Remote Control Experiment with DisplayBowl and 360-Degree Video

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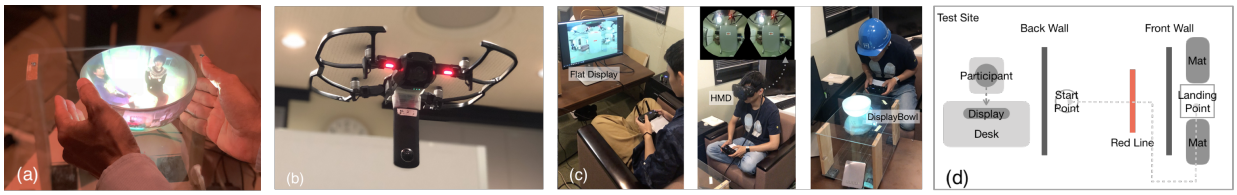

Figure 1: (a) DisplayBowl, (b) Drone with an omnidirectional camera, (c) Displays used in the experiment and subjects, (d) Experiment site

ABSTRACT

DisplayBowl is a bowl-shaped hemispherical display for showing omnidirectional images with direction data. It provides users with a novel way of observing 360-degree video streams, which improves the awareness of the surroundings when operating a remote-controlled vehicle compared to conventional flat displays and HMDs. In this paper, we present a user study, in which we asked participants to control a remote drone using an omnidirectional video streaming, to compare the uniqueness and advantages of three displays: a flat panel display, a head-mounted display and DisplayBowl.

CCS CONCEPTS

• **Human-centered computing** → **Displays and imagers**.

KEYWORDS

Spherical Display; 360-degree video; Drone Manipulation

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1 INTRODUCTION

First-person view (FPV) video is widely used for controlling remote drones or vehicles, such as the Mars Rover. One of the main problems of such remote operation is the narrow-angle of view. Since the field of view of typical cameras is below 100 degrees, a pilot cannot notice objects behind or at the side of the vehicle. This issue is even more serious in the case of multicopters, which have 6 degrees of freedom. Omnidirectional cameras solve these issues to some extent. Since omnidirectional cameras can shoot 360-degrees videos, it is possible to see all directions. The remaining question is how to show the 360-degree videos effectively to the pilot.

There are various works that proposed visualization techniques to solve the problem of Narrow View. Outside-In [Lin et al. 2017] is a visualization technique that shows panels which display important parts outside of the field of view. Chang et al. [Chang and Cohen 2017] address the narrow view problem using a close-up technique with an HMD. They zoom the center part of the field of view while displaying other parts in normal size.

There are also studies providing pilots with realistic sensations and further information on the image obtained from the omnidirectional camera mounted on the drone or telepresence robot. ScalableBody [Matsuda et al. 2017] and Heshmat et al. [Heshmat et al. 2018] conducted research on telepresence robots with omnidirectional cameras attached. Since their displays only show the FPV, it is not possible for a controller of a telepresence robot to notice events behind the robot and understand their direction of origin.

As a solution, we proposed a bowl-shaped display that can visualize an image on both the inside and outside of the hemispherical concave surface by projecting the image on a white translucent surface, as shown in Figure 1(a)[Miyafuji et al. 2018]. Figure 2 shows an example scenario of drone operation. An omnidirectional image is mapped onto a bowl-shaped display. This display provides a pseudo–Third-PersonView when it is observed from above diagonally. The display is also capable of providing a top-down view when it is observed from above. This way, it enables a remote pilot to observe the surroundings of the drone, while controlling it.

In this paper, we conducted a preliminary experiment, comparing a flat panel display, an HMD, and the proposed DisplayBowl. We then discussed the advantages and disadvantages of DisplayBowl.

