Design Method for Gushed Light Field: Aerosol-Based Aerial and Instant Display

Ippei Suzuki
University of Tsukuba
1heisuzuki@gmail.com

Shuntarou Yoshimitsu
Waseda University
gogoyoshimy@gmail.com

Keisuke Kawahara
University of Tsukuba

Nobutaka Ito
The University of Tokyo

Atsushi Shinoda
University of Tsukuba

Akira Ishii
University of Tsukuba

Takatoshi Yoshida
The University of Tokyo

Yoichi Ochiai
University of Tsukuba

ABSTRACT

We present a new method to render aerial images using aerosol-based fog screens. Conventional fog screens are easily affected by air flow, and their fog generators occupy large areas. In this study, we propose to add new tradeoffs between the display time and the payloads. We employ aerosol distribution from off-the-shelf sprays as a fog screen that can resist wind and has high portability. Results showed that the minimum weight of the entire system is approximately 600 g including all components, the screen raise time is approximately 0.5 s, the disappearance time is approximately 0.4 s, and the maximum wind speed at which we can project images is approximately 10 m/s. We conducted user studies on wearable applications, aerial imaging with a drone or radio-controlled model car, multi-viewpoint display, and a display embedded in the environment. This study will contribute to the exploration of new application areas for fog displays, and will augment expressions of entertainment and interactivity.

CCS Concepts

•**Hardware** → **Displays and imagers;**

Keywords

Display, aerial imaging, fog screen, design method, multicopter, projection, entertainment, communication

1. INTRODUCTION

Fog screens [27] have been used as the primary diffusers in passive aerial displays, and many studies have explored this type of display technology. In this type of display systems, diffusers are generated by the fog generator, and the projector projects images onto the fog. Previous studies aimed to display fixed and large images. However, there are some issues to be considered. The first problem has to do with the dimension and weight of the system. In this case, the fog generator is large and heavy. For example, FogScreen®eZ has 103 cm width and 85 kg weight[1]. The second problem is of low wind tolerance. Images cannot be projected in windy locations or attached to moving objects, since conventional fog screens are easily affected by air flow. These problems interfere with mobile applications. In addition, a fog machine cannot generate fog in a short period of time, and there is a delay before the fog can disappear. Therefore, we cannot produce conventional system as a wearable device, nor can these instantly project an image.

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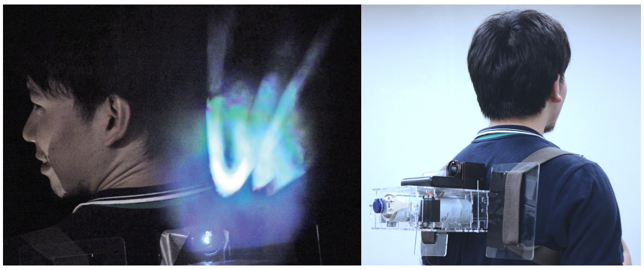

Figure 1: Application example: wearable version of our system (showing "OK" on man's back).

In this paper, we employ aerosol distribution from off-the-shelf sprays as diffusers and we use a portable laser projector as a projection source. Furthermore, we propose to add new tradeoffs between the limited display time and payload. Thus, we can solve the problems of conventional fog screens in some cases. Using aerosol distribution from sprays has several advantages:

- Because of its high projection speed, the system and its projected image can be moved and it has high wind tolerance.
- Because the ingredients of the spray evaporate immediately, we can instantly project an image and remove the screen.
- This enables the entire system to be lightweight and compact.

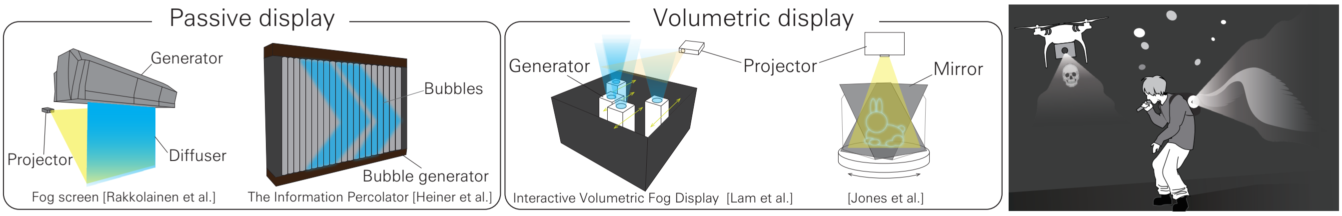

Figure 2: Left: fields of related work. Passive display utilizes various properties of the object (*e.g.*, diffusion property, lens-like property). Volumetric display forms an object in three physical dimensions. Right: example applications of proposed method. Our aerial imaging system can be attached to drone or dancer.

We present applications that utilize the benefits of our aerosol-based display. These benefits include a high refresh rate, small size, low weight, high tolerance for wind, and selective narrow viewing angle. Figure 2 (right) shows example applications of the proposed method. Our study is based on the demonstrations and discussions on applications in previous conferences [30, 31].

