Bubble Mirror: An Interactive Face Image Display Using Electrolysis Bubbles

Ayaka Ishii
Ochanomizu University
ishii.ayaka@is.ocha.ac.jp

Namiki Tanaka
Ochanomizu University
g1620523@is.ocha.ac.jp

Itiro Siio
Ochanomizu University
siio@acm.org

Figure 1: Overview of Bubble Mirror. (a) Matrix cathode pins and a common anode are placed at the bottom of the water pan. (b) A visitor looks into the Bubble Mirror, and the face image is displayed on the water surface. (c) The face image using grayscale bubble pixels.

CCS CONCEPTS

• **Human-centered computing** → **Human computer interaction (HCI)**; *Displays and imagers.*

KEYWORDS

bubble display, electrolysis, water, art

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1 INTRODUCTION

Several types of research have been conducted regarding a display that presents digital information using bubbles [Heiner et al. 1999; Hirayama and Kakehi 2010]. These systems require moving parts such as air compressors and electromagnetic valves to supply air from the outside, and to control the bubbles. Therefore, it is difficult to increase the number of pixels at a low cost. To solve this problem, a liquid-surface display using pixels of bubble clusters generated from electrolysis has been proposed [Ishii and Siio 2019]. The display generates a 10 × 10 pixel dot matrix pattern on the surface of a beverage. In the electrolysis bubble display, the number of pixels can be increased at a low cost because it consists of electrodes, and does not require moving parts. Although the pixels were implemented in binary form, it was pointed that grayscale display is possible by adjusting the time for which the electrodes are energized.

Utilizing these features and aiming at new interaction with bubble displays, we present *Bubble Mirror* as in Figure 1. Bubble Mirror is a water pan with a camera that captures a visitor's face and displays it using six levels of grayscale bubbles generated from the electrolysis of water. The face image is displayed on the water surface when a visitor looks inside the water pan.

2 BUBBLE MIRROR

Figure 2 shows a system configuration of the Bubble Mirror. The system consists of a water pan, a foot switch, a USB camera, and a PC. The water pan is filled with water darkened with instant coffee powder. The foot switch is connected to the Arduino which connects to the PC through USB. The PC receives the foot switch status and sends display image data. When a visitor stands in front of the system, the foot switch detects it. Next, when a visitor looks into the pan, the camera captures the visitor's face and displays it as a pixel of a cluster of bubbles on the water surface. The LED tape was attached to the outer edge of the pan to prevent the face from darkening when he/she looks into it.

Referring to the Wooden Mirror[1], we designed the display with 32 × 32 pixels. Figure 1(a) shows the bottom of the empty water pan. In the bottom of the pan, we fabricated a 32 × 32 matrix of electrodes

[1]Wooden Mirror displays a face image of a person who views the system with approximately 30 × 30 pixels. See: https://www.smoothware.com/danny/woodenmirror.html

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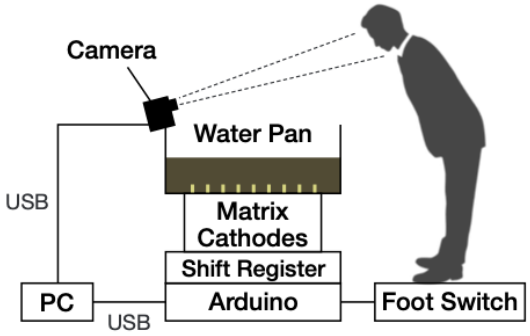

Figure 2: System Configuration of Bubble Mirror.

(cathode pins) with intervals of 5.08 mm, while a common anode is placed around the cathode. The overall size of the cathode pin area is 16 × 16 cm. We used off-the-shelf gold-plated pin header parts for the cathodes and copper tape for the common anode. To reduce the fabrication cost, we divided the printed circuit board (PCB) for the matrix cathodes into four pieces, i.e., four PCBs comprising 16 × 16 electrodes were placed at the bottom of the water pan. Then, blank black crossing lines appeared on the gap among the four PCBs (Figure 1(c)). Similar to the previous study [Ishii and Siio 2019], coffee was used as the electrolytic solution; we used instant coffee (made with 1.5% w/v coffee powder) added with sodium bicarbonate (0.4% w/v) to promote electrical flow and with cornstarch (0.4% w/v) to provide sufficient viscosity to avoid diffusion of bubble clusters.