2 PRELIMINARY STUDY

We conducted a within-subject user study to assess the usability of the proposed DisplayBowl for remote drone operation using an omnidirectional camera. An important issue regarding remote control is how quickly and accurately a user can check the surroundings

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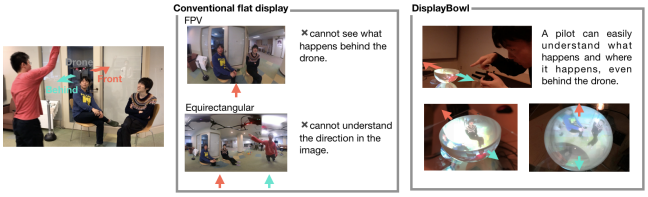

Figure 2: An example scenario of drone manipulation.

of the remote vehicle. Our experiment aims to see how well each display can address this issue. We prepared the test site as shown in Figure 1(d), and designed the task to operate a drone by remote control while relying only on the image on the display.

360-Degree Video Streaming: Figure 1(b) shows the drone (DJI Mavic Air) equipped with an omnidirectional camera (RICOH Theta S). The subjects observe the streaming video from this camera to operate the drone remotely. We use the THETA API to stream the video in real-time. The delay of the stream is 300 ms, the frame rate is about 5 fps and the image size is 320×640 pixels.

Displays: We prepared three displays to show the omnidirectional image as shown in Figure 1(c). The left image of Figure 1(c) shows the flat panel display (DELL 24 inch) with the omnidirectional image displayed in an equirectangular shape. The center of the display shows the front view from the drone. The middle image of Figure 1(c) shows an HMD, which is used as a normal FPV display. The right image of Figure 1(c) shows our DisplayBowl, which represents the third condition.

Subjects: We recruited people who have experience in operating a drone. Since operation methods are different depending on the drone type, we asked them to take a lecture on how to control the drone and to operate it more than 30 minutes before the study. We had 12 subjects with an average age of 23.7 ($\sigma = 1.75$).

Task: We designed a task that required the users to control the drone along a given path while avoiding an obstacle (Figure 1(d)). First, subjects were given an introduction to the experiment and three minutes to practice operating the drone at the test site. Then we asked them to complete the following procedure: (1) Take off and go forward to the red line; (2) Check the arrow on the back wall; (3) Move to the direction of the arrow to avoid the front wall. (4) Land at the landing point. The order of displays used in the task and the directions of the arrow were counterbalanced. During the test procedure, subjects were only allowed to use the display for observing the drone. After the experiment, we interviewed the subjects following semi-structured guide.

3 INTERVIEW RESULT AND DISCUSSION

In the interview, most subjects answered that they preferred the HMD over the flat panel display for remote control since HMD is more intuitive when looking around. However, this advantage cannot solve the problem that an operator of a drone fails to notice what is happening behind the drone. Also, some subjects said that they had troubles identifying the front side again of moving their head. The advantage of DisplayBowl is that users can see both front and back side at the same time, which helps to overcome these problems.

Figure 3 shows the advantage of the different displays based on interview results. DisplayBowl lacks visual intuitiveness mainly

	Direction Cognition	Surroundings Cognition	Visual Intuitiveness
DispalyBowl	O	O	-
Flat Panel Display	-	O	-
HMD	O	-	O

Figure 3: Comparison of the three displays. The ordinate denotes each display and the abscissa represents the factors of advantages. 'o' indicates the display has the advantage.

because of its small size and low resolution. The size of DisplayBowl is small and the resolution of projection low, since we use small projectors to project onto the entire surface of a DisplayBowl. We expect that these issues can be addressed in the future by using double-sided and curveable displays. Another option is to create a bowl-shaped display inside VR.

Besides multicopter control, our system can also be used for remote-controlling wheeled vehicles, such as cars or wheelchairs. Telewheelchair [Hashizume et al. 2018] proposed a remote-control system for a wheelchair with an omnidirectional camera. DisplayBowl could help to control the wheelchair while maintaining a perfect vision of the entire surrounding.

4 CONCLUSION

We conducted a comparative experiment with a flat panel display, an HMD, and DisplayBowl in a remote control scenario. From the user study, we learned about the advantages and disadvantages of the different display types. The study showed that DisplayBowl allows users to observe an omnidirectional image by overlooking the image from the side. This solves the inability of pilots to notice what happens behind them when relying on FPV. We believe the concept of the bowl-shaped display will change the method for remote manipulation of vehicles and ensure their safe operation in the future.

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