In addition, we considered the fabrication of this system in this paper. We explored different combinations of nozzles and sprays as design factors. It is relatively difficult to contaminate the surroundings while using off-the-shelf sprays such as deodorant sprays or cooling sprays. On the other hand, nozzles designed for graffiti purposes have some properties that are beneficial for distribution. We have evaluated several combinations of sprays and nozzles.

We also built a simple viewing angle simulator. The viewing angle of a fog screen is narrow because of Mie scattering. When the fog screen was fixed, the narrowness of the viewing angle was no longer a serious problem. However, our proposed method made the fog screen movable. Therefore, it is important to be able to demonstrate the image to the intended target during a simulation.

The contributions of current work are as follows:

- This study evaluates an aerosol spray as a screen.
- By simulating the scattering of aerosol distribution and evaluating different combinations of nozzles and spray, we present our design and fabrication method.
- By proposing a new method to render an aerial image, this study enables the exploration of new application areas for fog displays, and expands the use of aerial imaging for entertainment, communication, and interaction.

Conventional aerial imaging systems have been considered targets of appreciation. The proposed system can make the aerial display wearable, and can augment human from the perspectives of entertainment and interaction [Figure 2 (right)].

2. RELATED WORK

In this section, we cite related work. Figure 2 (left) shows the fields of related work.

[1]http://www.fogscreen.com/products/#!fogscreen-ez (last accessed January 25, 2017)

2.1 Passive displays

In this category, the projection area is filled with small objects that can passively reflect projected light or environmental light.

Studies of fog screens [27] have a close relationship to our study. There are several similarities between their studies and ours. Each study projects an image onto the fog, which has properties of forward-scattering. This technique is quite popular and has been studied for a long time. Despite the results from the previous studies, the fog screen still has two weak points: its system is sensitive to strong winds, and there is a delay when the screen is prepared or cleaned.

Passive displays utilize various properties of objects. The fog screen uses fog as a diffuser, while Bubble Cosmos [16] uses bubbles filled with fog. These displays utilize the diffusion property of the fog. Volumetric display with dust [4] and Pixie Dust [19] uses dust-like particles as diffusers. They utilize the reflection property of dust or foamed beads. Colloidal Display [23, 22] uses a membrane screen controlled by ultrasonic vibration. They can change their opacity and surface properties depending on the scales of ultrasonic waves. Bubble Cloud [11] uses a bubble cluster that can change shape, and there is no need to fill the bubble with fog. In [32], falling water droplets were utilized as a screen. The lens-like property of water droplets delivered projected images directly to eyes of the viewer. Heiner *et al.* designed a display that aimed to realize an ambient display [5], which is a passive midair display that uses water.

These studies were suitable for static and long-term projection. Our approach aims to render aerial images in different situations (*e.g.*, mobile and fast moving), and can be extended to accommodate them.

2.2 Passive volumetric displays

In this category, the dimensions are extended to 3D. The Interactive Volumetric Fog Display [12, 13] projects images on a nonplanar and reconfigurable fog screen. The Movable Immaterial Volumetric Display [28] is a prototype for the volumetric slices of a fog display. HANASUI [7] is a movable volumetric fog screen that uses markers, an infrared camera, and multiprojections. Splash Display [14] is a passive volumetric display that uses projectile beads as a projection medium. Holodust [25] illuminates small floating particles with lasers. Nayar *et al.* uses Laser Induced Damage scatterers as a volumetric diffuser [17]. Pixie Dust [19] manipulates reflective object by 3D acoustic-manipulation technology. However, their entire system was too large to attach to a drone or to use in wearable applications.

Three-dimensional displays based on the mechanical mo-

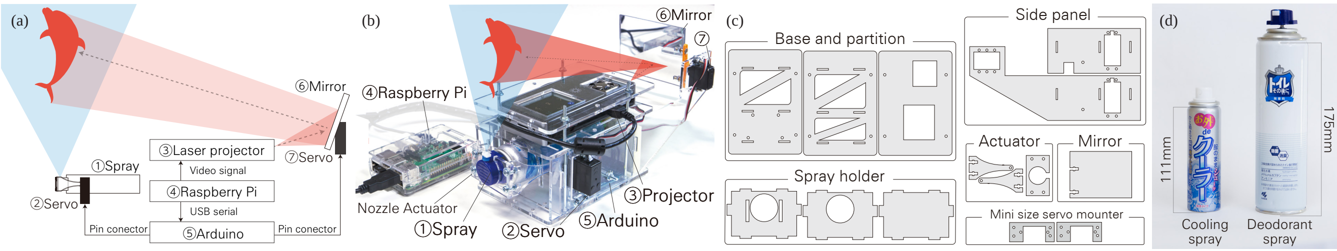

Figure 3: (a) System overview and data-flow diagram. (b) System appearance (acrylic-plate version). (c) Basic design of our system. These parts were formed with a laser cutter. (d) Off-the-shelf aerosol sprays considered in this study. Specifications are listed in Table 1.

tion of a mirror or screen are discussed in [24]. A spinning mirror is used with a high-speed projector in [8], where different images are projected onto the mirror according to the corresponding azimuthal angle expresses a 360° light field of an object. Similarly, a 100-million-voxel volumetric display [2] projects images onto a rotating screen, and VORTEX [9] projects images onto a rotating diffuser plate. In [1], multilayer water-droplet screens are created in air, and images corresponding to the spatial position of the water droplets are projected by synchronizing the projector with water bulbs.

