ARTISTS' ARTICLE

Sound of Ikebana

Fluid Artwork Created under Zero-G Using Parabolic Flight

NAOKO TOSA, AKIHIRO YAMADA, YUNIAN PANG, SHIGETAKA TOBA, AZUSA ITO, TAKASHI SUZUKI, AND **RYOHEI NAKATSU**

ABSTRACT

The authors, led by artist Naoko Tosa, discuss their collaboration on the video artwork *Sound of Ikebana*, made by applying sound vibration to fluid and shooting it with a high-speed camera. To study the fluid's shape under zero gravity, the authors experimented with generating the artwork under weightlessness achieved through parabolic flight. The authors confirmed that a new shape significantly different from the one created under normal gravity is created. A three-dimensional artwork was also generated by shooting the phenomenon from multiple viewpoints.

NEW ART IN THE SPACE AGE

Recently, there have been many space travel–related events: NASA's landing of an uncrewed spacecraft on Mars in February 2021 [1]; Virgin Galactic's Richard Branson and Amazon's Jeff Bezos flying to an altitude of approximately 100 km in July 2021; and a four-day flight to orbit around the earth by four civilians in SpaceX's spacecraft Crew Dragon in September 2021 [2]. Space travel is thus becoming a broader social reality fifty years after humans first landed on the moon.

Although the prospect of ordinary people routinely traveling into space is still a long way off, it is necessary to consider the implications for our lives and society should space travel become as common as air travel. Since ancient times, art has been deeply linked to human spirituality [3], and many artists were fascinated by the relationship between art and the universe. What art will look like as space exploration advances is one such relationship and an essential and exciting theme [4]. Weightlessness is one of the essential factors in the experience of the space age. Therefore, what art will become under weightlessness is an exciting research theme in the interdisciplinary area between art and technology.

We have been interested in fluid phenomena, primarily involving high-speed fluid, invisible to the naked human eye. Led by author Naoko Tosa, we have been producing fluid art [5] using a high-speed camera. Fluid behavior is significantly different in weightlessness than under normal gravity, making the study of fluid art in weightlessness an exciting and essential aspect of the genre. We therefore are exploring what art will look like in the weightless environment particular to space travel.

Below we describe our activities focused on high-speed phenomena and art, and on art and zero-G. Then we introduce the concept of art that uses the phenomenon of fluidity and the details of the fluid artwork *Sound of Ikebana*. We also consider *Sound of Ikebana*'s relationship to the Japanese idea of beauty. We then describe our experimental process in which Tosa creates artworks under weightlessness achieved by parabolic flight. We also describe an attempt to create a 3D art object from the 2D video obtained.

RELATED ACTIVITIES

Art and High-Speed Phenomena

Attempts to visualize high-speed events using technology have an extensive history. Harold Edgerton, a pioneer in this field, was a professor at MIT [6]. He studied high-speed phenomena using electronic flash, which he further developed into his invention the Stroboscope. His achievements are numerous, including taking a series of photographs of balloons or apples exploding by shooting the moment when bullets hit them. He is also well known for his photographs of the milk crown (the beautiful crown-like shape that a milk drop creates as it falls) [7]. Photographs and films taken with his Stroboscope are exhibited at the MIT Museum and Edgerton Center [8,9].

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Tosa worked at the MIT Center for Advanced Visual Studies as an Artist Fellow between 2002 and 2004. During that time, she often visited the MIT Museum and Edgerton Center. She was greatly inspired by the Stroboscope and Edgerton's works visualizing high-speed phenomena. This experience led her to visualize fluid phenomena in artworks using a high-speed camera.

Bill Viola provides another well-known example of an art creator using a high-speed camera [10]. While Tosa attends to natural fluid phenomena, Bill Viola explores elements of human life—death, consciousness, etc.—that exist at the foundation of human behavior by capturing human movement in super slow motion.

Art and Zero-G

When crewed flights to the moon and stationing astronauts in space became possible, attempts began to place artworks on spacecraft bound for the International Space Station and the Moon. There are also proposals for launching huge artworks that can be seen from the earth at the same altitude as satellites [11]. However, these have not been realized due to budgetary concerns.

