# floatio : Floating Tangible User Interface Based on Animacy Perception

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**ABSTRACT**
In this study, we propose floatio: a floating tangible user interface that makes it easy to create a perception of animacy (lifelike movement). It has been pointed out that there are three requirements that make animacy more likely to be perceived: interactivity, irregularities, and automatic movement resisting the force of gravity. Based on these requirements, floatio provides a tangible user interface where a polystyrene ball resembling a pixel is suspended in a stream of air where it can be positioned passively by the user, or autonomously by the system itself. To implement floatio, we developed three mechanisms: a floating field mechanism, a pointer input/output mechanism and a hand-over mechanism. We also measured the precision of the pointer input/output and hand-over mechanisms.

**Author Keywords**
Tangible User Interface; Animacy Perception; 3D Interaction;

**ACM Classification Keywords**
H.5.2. User Interfaces.

## INTRODUCTION
Recent studies of tangible user interfaces (TUIs) have shown increasing interest in active or autonomous movement that makes it possible to interact with physical interfaces not only in 2D planes but also in 3D spaces. Typical examples include the ZeroN system, where a ball is suspended in a magnetic field [3], and BitDrones, which uses miniature drones [1]. In TUIs that support autonomous movement, it is particularly easy for humans to feel a sense of animacy (lifelike movement), and it has been pointed out that this can help to attract the user's attention and increase the system's frequency of use [2]. In the field of robotics research, many studies have set out with the intention of designing a system whose movements create a perception of animacy [4]. However, in the TUI field, there are still very few studies where creating a perception of animacy has been the initial intention. Our aim in this study is therefore to implement a TUI that can be moved in three dimensions by users, and is also capable of moving autonomously and has animacy qualities.

Nakayama et al. cited two properties that are required in order to easily convey a sense of animacy: (`Requirement 1`) movements that interact with humans, and (`Requirement 2`) movements including irregular factors that express indecision or fluctuation [4]. Furthermore, Nakamura et al. stated that animacy can be perceived more immediately from automatic movements that resist the force of gravity (`Requirement 3`) [5]. The autonomous floating TUIs mentioned above all satisfy the requirements for conveying animacy in terms of (`Requirement 1`) and (`Requirement 3`). In this study, we focus on the use of a stream of air as a floating technique in order to express indecision or fluctuation (`Requirement 2`). A similar floating technique is used in the Aerial Tunes system [6], where balls appear to dance in mid-air due to instability, and it can be confirmed that this floating motion conveys a sense of animacy. In this study, we implement a TUI that not only exhibits autonomy but also conveys a sense of animacy by satisfying all of the above requirements.

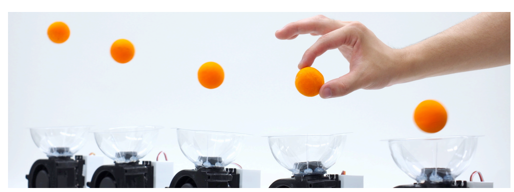
**Figure 1: The proposed system.**

## IMPLEMENTATION

### Overview
In this study, we propose a TUI called "floatio" that produces a display consisting of a ball resembling a pixel suspended in mid air, where the ball can be positioned passively by the user and can also be positioned autonomously by the system itself (Figure 1). To achieve this, we implemented three mechanisms: a floating field formation mechanism, a pointer input/output mechanism, and a hand-over mechanism. Our system is designed to convey a sense of animacy as discussed above by using a floating field formation mechanism to create fluctuations and uncertainty (`Requirement 2`), automatic floating


*UIST'16 Adjunct*, October 16-19, 2016, Tokyo, Japan
ACM 978-1-4503-4531-6/16/10.
http://dx.doi.org/10.1145/2984751.2985699

movements and hand-overs that resist the force of gravity (`Requirement 3`), and interaction via a pointer input/output mechanism (`Requirement 1`).

### Floating field formation mechanism

To enable the ball to be positioned at any height, we implemented a mechanism that performs floating control. To create a floating effect, we used the Coandă effect — the phenomenon whereby a sphere can float stably in a stream of fluid due to the way in which the fluid changes direction as it flows around it. For the basic system configuration, we used PCs, Arduino controllers, a polystyrene ball (diameter ~3.5 cm, weight ~1.2g), and a blower fan (SparkFun Com-11270) with a variable flow rate controlled by pulse width modulation (PWM). Also, by determining the minimum and maximum PWM duty ratios (corresponding to the flow rates when the ball begins to float and when the ball reaches its maximum height) and interpolating linearly between these duty ratios, we determined the duty ratio needed to make the ball float at any height. With several of these fans arranged on a plane, it is possible to form a floating field by expanding the region where floating is possible.