2.3 Emitting midair displays

In this category, we cite studies that render aerial images that are not limited to passive midair displays. The basic concept of laser-plasma 3D displays was demonstrated using a nanosecond laser [10]. Fairy Lights in Femtoseconds [21] render touchable aerial and volumetric graphics by using femtosecond lasers.

2.4 Free-floating displays

Some studies have examined attaching a display to a multicopter. Flying Display [18] is a movable display system that uses two drones. One drone has a projector, and the other one has a screen. BitDrones [3] is an interactive 3D display that uses several nano-quadcopters. The Midair Display [29] involves a prototype in which a large tablet device or E-ink device is installed under a multicopter. This system should be large because the entire size of the system depends on the size of the monitor. Therefore, the researchers would require to enlarge their system in order to expand the display area. In addition, the appearance of a display equipped with a large tablet device or solid display is irregular and not refined. By contrast, our study has the following advantages of midair imaging with no monitors, small size, and low weight.

However, their system with a display panel has three advantages that our system does not possess. First, by using a multifunction tablet device equipped with a high-resolution display, the images shown are clear. Secondly, using an E-ink display can attain high visual performance outside or in environments with bright light. Thirdly, their display can be used near open flames in contrast to our system where significant danger of ignition is present depending on the spray in use.

2.5 Interaction with aerial display

Volumetric or/and aerial displays can usually interact with the human hand. The fog screen enables users to interact directly with the graphics [27, 13, 7]. Touchable Holography [6], HaptoMime [15], and RePro3D [35] show 2D and 3D images in the air, and also provide haptic feedback. Fairy Lights [21] renders touchable 3D graphics by using femtosecond lasers. Cross-Field Aerial Haptics [20] renders aerial haptic images that uses femtosecond-laser light fields and ultrasonic acoustic fields.

Table 1: Specifications for sprays.

Name	(a) Cooling spray	(b) Deodorant spray[2] (Fragrance-free)
Manufacturer	Kiyou Jochugiku Co.,Ltd.	Kobayashi Pharmaceutical Co., Ltd.
Volume	70 ml	280 ml
Ingredient	Isopentane	Fatty acid salt-based deodorant, Quaternaty ammonium compounds, Ethanol

3. IMPLEMENTATION

In this section, we introduce the implementation of our system. Figure 3 (a) shows the system configuration. The system includes a portable laser projector, an aerosol spray, servomotors for actuating the spray, embedded computers, a servo-controlled mirror, a battery, and a frame on which these components are mounted. This system is intended to gush the aerosol out automatically, and uses the laser projector to project the image onto the distribution from the spray. The minimum weight of the entire system is approximately 600 g when balsa wood was used for the frame. The shape of the system, the spray to be used, and the nozzle of the can vary according to the purpose of use.

3.1 Aerosol spray

An off-the-shelf cooling spray for cooling human bodies was used as a projection medium. Table 1 (a) lists its specifications. It consists of isopentane (47 ml) and liquefied petroleum gas (LPG). Since these are highly volatile ingredients, they do not remain on surfaces of objects such as floors or walls. The aerosol sprays cool water vapor in the air, which upon condensation acts as a fog screen. We consider its characteristics in section 5. In some applications, where we ignore the weight of the system to some extent (such as in embedded applications), we can employ larger sprays such as those listed in Table 1 (b).

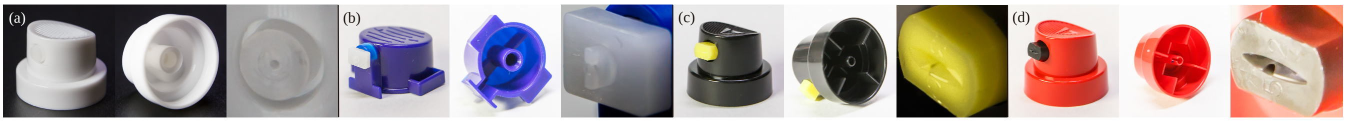

Figure 4: Appearances of nozzles considered in this study. Specifications are listed in Table 2. Nozzles designed for graffiti purposes shown in (c) and (d) do not fit the aerosol spray body we used. However, a part was removed while disassembling the nozzle of aerosol spray (purple), which was used as a conversion adapter.