Among these efforts to explore new art forms suitable for the space travel era is zero-G art: art under weightlessness, an environment particular to space travel. One pioneer in creating such art is Frank Pietronigro [12]. In April 1998, he flew from the NASA Johnson Space Center aboard a turbojet airplane to create "drift painting" under weightlessness achieved by parabolic flight. A 75-in-high-by-48-in-wide-by-52-inch-deep plastic bag was developed beforehand and tethered to the jet's interior. While freely floating in this "creativity chamber," he projected various color paints into the space surrounding his body.

Another pioneer creator of 3D art in weightlessness is Israeli artist Eyal Gever, who made a 3D-printed artwork called *#Laugh* [13] using a 3D printer on the International Space Station (ISS). In 2016, he and his team launched an app that converted the sound waves of users' laughter into digital 3D models. More than 100,000 people generated models. The one voted best by the app's users was then 3D-printed onboard the ISS.

The MIT Media Lab has launched the Space Exploration Initiative [14] to conduct various experiments under weightlessness. Among them is a project to explore art in the space age. For example, in an artist's project called *Telepresent Drawings in Space* [15], the theme concerns how to deliver sensations and emotions in outer space to the ground. The trajectory of an object floating under weightlessness is recorded with sensors. The goal is to reproduce the object's ground trajectory in an artwork.

The Japan Aerospace Exploration Agency (JAXA) has a laboratory called Kibo [16] on the ISS, which has been used for both scientific and artistic experiments. In 2008, the first call for proposals for art creation in space was issued, and nine resulting experiments were conducted in Kibo until 2011 [17]. From 2011 to 2013, eight other themes were implemented in a second phase [18].

These studies are significant as pioneering space art research. At the same time, there are only a few trials in which artists themselves tried to create artworks under weightlessness. In our project, as in Pietronigro's activity, the artist herself creates art under weightlessness.

FLUID ART: *SOUND OF IKEBANA*

Fluid Art

The behavior of fluid consists, in large part, of natural phenomena. Water flow, wave behavior, ocean currents, etc., are typical examples [19]. Fluids are known to be able to create beautiful shapes under a variety of conditions (see the milk crown mentioned earlier).

As beauty is a fundamental element of art, it is natural to use fluid phenomena as a basic methodology for art creation. Tosa has led a project to create fluid art by shooting the behavior of fluids with a high-speed camera. High-speed cameras have traditionally been used to capture a variety of phenomena that occur in a short period, such as the explosion of physical material. On the other hand, we were interested in producing various beautiful organic shapes using fluids. We found it possible to create an *ikebana*-like shape (ikebana is a Japanese flower arrangement) with a fluid such as paint by applying sound vibration. Figure 1 shows the generation system. A speaker is placed facing up, a thin rubber film is put on the speaker output, a fluid such as paint is placed on the rubber film, and sound causes the speaker

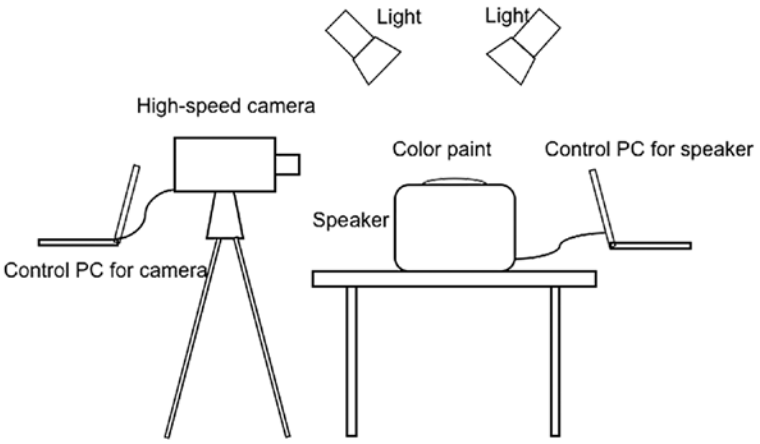

Fig. 1. Fluid art generation system. (© Naoko Tosa)

Fig. 2. Scenes of *Sound of Ikebana*. (© Naoko Tosa)

to vibrate. Then the paint rises from the surface and makes various shapes, and the process is captured with a high-speed camera. Here, a high-speed camera of 2000 frames per second is used. A PC connected to the speaker produces various sounds that cause vibrations.

Sound of Ikebana

Using this environment, we systematically changed the sound shape (sine wave, etc.), sound frequency, fluid type, and fluid viscosity, and shot various fluid forms with a high-speed camera [20]. We found that various ikebana-like shapes were generated, allowing Tosa to create the video art collection called *Sound of Ikebana* [21,22] by editing the resulting video images according to the colors of the Japanese seasons. Figure 2 shows images from the work. Tosa used this work in projection mapping in Singapore in 2014. Also, as part of her activities as a Japanese Cultural Envoy, she held an April 2017 exhibition in New York's Time Square using more than 60 digital billboards.

