UTAKATA: Floating Bubble Display

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

Yasushi Matoba
Ochanomizu University
Tokyo, Japan
y.matoba.2011@gmail.com

Manaka Fukushima
Ochanomizu University
Tokyo, Japan
g1620533@is.ocha.ac.jp

Itiro Siio
Ochanomizu University
Tokyo, Japan
siio@acm.org

CHI '20 Extended Abstracts, April 25–30, 2020, Honolulu, HI, USA.

ACM ISBN 978-1-4503-6819-3/20/04.
http://dx.doi.org/10.1145/3334480.3382801

Abstract
We propose *UTAKATA* [1], an ephemeral display device that presents information by using floating clusters of bubbles. In our previous study, we implemented an electrolysis bubble display using drinkable beverages. Although clear clusters of bubbles could be created in short times, they did not disappear for a long time; consequently, the refresh time period of the display was considerably long. To overcome this deficiency, we present UTAKATA, a ticker-like bubble display using a running-water channel. To establish this display, a linear array of seven electrodes is fabricated on the bottom of a water channel. By activating the appropriate electrodes among the seven ones, circular bubble clusters are generated above the electrodes and then imposed to float downstream using a water flow. This allows representing an N $\times$ 7 dot-matrix display to have a shorter refresh time compared with our previous method, and expanding the range of expressions of ephemeral user interfaces using bubbles.

Author Keywords
Bubble display; electrolysis; water; flow; ephemeral user interface.

[1] UTAKATA is an archaic Japanese word that means "foam."

CCS Concepts

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

Introduction

In Hojoki (1212), Kamo no Chomei stated that
"The current of the flowing river does not cease, and yet the water is not the same water as before. The *UTAKATA* (foam) that floats on stagnant pools, now vanishing, now forming, never stays the same for long. So, too, it is with the people and dwellings of the world."

A flowing river and bubbles floating within it have been used for a long time as a metaphor of the impermanence of all things. This is because the river water always changes, and floating bubbles promptly disappear. From the perspective of human-computer interaction (HCI), ephemeral user interfaces (EUIs) based on the concept of ephemerality of physical materials have been conceptualized and designed [3]. EUIs are intentionally designed to last for a limited period of time. Due to this temporality, EUIs are invaluable and allow avoiding overload of users. Furthermore, from the experiential and aesthetic perspectives, it has been noted that EUIs can offer multi-sensual experiences and induce strong emotional responses [4]. In this context, researchers often used transient materials, such as water [12] and soap bubbles [2, 16] as interfaces. On this basis, we propose an ephemeral display device using floating clusters of bubbles on a water surface.

In our previous work, we have implemented an electrolysis bubble display using 10 × 10 electrodes fabricated at the bottom of a liquid vessel [7]. This device displays 10 × 10 pixels of dot matrix patterns on the liquid surface without using a mechanical air compressor and valves that are typically required in the previously proposed bubble displays. Although a clear fine bubble cluster can be created in less than three seconds, it requires tens of seconds to disappear. Consequently, the refresh time of the display is extremely slow. To overcome this deficiency, we focus on a ticker-like design that facilitates floating bubble clusters to move downstream and to provide room for subsequent pixels of bubbles.

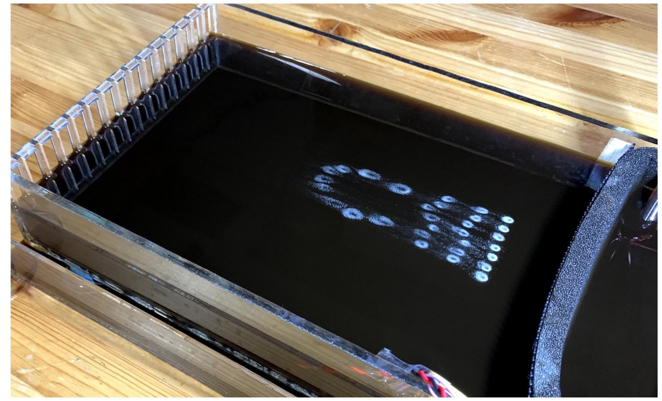

Figure 1: Overview of UTAKATA: "CHI" is displayed.