Table 2: Specifications for graffiti nozzles.

Brand	MOLOTOW	
Name	(c) Flat Jet Artist 1 Black/Yellow	(d) Flat Jet Artist 2 Red/Black
Stroke	1.0-4.0 cm	1.0-6.0 cm
Properties	Adjustable, Wide jet nozzles	
Pressure	Wide soft output	
Suitable for	Small calligraphic effects and tags	Fill-ins and large surfaces or large calligraphic effect

Table 3: Specifications for portable laser projector.

Name	seeser m1
Light source	RGB laser
Resolution	WXGA (800 × 480)
Image size	8-80 inch diagonal
Luminance	Up to 25 ANSI lumens
Size	60 × 118 × 20 mm
Weight	148.5 g
Battery	Li-Polymer, 3.7 V, 2200 mAh
Battery life	Approx. 120 min

3.2 Spray nozzle

We tested four spray nozzles, as shown in Figure 4. Two of them are from sprays (a) and (b) (Table 1), while the others are nozzles designed for graffiti purposes[3] (Table 2). We expected that nozzles for calligraphy would enable us to gush a thin and wide aerosol. We found that the shape of the nozzle can be quite sensitive to minor modifications in our system. With high-precision molding, it may become possible to design dedicated nozzles.

3.3 Spray actuator

Two servomotors are used as an actuator to gush the aerosol out automatically. The servomotors are fixed to the frame beside the spray. Power is supplied directly to the servomotors to prevent the loss of power to the Raspberry Pi when it takes the load. The servomotors are controlled by an Arduino microcontroller.

An actuator part made of an acrylic board was designed to depress the nozzle down by fitting the form of the nozzle. This part was also designed to be removable from the assembled state of the entire system. Therefore, we can change out the sprays quickly and easily.

We also tried to use a solenoid instead of a servomotor. However, we would need high voltage to depress the nozzle using a solenoid. We need to depress the nozzle effectively using a limited and lightweight battery because we assume that our system is used as a wearable or movable application. Therefore, we decided to use servomotors instead of a solenoid.

3.4 Body

We employed acrylic plates for our basic setup. This acrylic model was used to evaluate our system. However, when we equip the system on a multicopter, we must consider the payload. In this case, balsa wood is suitable as the material of the frame. Balsa wood is very lightweight and has considerably large strength per unit weight. In other cases where weight is not as important, materials with greater strength, such as acrylic plates, could be used.

3.5 Controller

We used an Arduino microcontroller and a Raspberry Pi as control devices. The Raspberry Pi sends the image to the projector and sends serial signals to the Arduino via USB. The Arduino controls the servomotors. When images are projected, we can make the spray gush and rotate the mirror. The programs on the Raspberry Pi are coded in Python. OpenCV2 is used for image processing. The Arduino is coded with the Arduino Integrated Development Environment (IDE).

3.6 Projection source

A portable laser projector was adopted to project images. Its specifications are listed in Table 3. It has a built-in battery. We also added a servo-controlled mirror to our system in order to obtain the optical path length and project a large image.

4. SIMULATOR OF VIEWING ANGLE

In this section, we simulate the appearance of a screen. We simulate the width of the viewing angle in our display. Similar to a fog screen [26], we can project an image onto the aerosol distribution by using the forward scattering property of particles called Mie scattering [33]. Simulating the viewing angle is important in designing applications for our system since a display with a narrow viewing angle is able to move freely. We can design positions and angles of nozzles, projectors, and mirrors according to the viewing angle. For example, in an application to be installed on a drone, the drone must be navigated in a way that observers always enter the viewing angle.

Graphics are rendered using openFrameworks. First, we created a function that calculates the scattered light for each scattering angle of one particle. The inputs are the wavelength of the incident light and the particle size, as shown

[2]http://www.kobayashi.co.jp/seihin/tsa_2/(in Japanese)
[3]http://www.molotow.com/products/supplies/caps/
(last accessed January 25, 2017)

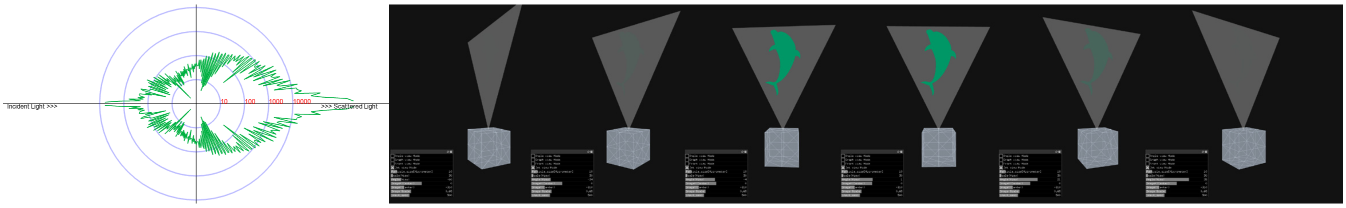

Figure 5: Viewing angle simulator, which simulates scattering of aerosol distribution.