Sound of Ikebana's Concept

Sound of Ikebana is an artwork based on fluid movement resulting when vibrations at various frequencies are applied. Therefore, it is an art based on natural phenomena. People generally understand traditional art as an embodiment of beauty created by an artist. In that sense this work is different from traditional art; therefore, its concept is essential.

Tosa was appointed as a Japanese Cultural Envoy in 2016 to exhibit her artworks worldwide. Many people, including those involved in the art community, commented, "I feel Japanese beauty in her art." The question arises why people felt "Japanese" beauty in this work.

Sound of Ikebana is made by imparting sonic vibration to liquid, but the artist controls the production process. Tosa conducted various experiments systematically changing the fluid's viscosity, frequency, volume, etc. She learned what kind of shape was produced under what conditions and selected several specific conditions as a result. She also learned how much liquid to apply on the speaker, what colors to select, etc. She then edited the video to create the video artwork. This process resembles how an artist uses paints and paintbrushes to create artwork through trial and error, using sounds and fluids instead of brushes and paints.

Once the sound, fluid, color, etc. are decided, the shape created by the sound vibration is greatly influenced by chance. Such an art production method is like Jackson Pollock's. He is well known for developing the technique called action painting [23], in which paint is dripped or thrown onto the campus instead of painted with a paintbrush. In his case, the paint color and where to drop it on the canvas were carefully considered in advance. At the same time, the shape of the dripped or thrown paint is greatly influenced by chance. It is notable that Pietronigro's "drift painting" method [24] was achieved under weightlessness. One crucial aspect of both methods is a balance between the artist's intentions and random chance. If a carefully crafted balance is achieved, people perceive and admire beauty in such artworks.

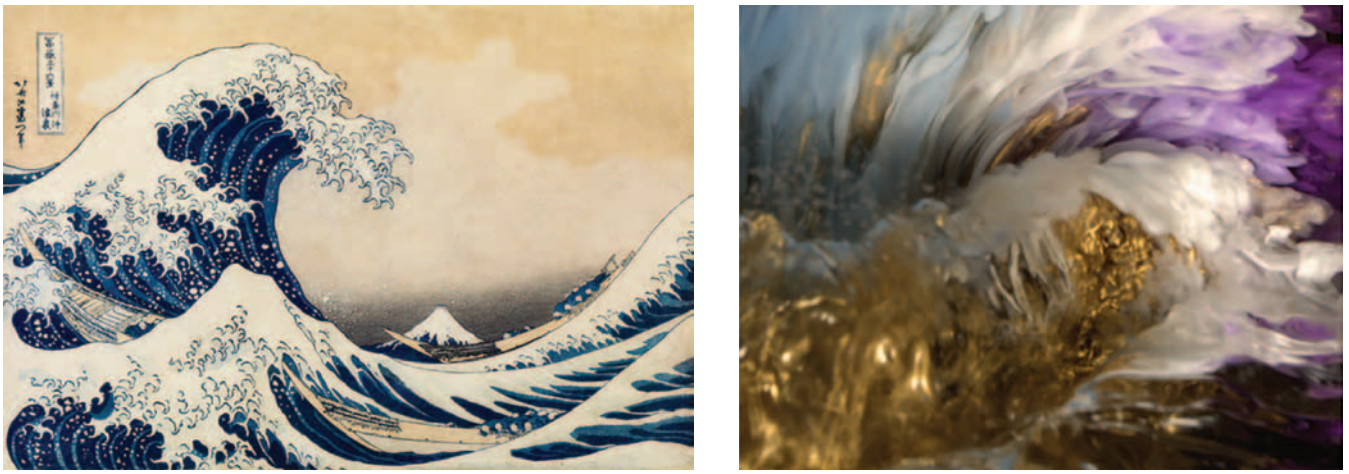

Fig. 3. (left) Katsushika Hokusai, *The Great Wave off Kanagawa from Thirty-Six Views of Mt. Fuji* (Public domain); (right) behavior of fluid captured by a high-speed camera. (© Naoko Tosa)

Another feature of Tosa's art production method is use of technologies. The movement of the fluid vibrated by sound is swift, and the developed liquid form would, under normal circumstances, be too fleeting to be appreciated. The moment of beauty is captured only by shooting it with a high-speed camera.