In this study, we present UTAKATA, a ticker-like bubble display using a running-water channel (see Figure 1). The water channel is composed of a linear array of the seven electrodes on the bottom of the upper stream part, which generates up to seven circular clusters of fine hydrogen bubbles on the water surface using electrolysis. By activating the appropriate electrodes among the seven ones, an N × 7 dot-matrix display having a short refresh time can be implemented, as the bubble clusters float downstream.

Moreover, in addition to improving the refresh time, the proposed device can be used as an ephemeral display to offer temporal and precious information via fragile and floating bubble characters. We believe that the proposed method can contribute to new experiences in the field of EUIs. For example, using the proposed method, it will be possible to generate bubble characters on the natural brook surface continuously. Therefore, by introducing computer technologies into the constantly changing natural objects of the real world, it would be possible to construct a large-scale ephemeral interface utilizing nature.

Related Work

Research has been conducted regarding a display using bubbles as pixels to present information. The information percolator [5] is a scrolling display using rising bubbles in the water. This system requires 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 avoid the need in such expensive moving parts, we have proposed a method employing electrolysis to supply gases for a display and have developed a cup-type device BubBowl to generate 10 $\times$ 10 pixel dot matrix patterns on the surface of a beverage [7]. This device has been capable of quickly generating a fine foam but has required a long time to eliminate the foam. In this study, we seek to improve the deficiency of the slow refresh time by using running water to introduce a ticker-like display. Similar to BubBowl and UTAKATA, there are several studies aimed to present information using physical materials, by utilizing the energization of electrodes located in the aqueous solution. In these studies, liquid metal drops were moved by controlling their surface tension of them by varying energization [9, 13, 17]. The voltage was applied to anodes and cathodes placed in the aqueous solution of sodium hydroxide. Consequently, electrolysis occurred, and hydrogen and oxygen gases were generated. The main purpose of these studies was to implement a visual and tactile display by controlling liquid metal drops and, therefore, the generated gases were not used as pixels for presenting the information. In this study, we realize an information display utilizing the gases generated by electrolysis as pixels.

By using a water flow, the bubbles become fragile, and the information displayed becomes precious, inducing users to focus on it. In this context, interfaces that last only for a limited time period are referred to as ephemeral user interfaces (EUIs) [3]. There are several examples of using transient materials to implement EUIs. For example, water and bubbles have often been used to develop EUIs. Bit.Fall [12] is an example of an EUI implemented using water. It is an art installation that displays words as a water curtain in which words are visible only for ~1 s, while water drops are falling to the ground. Another similar implementation, Bit.Flow [11], is a display that uses water drops moving in a tube as pixels. Several tubes are arranged vertically, and characters can be displayed by controlling the position of colored water drops poured into each tube. In association with Bit.Flow, another technology, called Tuve, has been proposed to establish a dynamical shape-changing display using a single tube and wrapping around various objects [6]. In these display systems, characters are gradually formed based on a mere collection of bits that flow and disappear. Therefore, the information displayed becomes precious, and users monitor the display with natural attention, which is an effect we seek to achieve with regard to the proposed method. Moreover, user interfaces make use of the frailty of bubbles have been proposed. For example, Bubble Cosmos is a soap bubble display in which an image is projected to the real soap bubbles with white smoke entering inside them [10]. It provides the sound and image output by employing user interactions, such as the bursting of soap bubbles. Then, mid-air displays that provide visual and olfactory outputs by injecting scented white smoke into soap bubbles have been proposed [8, 14]. Moreover, a method using soap bubbles as fragile tangible handles as input has been proposed [2, 16]. When the user makes the soap bubbles move, the room lighting can be changed according to the position of bubbles. Furthermore, an art project representing the ephemeral and intangible aspects of human communication by soap bubbles has been introduced [1]. As in the aforementioned examples, bubbles are considered as the main material for representation which is often used for EUIs, as they easily burst and disappear, thereby embodying transience. We combine the bubbles with a water flow, enabling the possibilities facilitating of new experiences in the context of EUIs. It should be also noted that there is an artwork that aimed to project words onto a water flow [15]. In this work, words projected on the surface of the water are supposed to float like leaves in a stream. In this study, the researchers attempted to introduce computer technologies into a real garden in harmony with stone, water, and plant materials. On this basis, we consider that we can introduce computer technologies like displaying digital information, into the constantly changing natural objects of the real world, such as a stream or a brook.