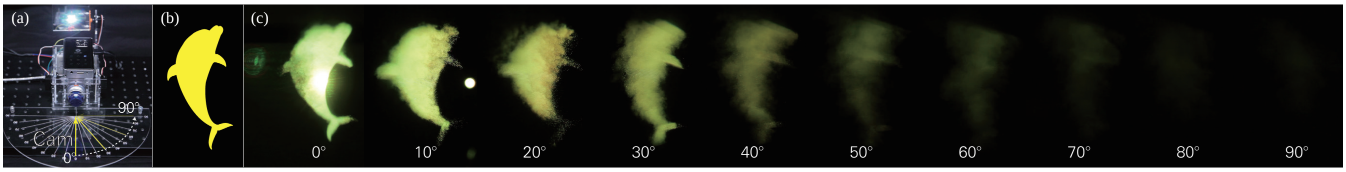

Figure 6: (a) Setup for visibility experiment. (b) Source image (a yellow dolphin) for this experiment. (c) Results from every 10°.

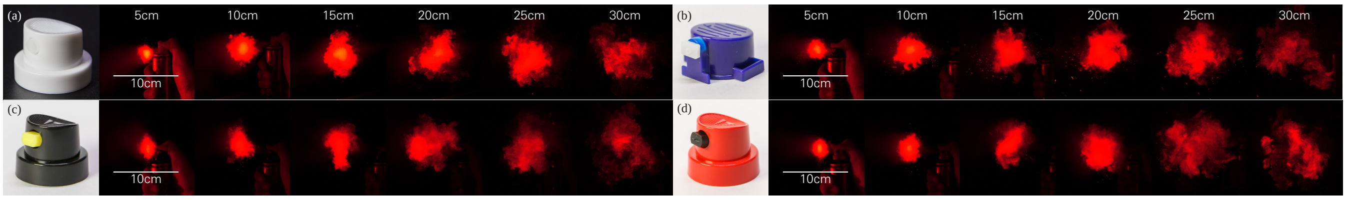

Figure 7: Setup and results for the experiment of spray patterns: (a) nozzle of coooling spray, (b) nozzle of deodorant spray, and (c)(d) nozzles designed for graffiti purposes.

on the left side of Figure 5. Second, we rendered our system and aerosol distribution. This simulator can render the projected image on aerosol distribution seen from the front of the projector. The thickness of the fog is not taken into consideration. In other words, it is assumed that the particles are arranged in a plane. Therefore, it is possible to see some lights from the side by Tyndall phenomena or the internal mutual scattering of particles in the real world.

5. EXPERIMENTS AND EVALUATIONS

In this section, we describe our experimental procedures and results. All experiments were conducted in a dark room.

5.1 Viewing angle

The viewing angle of our system is limited since our display uses the forward scattering characteristics of the Mie scattering theory [26]. We fixed the system at a point and recorded it while moving the camera by 10° in the horizontal direction. The experimental setup and results are shown in Figure 6.

However, it is difficult to determine the exact angle at which we can observe the system because of the turbulence of the sprays and the unstable output of the aerosol. From the results, we consider that the viewing angle of our display is approximately less than ±10° around the central point projected by the laser projector.

5.2 Spray pattern

Spray patterns play an important role in the experiment and therefore, the performance of various spray patterns should be considered. If a spray pattern is planar, our display creates a clear image because of simple scattering. In order to evaluate the spray patterns, we used a red laser slit light projector (5 W). The camera was placed in the direction of the injection, at the front of the nozzle. In a dark room, the air that has been sprayed with the aerosol was illuminated. The results are shown in Figure 7.

From the results of the experiment, the spray patterns of nozzles for deodorant spray and graffiti are wide near the nozzle. The distribution of aerosol from the nozzles for graffiti is high density; however, it is also narrow and short. The ideal spray pattern for this system is flat and wide. Although the nozzle for deodorant spray is optimal, when it is attached to a small and low-pressure spray, the width becomes narrow.

5.3 Length of distribution

The screen size of our system is determined by the spray length. In order to evaluate the spray length, we used a red laser slit light projector (5 W) set in front of the nozzle, similar to the one used in the experiment for the spray patterns. Fifteen photos were captured from the vertical side of the optical path. The photos of the results are lighten composed 15 frames to enhance the actual length of distribution. The results are shown in Figure 8.

Distribution from the nozzle of spray (b) is the longest and is moderately wide; however, it is not steady owing to the low pressure of the spray. The distribution from the nozzles for graffiti is of high density; however, they had a narrow width and short length. Nozzles should be chosen depending on their objectives.