Sound of Ikebana and Japanese Beauty

When Tosa exhibited her artwork overseas, many people perceived the presence of Japanese beauty in her art. Why is this? To answer this question, we try to explain what Japanese beauty is.

Bruno Taut pointed out that Japanese artworks and architecture have always emphasized and expressed a sense of unity with nature [25]. In tracing this origin, we arrive at the idea of so-called oriental monism. Oriental monism preaches the unification of humans and nature and is the basis of the philosophy of Laozi and Zhuangzi [26]. This suggests that beauty is already present but primarily hidden in nature and that some Japanese artists have found ways to reveal and draw focus to such hidden beauty.

The methodology of extracting the beauty hidden in physical and natural phenomena fits the traditional concept of Japanese beauty. Below are several examples showing the relationships between Tosa and traditional Japanese art.

Japanese artists have found beauty in natural phenomena such as rivers and scattered waves and have created artworks to express it. Katsushika Hokusai's *The Great Wave off Kanagawa from Thirty-Six Views of Mt. Fuji* (Fig. 3, left), which expresses the dynamic movement of the waves, has long been considered a typical expression of Japanese beauty and has had a significant influence on artists around the world [27]. Interestingly, this dynamic wave movement resembles the shape created in a fluid captured with a high-speed camera. Figure 3 (right) shows the form resulting when we fired an air gun projectile into the water-paint mixture, revealing similarities between the two images.

Another example of the similarities between the artwork and nature is the primary form of ikebana [28]. The primary form of ikebana is an asymmetric triangle that connects three points of different heights: "core," "sub," and "body" (Fig. 4, left). It is interesting to note that the shapes in the *Sound of Ikebana* often resemble the form of ikebana (Fig. 4, right).

Although, at this moment, we do not have evidence to confirm such relationships, we are approaching this issue from a scientific point of view, as discussed below [29].

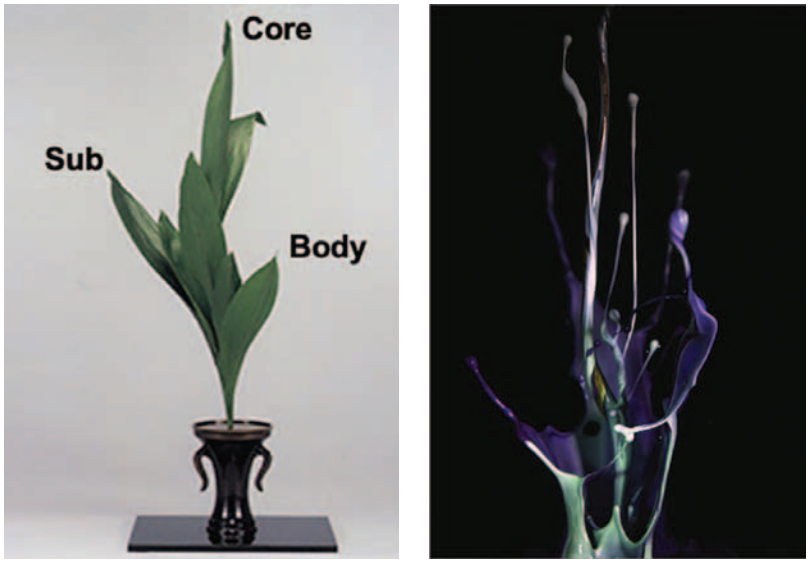

Fig. 4. (left) The basic form of Ikebana. (Public domain). (right) A form created in the *Sound of Ikebana*. (© Naoko Tosa)

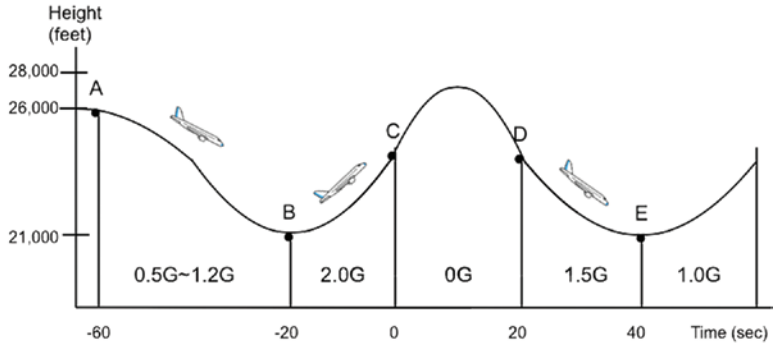

Fig. 5. Parabolic flight.