UTAKATA

Figure 2 shows an overview of the UTAKATA. An acrylic water channel box is placed in a larger water saucer that contains liquid (instant coffee). This water channel box is made thick acrylic plates of 5 mm width, and its outer dimensions are approximately 35$\times$21$\times$6 cm. We placed this water channel higher than the bottom of the water saucer using 2 cm legs. A water pump is placed in the water saucer to move the liquid to the upstream part of the water channel. At the downstream end of the channel box, we placed an acrylic wall with slits that are used to control the amount of

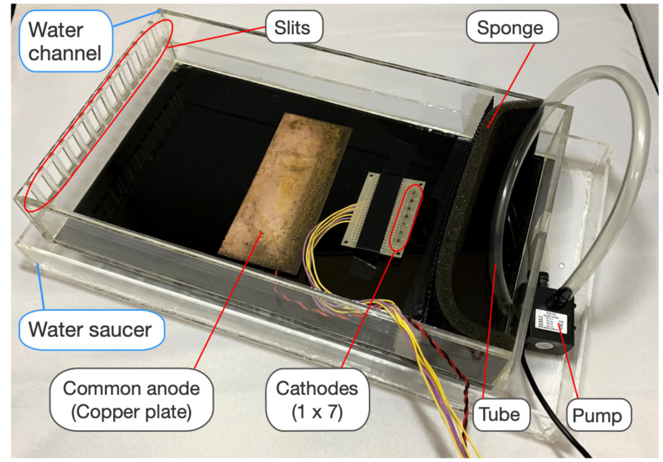

Figure 2: UTAKATA without liquid: a water channel is implemented in a larger water saucer. The pump is placed in the saucer to supply liquid to the channel via a tube.

the liquid drained out of the channel. At the bottom of the upstream of the channel box, seven electrode pins (cathodes) are embedded linearly to generate hydrogen gas bubbles using electrolysis. The bubbles move upwards in the liquid, forming round clusters (pixels) on the surface of the liquid, and flow downstream with the running water. By activating the appropriate cathodes dynamically, a ticker-like display with bubble clusters on the running water surface can be realized.

To generate a water flow, it is necessary to supply and drain the liquid in and out of the channel box. To supply the liquid, the end of the output tube from the water pump is placed at the upstream end of the channel box. Between the end of the tube and the main channel, we placed a sponge to mitigate possible turbulence generated by using the pump-

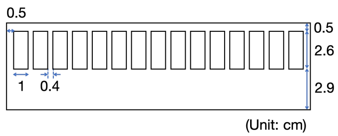

Figure 3: Slits used to drain the liquid.

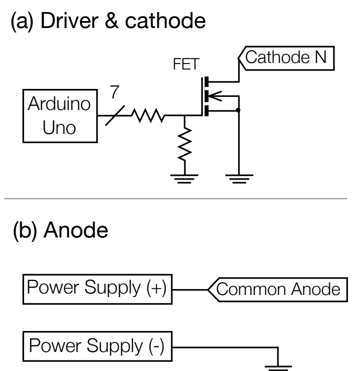

Figure 4: Circuit diagram representing the wiring of Line N. (N = 1 to 7)

ing mechanism. The sponge is 1 cm thick and is placed 3 cm above the upstream with regard to the cathodes to facilitate a laminar flow at the pixel generation part. To drain the water, slits are implemented in the opposite wall of the water channel to the part where the water tube is inserted (see Figure 3). As the slits do not reach the bottom of the channel box, their lower ends are maintained the water inside the channel box, and the surface of the water drains out of the channel primarily. We used the slits to minimize the effect of surface tension, aiming to generate a constant flow over the channel. We placed 15 slits at 4 mm intervals; the size of each slit is 1.0×2.6 cm.