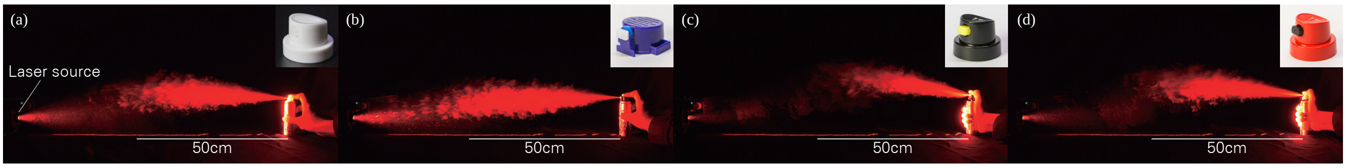

Figure 8: Results for experiment on spray angle and length. Photos of results are lighten composed 15 frames to enhance actual length. (a) Nozzle of cooling spray. (b) Nozzle of deodorant spray. (c)(d) Nozzles designed for graffiti purposes.

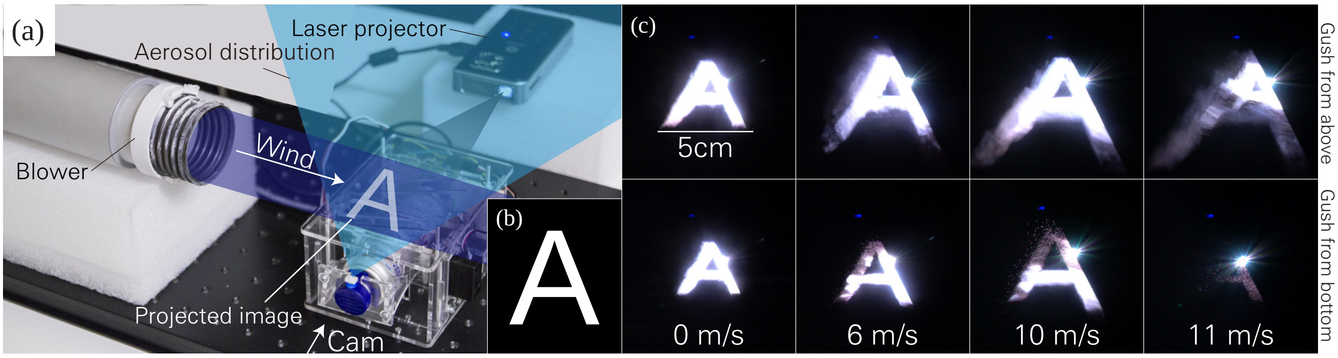

Figure 9: (a) Setup for wind resistance experiment. (b) Source image (The letter "A" written in Helvetica, Regular) for this experiments. (c) Results of experiment.

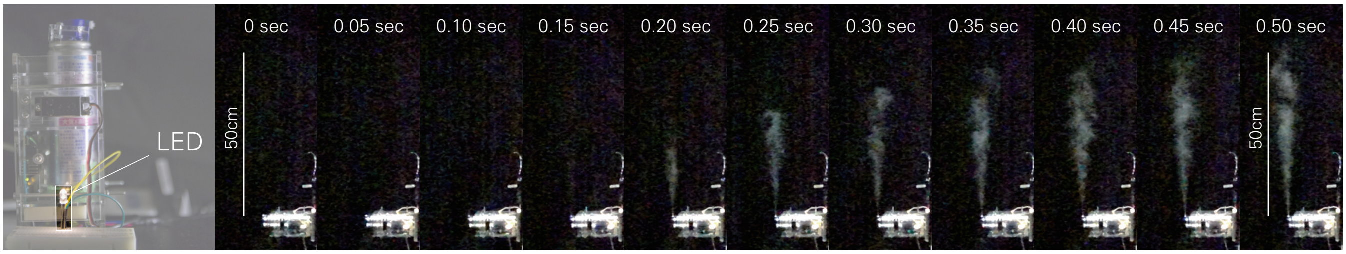

Figure 10: Setup and results for experiment on response. We used a high-speed camera (SONY DSC-RX10M2, 960-fps mode).

5.4 Wind tolerance

We measured durability of the system when it was mechanically shaken or when it experienced strong winds. First, we set the outlet of the blower to hit to the emitted aerosol distribution. This blower can change the extent of the air flow. Next, we measured the wind speed with an anemometer. Then, we projected the image onto the aerosol distribution, and recorded its appearance while maintaining the wind speed.

The experimental setup and results are shown in Figure 9. The image is the same as in the situation with no wind until the wind speed reaches 10 m/s. When the wind speed increased, we were unable to project the image because the distribution and motion of the particles were affected by the wind. However, in practice, we could continue to project images if we can change the angle of the mirror depending on the jet flow.

5.5 Response speed

We measured the time from pressing the button for the spray to completing preparations for projecting the image, and the time when the aerosol distribution disappears. We modified the system to turn an LED on and off when the servomotor is activated. Strong light was irradiated continuously into the distribution and was recorded using a high-speed camera. The duration of actuating spray was 10 s with the cold spray attached the nozzle for the deodorant spray being adopted. The experimental setup and photos are shown in Figure 10. We report that the approximate rise time was 0.5 s and the approximate disappearance time was 0.4 s.