### 3.3 Pointer input/output mechanism

We implemented a pointer input/output function whereby input consists of grasping the ball and changing its position, and whereby the ball continues to float in the same position when it is released. Thus was achieved using a Kinect system in addition to the basic system configuration. The Kinect is used to ascertain the position and shape of the user's hand, and the position of the ball. From this information, it figures out whether or not the user is holding the ball, and if so, the output of the fan directly beneath the ball is updated to match the ball's position. In this way, the ball stays where it is when the user releases it, allowing system to show the finished input position. This makes it possible to perform pointer operations where the input and output are represented by the position to which the ball is moved when the user holds it.

### 3.4 Hand-over mechanism

To move the ball to any fan situated on the plane, we implemented a mechanism for handing over the ball from one fan to another. In addition to the basic system configuration, this is configured from servo motors that change the direction in which the ball is to be passed, and servo motors that tilt the fans forwards and backwards. The hand-over method involves keeping the ball at a height of about 10 cm, and then tilting the fan at an angle of about 70° in the direction in which the ball is to be handed over. This causes the ball to fall onto the neighboring fan situated 19 cm away, and the hand-over is complete. To improve the hand-over success rate, we attached a saucer of 9 cm in diameter around the outlet of each fan. The hand-over mechanism made it possible for the system to move the ball autonomously in three dimensions when the fans are arranged in the form of an array.

## EVALUATION

To clarify the accuracy of the pointer input/output mechanism and hand-over mechanism, we carried out simple experiments to test them individually.

First, we measured the precision during pointer input/output actions (the height error of the ball when controlled by the system, compared with the height of the ball when placed by the user). With the current mechanism, we used a laser rangefinder (Bosch GLM 100C) to measure the height of the ball across the possible output range (0–175 mm) in 14 equal height increments. As shown in Figure 2, the maximum error was about 20 mm. Next, we measured the success rate of the hand-over mechanism. At 4 seconds per hand-over, the success rate was 99%. And at 1.8 seconds per hand-over, the success rate was 90%.

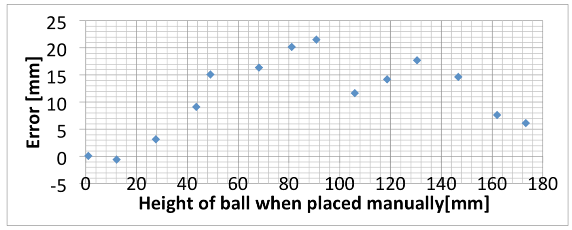


**Figure 2: Positioning error vs. height of ball.**

## APPLICATION

By combining the three mechanisms mentioned above, we implemented an application that operates a slider by making a single ball follow the user (Figure 3). Of the five fans arranged in a row, the ball is handed over to the fan closest to the user's position. This can be operated as a slider by having the user change the height of the ball above the fan. With this implementation, we confirmed that it was possible for the ball to move to the intended position, and for the user to operate the system as a slider.

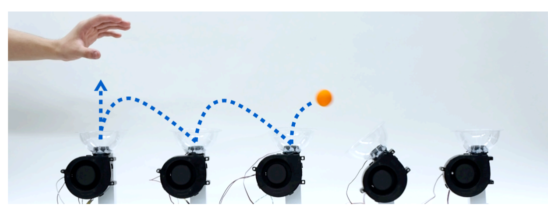

**Figure 3: A slider application that tracks the user.**

## CONCLUSION

We have designed a floating TUI based on the findings relating to animacy perception. We exhibited floatio with a pointer function at the Interaction 2016 event (held at the Science Museum on March 3, 2016) and invited 200 visitors to try it out. They reported that the system was "cute" and "like a living thing", thus showing that animacy was perceived. Many of them were also very interested in the system, and were keen to interact with it.


## ACKNOWLEDGEMENTS

This paper is a part of the outcome of research performed under a Waseda University Grant for Special Research Projects (Project number: 2015A-502).

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