To generate bubbles by electrolysis, we set a common anode and cathodes, an electrolytic solution, and a circuit to regulate the timing of electrolysis. A copper plate with 15×6.2 cm is used for the common anode. Seven cathodes are arranged in a row at the bottom of the water channel. The off-the-shelf gold-plated pin header parts were used for the cathodes, as we considered that the pillar shape of the pin header parts would help bubbles rising up toward the water surface. The interval between the cathodes is 7.6 mm. Similar to our previous study [7], coffee is used as the electrolytic solution; we used instant coffee with sodium bicarbonate added to promote an electrical flow and with cornstarch added to provide sufficient viscosity to avoid diffusion of bubbles. However, the amount of cornstarch is larger than that used in the previous study setup. Specifically, we used instant coffee, including 16 g/L coffee powder together with a 0.4 % concentration of sodium bicarbonate and 2.4 g/L of cornstarch, as a higher viscosity is required to hold pixels with bubbles in the presence of the flow.

Figure 4 shows the circuit diagram employed in the UTAKATA. Here, seven pixel electrodes are connected to an Arduino Uno microcontroller board via a metal-oxide-semiconductor field effect transistor (MOSFET). The gate of MOSFET is connected to the Arduino board, the source is connected to the ground, and the drain is attached to the pixel electrode. When the Arduino activates several MOSFETs, the corresponding pixel electrode is connected to the ground. Subsequently, the electrode functions as a cathode for electrolysis, and hydrogen is generated from the electrode. As shown in Figure 4 (b), the positive output of DC power supply is connected to the common anode, and the negative output is connected to the common ground.

Technical Evaluation and Discussion

In Figure 1, it is shown that UTAKATA displays the text "CHI." The current applied to each electrode was approximately 20 mA, and the depth of the liquid was 3 cm. To realize a clear dot display on the water surface, the position of the pin header parts (cathodes) was adjusted above the bottom so that the distance between the tips of the cathodes and the water surface was approximately 0.5 cm. The interval between pixels is 7.6 mm (approximately 3 dpi). As the pixel size is around 6 mm in diameter, a higher resolution is still possible to achieve in the current configuration.

Figure 5 shows the transition of the bubble character due to the flow. In the present implementation, up to three characters could be visible simultaneously. However, the first bubble character to appear has been shed and diffused considerably. This is because the surface flow at the downstream is faster than the one at the upstream because of the continuity equation of fluid dynamics. In the downstream, as the liquid near the bottom of the vessel is blocked by the wall without slits, the surface flow becomes relatively faster. Another type of distortion was caused by a faster flow of the central bubbles compared with other flows. We consider that this may be caused by the friction between the inner wall of the water channel and the liquid. The actual speeds

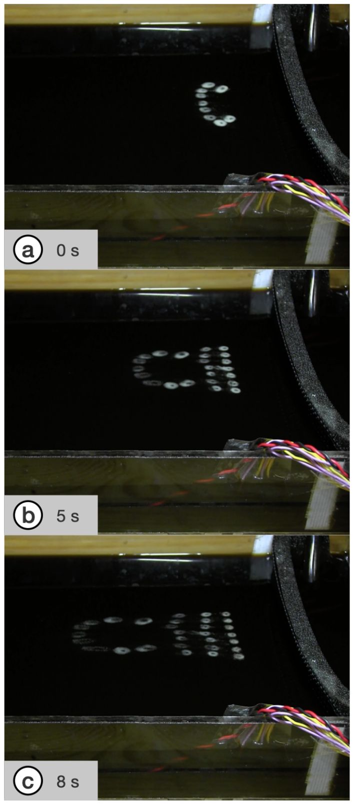

Figure 5: Transition of the bubble display of “CHI.” (a) The word “C” is displayed; (b) then, “CH” is displayed; (c) finally, “CHI” is displayed on the water surface.

of the central bubbles was 7.6 mm/s at the top of the cathodes in which bubbles have been generated and 21 mm/s at the downstream part where the flow was fast. These distortions caused by the different surface flow speeds could be improved by redesigning the end wall with slits or using longer and wider water channels.