5.6 Display time

In order to evaluate the endurance of our system, we held the spray nozzle down and maintained the projection of the image. The results are shown on the left side of Figure 11. The time from the beginning of the image projection to its disappearance was $\sim$120 s. However, when the aerosol spray is nearly depleted, the density of the aerosol distribution drops. Aerosol sprays are not designed for long-duration gushing; therefore, we conducted another experiment that repeats 1 s of gushing at 1 s intervals. The results show that the latter approach has a slightly higher density than the former.

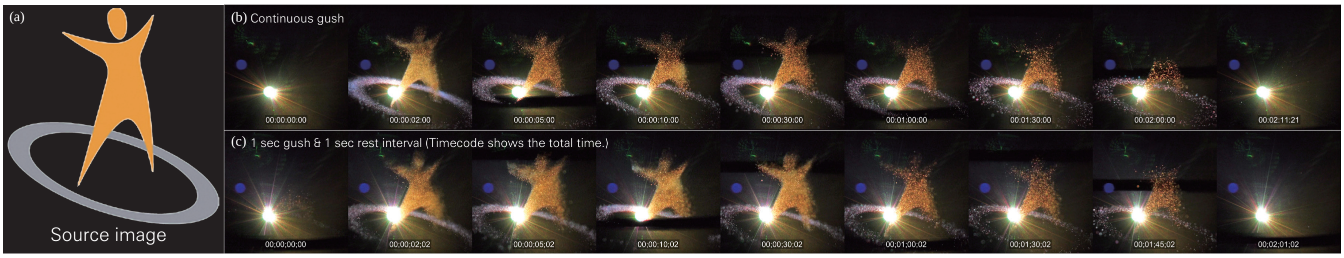

Figure 11: Results of the experiment on display time. Timecodes are SMPTE for non-drop 30 fps. Timecode for trial below (c) has interval and shows total of gushed time.

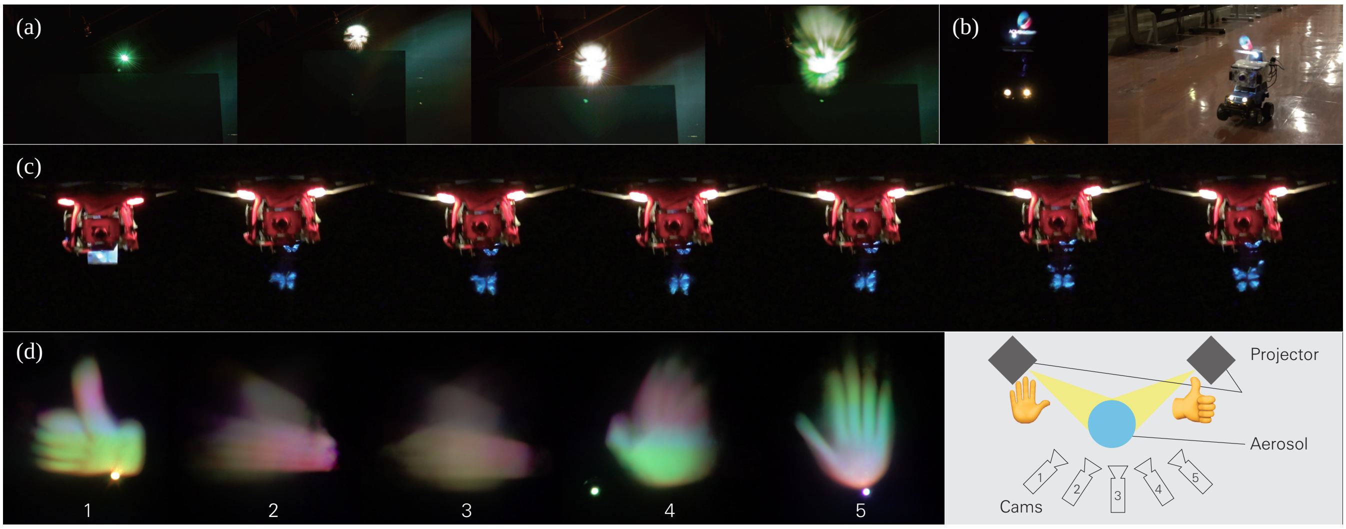

Figure 12: Application examples: (a) "Gas Ghost" lobby decoration at a live music club. (b) A radio-controlled model car with our system. (c) A drone with our system. (d) Multi-viewpoint aerosol-based fog display. Photos were taken from different angles.

6. APPLICATIONS

In this section, we introduce some aerial display applications that use the advantages of our system.

