Bubble Cloud: Projection of an Image onto a Bubble Cluster

Yuki Kubo
University of Tsukuba
1-1-1 Tennodai, Tsukuba,
Ibaraki, 305-8573, Japan
kubo@iplab.cs.tsukuba.ac.jp

Takayuki Hoshi
The University of Tokyo
7-3-1 Hongo, Bunkyo-ku,
Tokyo, 113-0033, Japan
star@hoshistar81.jp

Hirobumi Tomita
University of Tsukuba
1-1-1 Tennodai, Tsukuba,
Ibaraki, 305-8573, Japan
tomita@iplab.cs.tsukuba.ac.jp

Yoichi Ochiai
University of Tsukuba
1-2 Kasuga, Tsukuba,
Ibaraki, 305-8550, Japan
wizard@slis.tsukuba.ac.jp

Shuta Nakamae
University of Tsukuba
1-1-1 Tennodai, Tsukuba,
Ibaraki, 305-8573, Japan
nakamae@iplab.cs.tsukuba.ac.jp

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Abstract
We introduce Bubble Cloud —a technology that uses a bubble cluster for displaying images onto a screen. Bubble Cloud projects images onto bubbles without confining a fog and can float in the air by changing an operating condition of the bubble cluster such as altering the size of the bubble. Moreover, the user can modify the display because its shape is composed of clusters. A floating bubble cluster can be controlled and adjusted by hand in arbitrary directions by electrifying the bubble cluster.

ACM Classification Keywords
I.3.1 [Computer Graphics]: Hardware architecture – Three-dimensional-displays; B.4.2 [Input/Output and Data Communications]: Input/Output devices – Image display

Author Keywords
Bubble display; electrostatic charge; mid-air display.

Introduction
Research has been conducted on displays that project an image onto fog confined in a bubble [2] and a display that can project images onto soap films by changing their reflectance property using ultrasound waves emitted from an ultrasonic-phased array [3].

In our demonstration, we introduce Bubble Cloud, which is a display that uses a bubble cluster (Figure 1). We introduce two types of Bubble Cloud—one that changes the size of the display and one that floats by confining helium in the bubble. Moreover, the bubble cluster is flexible in the sense that its shape can be changed.

Figure 1: Bubble cluster.

We were able to demonstrate the utility of using bubble clusters when creating a bubble display. For example, we can project images onto a bubble cluster without confining fog, as shown in Figure 2. Furthermore, methods involving the use of ultrasonic waves, in the past, used single bubbles, thereby limiting the size of the display. In contrast, a bubble cluster can enlarge the size of the display.

Related Work

Bubble Cosmos [2] provides tangible interactions with bubbles, and a sound plays when the user bursts a bubble. Bubble Cosmos is a single-bubble display that projects an image onto fog confined in a bubble. Shaboned Display [1] is a display that employs a soap bubble as an image pixel. SensaBubble [5] uses the confinement of fog bubbles to deliver information to users by using a projector and fragrances. Colloidal Displays [3] project images onto a soap film by using ultrasound waves emitted from an ultrasonic-phased array. The reflectance property can be changed by vibrating the film using the phased array. Sahoo et al. [4] proposed a method that can change the trajectory of a bubble by confining an electrostatically charged fog in the bubble and applying an electric field. While these displays utilize single soap bubbles or a soap film, our Bubble Cloud utilizes a bubble cluster.

Figure 2: Mini-bubble cloud.