We measured the black-to-light-gray (BTG) response time of UTAKATA, which is the time between the moment of the energization of electrodes and the appearance of pixel bubbles. One of the electrodes was activated with a 20 mA current, and the bubble pixel was video recorded. Then, the time lapse between black and 80% of the maximum lightness was measured by analyzing the video. The obtained result was approximately 1 s, which was shorter than the one obtained in our previous device, BubBowl [7]. Shorter BTG is required in the UTAKATA configuration in the case when pixels tend to be distorted due to the flowing water.

Conclusion

In this study, we proposed UTAKATA, a floating electrolysis bubble display system. Using this device, we improved the refresh speed of the previous electrolysis bubble display and enabled a new experience in the field of EUIs.

Future work will be focused on improving the distortion of the display and pixel brightness. We plan to test the various water channel sizes, slit designs, electrolytic solutions, and flow speeds to optimize the proposed display system parameters.

REFERENCES

[1] Kyung Yun Choi and Hiroshi Ishii. 2019. Bubble Talk: Open-source Interactive Art Toolkit for Metaphor of Modern Digital Chat. In *Proceedings of the Thirteenth International Conference on Tangible, Embedded, and Embodied Interaction (TEI ’19)*. ACM, New York, NY, USA, 525–530. DOI: http://dx.doi.org/10.1145/3294109.3301271

[2] Tanja Döring, Axel Sylvester, and Albrecht Schmidt. 2012. Exploring Material-centered Design Concepts for Tangible Interaction. In *CHI ’12 Extended Abstracts on Human Factors in Computing Systems (CHI EA ’12)*. ACM, New York, NY, USA, 1523–1528. DOI: http://dx.doi.org/10.1145/2212776.2223666

[3] Tanja Döring, Axel Sylvester, and Albrecht Schmidt. 2013. A Design Space for Ephemeral User Interfaces. In *Proceedings of the 7th International Conference on Tangible, Embedded and Embodied Interaction (TEI ’13)*. ACM, New York, NY, USA, 75–82. DOI: http://dx.doi.org/10.1145/2460625.2460637

[4] Tanja Döring. 2016. Reflections on Plants as Interaction Material. In *Workshop Proceedings: NatureCHI 2016 - Unobtrusive User Experiences with Technology in Nature (CHI ’16)*. 48–53.

[5] Jeremy M. Heiner, Scott E. Hudson, and Kenichiro Tanaka. 1999. The Information Percolator: Ambient Information Display in a Decorative Object. In *Proceedings of the 12th Annual ACM Symposium on User Interface Software and Technology (UIST ’99)*. ACM, New York, NY, USA, 141–148. DOI: http://dx.doi.org/10.1145/320719.322595

[6] Yuki Inoue, Yuichi Itoh, and Takao Onoye. 2018. TuVe: A Flexible Display with a Tube. In *SIGGRAPH Asia 2018 Emerging Technologies (SA ’18)*. ACM, New York, NY, USA, Article 16, 2 pages. DOI: http://dx.doi.org/10.1145/3275476.3275487

[7] Ayaka Ishii and Itiro Siio. 2019. BubBowl: Display Vessel Using Electrolysis Bubbles in Drinkable Beverages. In *Proceedings of the 32Nd Annual ACM Symposium on User Interface Software and Technology (UIST '19)*. ACM, New York, NY, USA, 619–623. DOI: http://dx.doi.org/10.1145/3332165.3347923