GENERATING WEIGHTLESSNESS

There are two typical methods of realizing weightlessness on earth.

Parabolic Flight

Flight on a parabolic flight path [30] is achieved when after gaining sufficient speed by a rapid descent the aircraft is raised and the thrust is narrowed down to the extent that it compensates for air resistance to execute a parabolic motion. A weightless environment of about 10^{-2}G to 10^{-3}G can be realized during parabolic flight for about 10–20 seconds. One company in Japan provides commercial services for parabolic flights [31], which have been used for various weightless experiments and the training of astronauts. Figure 5 shows the flight curve in parabolic flight and the gravity in each phase.

Free Fall

When an object falls while being pulled by gravity, it is weightless. In other words, weightlessness can be achieved by creating a free-fall state through a drop from a sufficient height.

In Japan, the Micro-Gravity Laboratory of Japan (MGLAB) in Gifu Prefecture has a free-fall system with a distance of 100 m and a free-fall time of 4.5 seconds. A vacuum is maintained inside the drop tower eliminate air resistance [32]. Also, the Bremen Drop Tower at the University of Bremen, Germany, is well known. Its height is 147m (actual fall distance is 110m), and when a falling capsule is dropped in the evacuated tower, weightlessness can be achieved for almost 4.7 seconds [33].

CREATING FLUID ART UNDER WEIGHTLESSNESS

Basic Methodology

To create art under weightlessness, we worked on an experiment in which the artist took the initiative in creating the *Sound of Ikebana* under weightlessness. At the same time, in addition to shooting the image of the artwork under weightlessness and making it a two-dimensional video work, we attempted to realize it as a three-dimensional object. The artwork has often been recognized as "Japanese" [34]. Making the artwork into a 3D object allows us to exhibit it so people may examine and consider the work from entirely new perspectives. It will then be possible to receive more total impressions and comments on why it resonates as "Japanese" to so many people. To pursue this idea, we tried to render the artwork in 3D [35].

To realize 3D restoration, we are studying a method to create a 3D model based on images taken from multiple directions [36]. Multiple still cameras and multiple high-speed video cameras are used. Synchronous shooting using multiple still cameras can be done at a relatively low cost, but the timing of pressing the shutter becomes a problem. We first constructed a system using multiple still cameras and conducted various experiments. However, we found that it is challenging to obtain results that are satisfactorily shaped depending on the precise shutter timing. Based on our preliminary experiments, we decided to try using multiple high-speed cameras.

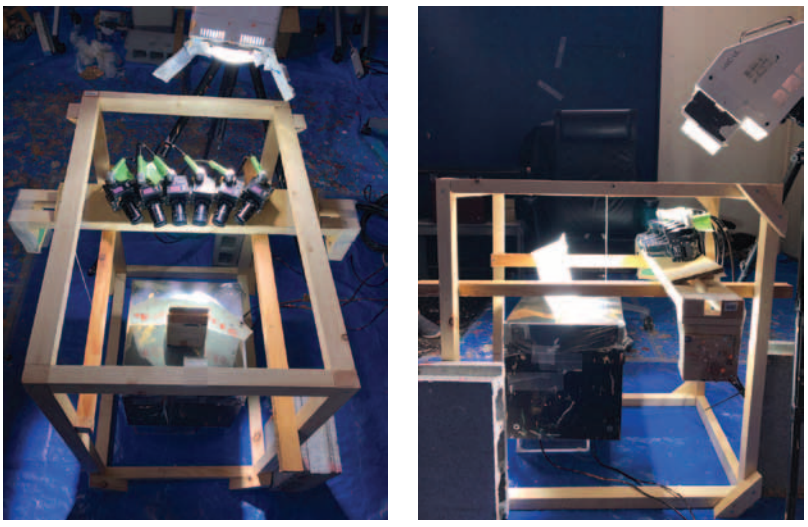

Fig. 6. *Sound of Ikebana* generation system for parabolic flight. (a) Front view. (b) Side view. (© Naoko Tosa)

Art Creation Using Parabolic Flight

Creating the *Sound of Ikebana* during parabolic flight requires a smaller version of the generation system shown in Fig. 1 adapted for use on the aircraft. Furthermore, to make the artwork into a 3D object, it is necessary to have a system equipped with multiple high-speed cameras. Figure 6 shows the generation

Fig. 7. Scenes of creation of *Sound of Ikebana* during an actual parabolic flight. (© Naoko Tosa)

system we developed, which uses a high-speed multi-camera setup, featuring 2M-pixel resolution and 2000-frame-per-second shooting speed. Six units surrounded the speaker. For complete 3D restoration, it was necessary to shoot from 360°. However, since a workspace for setting paint was required, we eventually decided to use six high-speed cameras surrounding the speaker at about 120–180°.