Implementation

We used a bubble generator (assembly shown in Figure 3) to produce the bubbles that comprise the bubble cluster. The bubble generator consists of a helium cylinder, pressure gage, an air tube, bucket containing soap solution, and an acrylic case with five holes. To generate bubbles that can float, helium gas is passed through a soap solution through holes in the acrylic case. A floatable bubble cluster is made by separating the bubbles from the bucket by using an air tube having an inner diameter of 3 mm. The pressure gage regulates the pressure inside the air tube. We placed an acrylic panel on the bucket with a 25 cm square hole at its center from which the bubbles escaped out of the bucket. To hold the soap bubble solution and to store bubbles, we used a bucket with a diameter of 45 cm and height of 15 cm. Since the solution had to generate bubbles that did not burst easily, we used a solution of water, detergent (including a surfactant), and laundry starch that (included polyvinyl alcohol). These were then mixed in a ratio of 5:1:5.

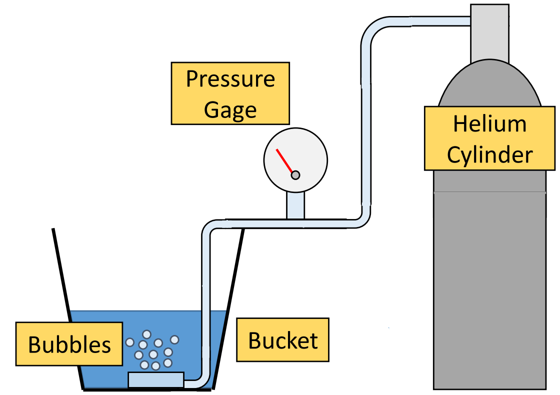

Figure 3: Bubble generator.

An ultrasonic-phased array, having approximately 280 ultrasonic transducers, was used (Figure 4). Ultrasound waves,

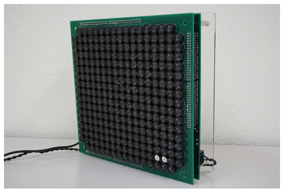

Figure 4: Ultrasonic-phased array.

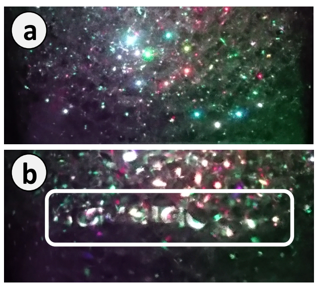

Figure 5: Floating-Bubble cloud using an ultrasonic-phased array: (a)non-vibrating bubbles with projection, and (b) vibrating bubbles with projection.

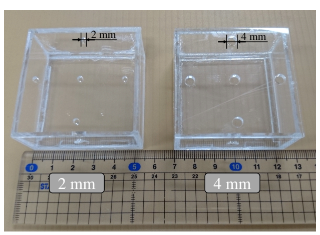

Figure 6: Acrylic cases with five holes (scale is 54 × 54 × 24 cm). Left: hole diameter of 2 mm. Right: hole diameter of 4 mm.

generated from an ultrasonic-phased array and incident on the bubbles, change the reflectance of the soap film, thereby causing vibrations that project the image onto the film.

Bubble Cloud

We introduce two types of Bubble Cloud: Mini-bubble Cloud and Floating-bubble Cloud.

Mini-bubble Cloud
When the bubbles are small, they seem to appear as if they are pixels of a projected image, as shown in Figure 2. A mini-bubble cloud allows each bubble to work as an individual pixel, and hence does not require fog or additional material to project color images onto the cluster.

Floating-bubble Cloud
We tried to project images onto a floating bubble cluster. However, this caused the soap film to pass light. Therefore, we changed the reflectance property of the film by using an ultrasonic-phased array (Figure 4). The image was projected clearly compared to the bubble cluster without ultrasonic waves (Figure 5). However, the bubble cluster moves owing to the vibrations produced by the ultrasonic wave emitted from the phased array when floating. Therefore, in order to project images onto a floating bubble cluster, we need to track the movement of the cluster and adjust the system so that the effect of the ultrasonic wave is canceled.