[8] Yutaro Kyono, Takuro Yonezawa, Hiroki Nozaki, Jin Nakazawa, and Hideyuki Tokuda. 2013. FRAGWRAP: Fragrance-encapsulated and Projected Soap Bubble for Scent Mapping. In *Proceedings of the 2013 ACM Conference on Pervasive and Ubiquitous Computing Adjunct Publication (UbiComp '13 Adjunct)*. ACM, New York, NY, USA, 311–314. DOI: http://dx.doi.org/10.1145/2494091.2494187

[9] Qiuyu Lu, Chengpeng Mao, Liyuan Wang, and Haipeng Mi. 2016. LIME: LIquid MEtal Interfaces for Non-Rigid Interaction. In *Proceedings of the 29th Annual Symposium on User Interface Software and Technology (UIST '16)*. Association for Computing Machinery, New York, NY, USA, 449–452. DOI: http://dx.doi.org/10.1145/2984511.2984562

[10] Masahiro Nakamura, Go Inaba, Jun Tamaoki, Kazuhito Shiratori, and Junichi Hoshino. 2006. Mounting and Application of Bubble Display System: Bubble Cosmos. In *Proceedings of the 2006 ACM SIGCHI International Conference on Advances in Computer Entertainment Technology (ACE '06)*. ACM, New York, NY, USA, Article 47. DOI: http://dx.doi.org/10.1145/1178823.1178879

[11] Julius Popp. 2011. Bit.Flow. (2011). https://vimeo.com/22390871

[12] Julius Popp. 2016. Bit.Fall. (2016). https://www.ludwigmuseum.hu/en/news/julius-popp-bitfall

[13] Deepak Ranjan Sahoo, Timothy Neate, Yutaka Tokuda, Jennifer Pearson, Simon Robinson, Sriram Subramanian, and Matt Jones. 2018. Tangible Drops: A Visio-Tactile Display Using Actuated Liquid-Metal Droplets. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems (CHI '18)*. Association for Computing Machinery, New York, NY, USA, Article Paper 177, 14 pages. DOI: http://dx.doi.org/10.1145/3173574.3173751

[14] Sue Ann Seah, Diego Martinez Plasencia, Peter D. Bennett, Abhijit Karnik, Vlad Stefan Otrocol, Jarrod Knibbe, Andy Cockburn, and Sriram Subramanian. 2014. SensaBubble: A Chrono-sensory Mid-air Display of Sight and Smell. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '14)*. ACM, New York, NY, USA, 2863–2872. DOI:http://dx.doi.org/10.1145/2556288.2557087

[15] David Small and Tom White. 1998. Stream of Consciousness. In *ACM SIGGRAPH 98 Electronic Art and Animation Catalog (SIGGRAPH '98)*. Association for Computing Machinery, New York, NY, USA, 50. DOI:http://dx.doi.org/10.1145/281388.281499

[16] Axel Sylvester, Tanja Döring, and Albrecht Schmidt. 2010. Liquids, Smoke, and Soap Bubbles: Reflections on Materials for Ephemeral User Interfaces. In *Proceedings of the Fourth International Conference on Tangible, Embedded, and Embodied Interaction (TEI '10)*. ACM, New York, NY, USA, 269–270. DOI: http://dx.doi.org/10.1145/1709886.1709941

[17] Yutaka Tokuda, Jose Luis Berna Moya, Gianluca Memoli, Timothy Neate, Deepak Ranjan Sahoo, Simon Robinson, Jennifer Pearson, Matt Jones, and Sriram Subramanian. 2017. Programmable Liquid Matter: 2D Shape Deformation of Highly Conductive Liquid Metals in a Dynamic Electric Field. In *Proceedings of the 2017 ACM International Conference on Interactive Surfaces and Spaces (ISS '17)*. Association for Computing Machinery, New York, NY, USA, 142–150. DOI:http://dx.doi.org/10.1145/3132272.3134132