2.1 Electrode Control

As in the previous study [Ishii and Siio 2019], we applied an active-matrix circuit to this system. We connected 1,024 pixel electrodes to the active matrix circuit that is controlled by an Arduino UNO. We used eight shift registers for 32 column and 32 line wires to reduce the number of necessary output pins to the Arduino board. With control from Arduino, arbitrary electrodes are grounded. The grounded electrodes function as cathodes for electrolysis, and clusters of hydrogen bubbles are generated from the electrodes.

The Arduino program applies an electric current to arbitrary pixel electrodes on a line wire among 32 line wires for 10 ms, and it requires 320 ms to scan all the line wires. To provide six levels of grayscale display by using pulse-density modulation (PDM) of the electrolysis current, we performed programming to repeat the above mentioned 320 ms scan five times. For a pixel assigned to level N (0 - 5) of the grayscale, the program activates the corresponding electrode N times (in total N × 10 ms) during the five scans. As the electrolysis process for a picture requires 1.6 s (320 ms × 5), the refresh rate of the display is 0.6 Hz.

2.2 Face Image Processing

The PC captures the visitor's face via the camera, and converts the face image to 32 × 32 pixels with six levels of grayscale. In our system, when a visitor stands on the foot switch in front of the water pan, the PC starts detecting a face via the camera. We used OpenCV for Processing as the face detection library. Subsequently, the system saves five face images with 100 ms intervals only when the visitor's face is detected around the center of the camera frame.

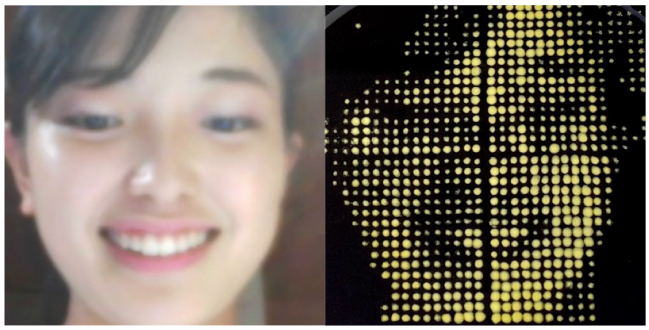

Figure 3: Face image acquired by face recognition(left) and the actual bubble display(right)

The saved image is then resized to 32 × 32 pixels of 256 grayscales, and the image with the maximum contrast (i.e., the sum of the absolute value of the difference between the adjacent pixels is the greatest) is selected from among them. Then the pixels are assigned to equally populated six grayscales, and 32 × 32 pixels of six grayscales (0 ~ 5) image is generated. Once the face data for bubble display is ready, the PC sends it to the Arduino to energize each cathode according to the grayscale data obtained using the PDM current. When the visitor leaves and the foot switch turns off, the PC sends an image of 32 × 32 black pixels to Arduino to stop energizing the electrodes.

3 DEMONSTRATION

We have demonstrated the operation of the display for students from local university. All the participants could easily recognize the displayed bubble face image as their faces as in Figure 3 and Figure 1 (c). It took about 1 s from the time the participant looked to the time the bubbles appeared, and some participants commented that the display speed of the bubbles was faster than expected. We measured 0% black to 80% gray (BTG) and 100% white to 40% gray (WTG) response times for a single dot of bubbles. The result shows that the BTG and WTG response times are approximately 3 and more than 60 s, respectively.

4 CONCLUSION AND FUTURE WORK

We propose Bubble Mirror, a water pan with a camera that captures a visitor's face and displays it on the liquid surface by the grayscale electrolysis bubbles. We plan to explore other possibilities of modifying the images such as timing, cropping, contrasting, and so on for processing on the proposed system.

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