Evaluation of A Bubble Generator

We evaluated the effect of the pressure and diameter of the holes on the acrylic case. We performed this experiment because we aimed to evaluate whether these conditions fulfill the smallest diameter of bubbles that enable the display to float. Pressure values can be measured by using a pressure gage and for our experiment, we used the following values: 0.02 MPa, 0.04 MPa, and 0.06 MPa. There are two diameter sizes for the acrylic cases: 0.02 mm and 0.04 mm. There are five holes in the case, positioned at the same distance from each other (Figure 6). The diameter of a bubble cluster is measured by a ruler. Since bubbles cannot be uniform, we measured the diameter of a variety of bubbles and averaged the result.

The results are shown in Table 1. As the results indicate, we observed that higher pressure or larger holes create larger bubbles. These conditions fulfilled the smallest diameter that enabled it to float. We chose the following conditions to generate the smallest bubbles possible: a pressure value of 0.02 MPa and diameter size of 2.0 mm.

Shape of a Bubble Cluster

We investigated the shapes that could be created using the bubble cluster. In this experiment, we created five shapes with the bubble cluster—cube, quadrangular pyramid, sphere, mountain, and two mountains. Figure 7 shows the different cluster shapes. Bubble cluster reshaping was performed by using a 5 × 30 cm plate. We poured the soap bubble solution into the bucket and fixed an acrylic case to the bottom. A helium cylinder was connected to the acrylic case by an air tube. Helium gas was released at a constant rate from the acrylic case into the soap bubble solution. Bubble clusters escaped from a 25 × 25 cm hole on a plate that was placed on the bucket. Thus, the user could reshape the

		Pressure (MPa)		
		0.02	0.04	0.06
Diameter Size (mm)	2.0	10mm	15mm – 20mm	20mm – 30mm
	4.0	15mm – 25mm	25mm – 30mm	30mm – 35mm

Table 1: Effect of hole diameter and pressure on the bubble diameter.

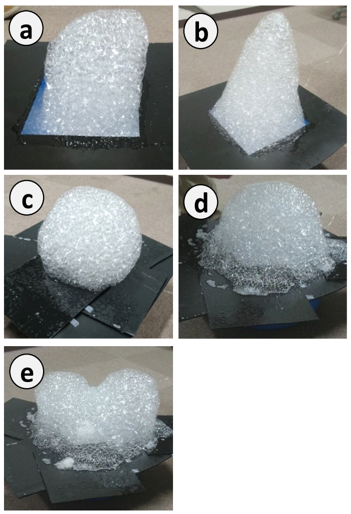

Figure 7: Forms of bubble cluster: (a) cube, (b) quadrangular pyramid, (c) sphere, (d) mountain, and (e) two mountains.

bubble cluster to any shape.

Figure 7 illustrates the five shapes of bubble cluster we produced. The cube shown in Figure 7a was made by placing a cubic mold on top of the hole. The cubic mold was made from five plates, and we separated each plate one by one to create a cube. The quadrangular pyramid shown in Figure 7b was made by sharpening the tip by scraping the bubble cluster using a plate. The sphere and mountain shown in Figure 7c and d were made by adjusting the hole with the plates. The two mountains shown in Figure 7e were made by scraping the middle of the bubble cluster.

Interaction with Electrified Bubbles

We investigated whether an electrified soap bubble cluster could be interactive. This was verified in an indoor still air environment. As a result, we could observe the bubble cluster being tracked by the user's hand. We could see that the bubble cluster moves in the same direction as the hand. We think that this occurs due to Coulomb's force between the user's hand and the bubble cluster. Therefore, we can manipulate the soap bubble cluster in midair. We also observed that the tracking was lost once Coulomb's force ceased to exist.

Conclusion

We introduced Bubble Cloud, which is a display that uses a bubble cluster. We described several Bubble Clouds that can change the size of the bubbles or allow them to float in the air by using confined helium gas. The display can change shapes because it is composed of a bubble cluster. Moreover, a floating cluster can interact with a user, who can control the display by moving his or her hand, by utilizing Coulomb's force between his hand and the cluster.

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