6.1 Wearable use

As a proof of concept with regard to the mobility and low weight of our system, we present a wearable application. For our first example, we present an entertainment application in which we install the system on the back of a performer such as a dancer. If we use a conventional fog screen, the performer cannot move swiftly, since movement results in the displacement of air that can distort the fog screen. A large 2D display can be used as a wearable display; however, it is too heavy to wear and lacks an attractive appearance.

For another wearable example, we can communicate visually with other people using our system. People can project aerial images over their heads or on their backs, as shown in Figure 1. For example, in a television program such as a quiz show, people can express surprise by projecting an overhead image of an exclamation point that is produced by our system.

6.2 Floating or fast moving midair display

We fabricated a prototype of the display that we installed on a drone, as in [29]. This is shown in Figure 12 (c). The system can be easily installed on a small drone since our system weighs approximately 600 g in its smallest configuration, including all components. The drone can compensate for the narrow viewpoint of our system by adjusting the angles of display. If the drone is controlled according to the position of the observers, the image is always visible to them. Furthermore, we can install our system on a radio-controlled model car, as shown in Figure 12 (b). We can also demonstrate a sudden aerial image by using the instantaneous feature of the system, which will constitute an attractive component of the interaction of the audience.

Table 4: Specifications for Drone.

Name	DJI Phantom 2
Weight (Battery and propellers included)	1000g
Diagonal length	350mm
Max flight speed	15 m/s
Battery	3S Li-Polymer, 11.1 V, 5200 mAh
Flight time	25 min

6.3 Display embedded in the environment

We developed another application in which an aerial image suddenly appears and disappears. A conventional fog generator takes some time to generate fog to a state in which images can be projected. By contrast, our display can prepare the projection area within 0.5 s. We suggest "Gas Ghost" as a specific example. We incorporated "Gas Ghost" in the decorations of a live music club [Figure 12(a)]. When a person came close to the projection point, the system emitted aerosol and projected an aerial skull image. Some of the audience members who observed the image of a skull suddenly appear expressed strong reaction and departed from the area.

6.4 Multi-viewpoint aerosol based fog display

We implemented a multi-viewpoint aerosol display that creates motion parallax to the observer, as in [34]. In our prototype, we used two laser projectors, as shown in Figure 12 (d). The aerosol distribution shows forward scattering, in the form of a cylinder. This technique enables users to create multiview aerial images instantly.

7. DISCUSSION AND FUTURE WORK

7.1 Risk

When the system is set on a human body or in the environment, there is a risk that large quantities of the aerosol distribution may come in contact with the face. In addition, the environmental impact of the system should be considered. Even if there are few negative effects of the cooling spray on humans, these sprays typically contain ingredients that are toxic and harmful to the environment.

Problems regarding safety also exists as the gas contained in the spray is flammable. If our system is used in a situation that includes fire, the spray could ignite or cause an explosion. Moreover, considerable attention should be paid when using the system with real fire, such as that of a flame machine. When we use the system indoors, we must ventilate the area.

7.2 Spray performance

The spray has several functional issues: the angle of aerosol distribution is narrow; therefore, aerosol distribution is blurred when the moving speed exceeds 10 m/s. This problem can be resolved by increasing the gas pressure and increasing the kinetic energy of the particles instead of the volume.

There are also tradeoffs between the display time and payloads. Since off-the-shelf sprays are not designed to jet for a long duration, the quality of the created screen is better when we release the jet in small intervals than when we jet continuously, as described in the previous section.

In future works, we would like to try the design for not only the nozzle but also the overall structure of the spray. We will consider points of design as the following: (1) forming the spray made with safe ingredients and (2) increasing the gas pressure in order to increase the output and widen the angle of output. We consider sprays of the proposed system as cartridge and they are used accordingly.

7.3 Image qualities

This system employs turbulent aerosol, which affects the projected appearance. Since the jet distribution is not stable, it is very difficult to measure the actual viewing angle. However, we can clearly see the image through the naked eye using conventional fog screens because the turbulence occurs at high speed.

7.4 Narrow viewing angle

Our system has a limited viewing angle, which is as narrow as conventional fog screens. There are many approaches to solving this problem for conventional fog screens, including the 360-degree fog projection interactive display [34] proposed by Yagi *et al.*, or HANASUI [7] proposed by Ishikawa *et al.* We can apply these techniques to our system since our method of projection of images is based on the same theory.

8. CONCLUSION

In this paper, we introduced a new method to render aerial images using aerosol-based fog screens. We employed aerosol distribution from off-the-shelf sprays as a fog screen that can resist wind and has a high portability. We evaluated the feasibility of the aerosol type of fog screen. The size of the screen depends on the pressure of the aerosol spray and the nozzle used. We presented a design of the system setup and evaluated our experiments, system scalability, and applications. Our system enables a new type of application by combining it with a multicopter, wearable item, multi-viewpoint aerosol-based fog display, or embedding it in the environment. Our system allows for the exploration of new application areas for fog displays, and augment expressions of entertainments and interactivity.

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