Creating an artwork during parabolic flight requires quickly completing all necessary processes within a short time. All participants in the experiment, including artist Tosa, were new to parabolic flight. We installed the generation system in our laboratory to minimize failures in that unfamiliar environment and conducted training by simulating the actual flight. We practiced setting a new film on the speaker, setting paints on it, driving speakers, shooting in synchronization, and cleaning after shooting within the time intervals necessary during the actual flight. By practicing about 30 times, we were able to perform each procedure skillfully and quickly. It was possible to create and shoot *Sound of Ikebana* almost without failure by following the practiced procedure during the actual parabolic flight. The weightless experience had a duration of about 20 seconds. Figure 7 shows scenes during the flight.

Sound of Ikebana under Parabolic Flight

One parabolic flight allowed us to experience weightlessness 10 times. The flight was carried out twice over two days, and the artwork was created 18 times, with only two failures. Therefore, obtaining a video image of 6 positions was possible 18 times. Figure 8 shows one example of how the images changed over time. Color Plate B No. 1 shows an image of a video taken from 6 positions at a particular moment.

We found that the *Sound of Ikebana* generated under weightlessness has the following characteristics compared to the same process conducted under normal gravity.

- Under gravity, the height to which the paint rises is lesser. The paint can reach higher under weightlessness and create more extended shapes.
- Under normal gravity, the paint achieves a certain height, then starts to fall; thus, the resulting shape comprises both rising and falling paint. However, since falling does not occur under weightlessness, the created shape, extending itself more fully, looks more novel and sophisticated.
- A more detailed and scientific comparison of the created forms under weightlessness and normal gravity will be carried out in future work.

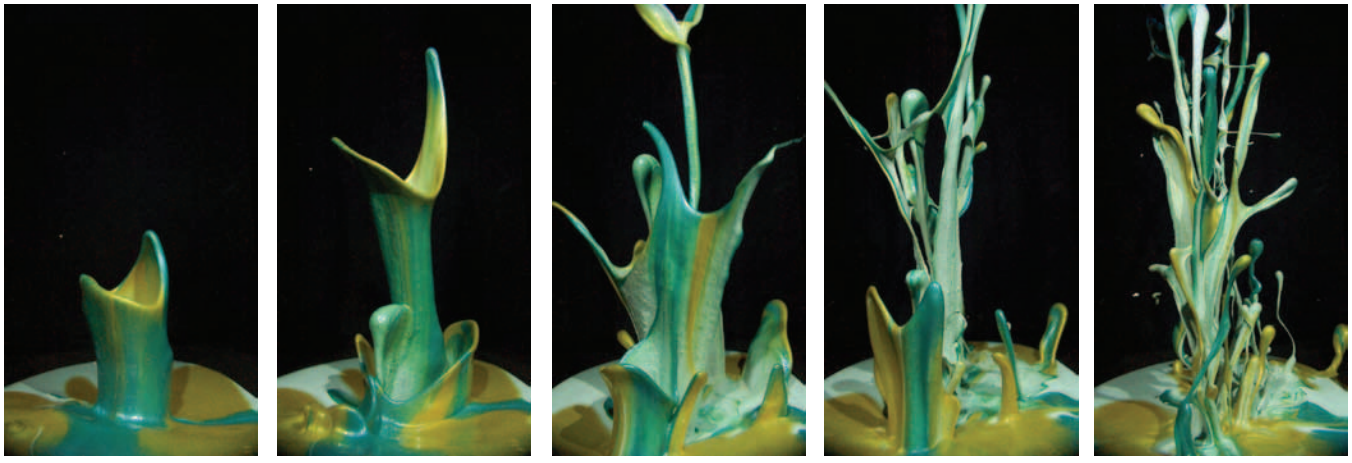

Fig. 8. An example of how the *Sound of Ikebana* changes its shape depending on time. (© Naoko Tosa)

3D Materialization of *Sound of Ikebana* under Weightlessness

Various studies have created a 3D model from images from multiple viewpoints [37]. There is also some commercial software for these purposes. The obtained 3D model makes it possible to generate a 3D object with a 3D printer. An example of the completed *3D Sound of Ikebana* is shown in Color Plate B No. 2. The resulting 3D artwork is still in an early stage. The created form is incomplete, as the multiple high-speed camera units captured only the front side of the 360-degree form. We are now attempting the completion of a 360-degree form using AI [38].

