split the stream to equally distribute water to each. By detecting hands of users, it can also prevent them from touching the water when the temperature is too cold/hot, or guide the water to hit hands to help children wash their hands.

Interior Display

HydroMorph may also be used as an interior display. For example, we can imagine the device working as an interactive piece of furniture in our home (Figure 10 b). With the dynamic shape of a membrane, it may represent information about the weather, for instance

by showing iconic shapes of umbrella or a sun so that a user can prepare for the weather of the day ahead.

HydroMorph might also be used as a playful, dynamic sculpture. Users may touch the water membrane with their hands or tools, blocking water flow and changing the shape. As the system could recognize these blockages through the camera and trigger changes in the shape of the water display.

Exterior Fountain

Finally, HydroMorph may be used in exterior spaces, such as a fountain in a public park or square. Imagining the current prototype scaled up, it can create dynamic water sculpture in a park with aesthetic shapes of membrane (Figure 10 c). In the same context, it would also be possible to engage the people in the space with full body interaction by enabling them to interact with HydroMorph and modify the shape of the water membrane.

Technical Challenge and Future Work

Here we describe challenge and future work on technical implementation. There are a lot of potential to improve the water-shaping device of our system. For example, our water-shaping device has a limited variety of shapes it can create. The resolution is one of the main factors limiting the variety of shapes. Although our current prototype has only 10 actuated blocks around the flat surface, increasing the number and granularity using smaller actuators can enrich the transformation capability. Also, our proposed prototype has flat 'static' surface which is hit by stream of water to create membrane, this surface could dynamically change to vary the shape we can create. Because this surface is required to be smooth, pneumatic actuations



Figure 11. Changing the shape of the surface with pneumatic actuation.

may be an appropriate technique as shown in Figure 11. By changing the shape of the surface, it may change the angle of the expanded water membrane so that iconic shape of birds can flutter wings expressively.

Another technical challenge is the size of the hardware. When locating our device in daily scenes especially for faucet scenario, current prototype is too bulky. It is required to modify the actuation mechanism to be thinner or to design the mechanism to be incorporated to underneath structure.

To develop further interactions, it is required for the system to understand the complex geometry of objects around the device. As the color recognition technique using camera has a limitation in detecting objects, we think other sensors such as depth cameras can improve the interaction system.

Conclusion

HydroMorph evolves the way water can display and interact by creating dynamic shape of water membrane. Imagining this device applied in daily life or in public spaces would give, on a practical level, a more responsive and sensitive way to interact with water. On a conceptual level, HydroMorph expands the vocabulary of interactions with this everyday medium of water.

HydroMorph gives a life to water, giving it a voice through its shape change. We envision a world filled with living water that conveys information, supports daily life, and captivates us.

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