CONCLUSION AND FUTURE PROSPECTS

As space travel becomes more accessible, it is essential to consider new art in this new era. Tosa has created the video work *Sound of Ikebana* based on fluid phenomena. We are investigating what shapes this art would produce under weightlessness.

We introduced parabolic flight to the work process to create weightlessness and conducted experiments led by the artist. We also took on the challenge of rendering the artwork as a 3D object by using multiple high-speed cameras.

We found that the fluid expands dynamically and does not fall under the conditions of weightlessness. As a result, we obtained more sophisticated, beautiful, and organic shapes under weightlessness than ordinary gravity and so obtained new 2D and 3D images to symbolize space travel.

One outstanding problem is that it is very costly and challenging to carry out these trials continuously. We found an alternative solution: fluid art creation in weightlessness using free fall. Although it is difficult and costly to achieve extended weightlessness (10-plus seconds), it is relatively easy to create brief weightlessness (around 0.5 seconds) by developing a simple free-fall system. Fortunately, the *Sound of Ikebana* creation process requires less than one second. We plan to pursue free-fall art creation as a continuation of fluid art creation using parabolic flight [39].

Based on such efforts, we plan to exhibit this new work as 2D and 3D artwork so that people can appreciate its original and organic shapes. Furthermore, we are considering proposing it for the shape of vehicles and architecture in the future. Such new applications will be exhibited at the Osaka World Expo in 2025.

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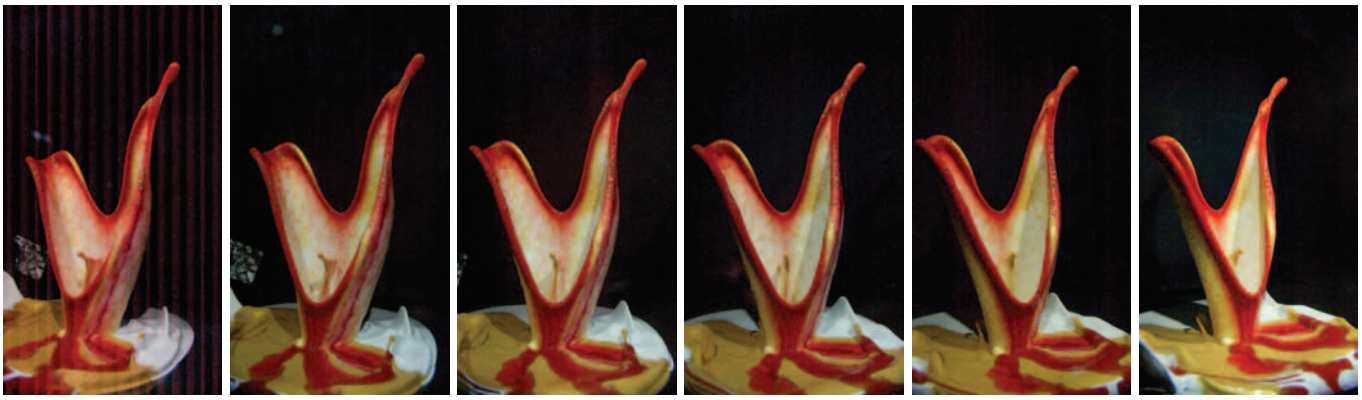
COLOR PLATE B: ***SOUND OF IKEBANA:*** **FLUID ARTWORK CREATED UNDER ZERO-G USING PARABOLIC FLIGHT**



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2D and 3D shapes of the *Sound of Ikebana* generated under weightlessness. (a) An example of images shot from multiple positions. (b) An example of the 3D *Sound of Ikebana* created by using a 3D printer. (© Naoko Tosa) (See the article in this issue by Naoko Tosa, Akihiro Yamada, Yunian Pang, Shigetaka Toba, Azusa Ito, Takashi Suzuki, and Ryohei Nakatsu.)