INTUITIVE OPERATION OF DRONES USING NEWLY DEVELOPED THREE-DIMENSIONAL INPUT DEVICE

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ABSTRACT
Based on improvements to our 2003 prototype of a suitable input device for VR space, we used a newly developed device called Cyberbird for drone operation. This study evaluated Cyberbird's learnability for drone operation in an experiment that determined its optimal operation method among four designs.

1. INTRODUCTION

As an input device suitable for VR spaces, we developed a prototype of a new device in 2003. Comparison experiment results with other input devices (including game controllers) showed that our prototype had learnability and memorability advantages (Ohkura, et al., 2004). Next the device, which was named Cyberbird (Mochiyoshi Engineering Development Co., Ltd., 2013), was improved and placed on the market.

Drones, which began to spread recent years, are used for rescue operations from advantages without spatial restrictions. They are also used for entertainment. In fact, the Drone Race was held at California in 2015 (Ground Flight, Inc., 2015), and a Bebop Drone (Parrot, Parrot Bebop Drone, 2016) was developed to be used with Oculus Rift. However, when operators control the drones that are currently available on the market, their controllers must be grasped with both hands and operators must be trained to control them.

We address this training requirement with Cyberbird. Since we believe that it provides intuitive drone operation because it was developed as a device for intuitive operation in VR space, this study evaluated its learnability for drone operation.

Generally, there are four movements for flying drones: pitch, roll, throttle, and yaw. On the other hand, Cyberbird has three movements of an analog stick and two buttons. Since drone operation is impossible by just using an analog stick, we examined drone operation methods using Cyberbird to find the best combination of drone movements and Cyberbird operations. Here, we describe our experimentally attempt to determine the best combination of drone movements and Cyberbird operations.

2. OPERATION METHODS OF CYBERBIRD

Figure 1 shows how to hold Cyberbird. The operator's thumb is placed on the analog stick, and both of her pointer and middle fingers are on specific buttons. Operators can control drones with these analog sticks and buttons.

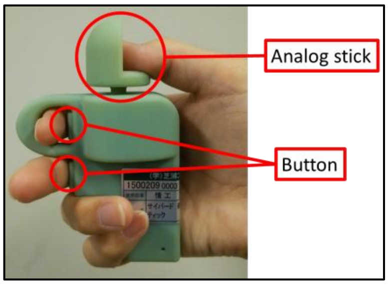

Fig. 1 Holding Cyberbird

A drone has four flight control inputs: pitch, roll, yaw, and throttle (Fig. 2). The pitch input is the horizontally front and back movement parameters, and the roll is the horizontally left and right movement parameters. The yaw turns the drone left or right. The throttle moves it up or down.

First, we designed operation methods 1 and 2. Their differences are shown in Fig. 3. In operation method 1, when the operator turns the analog stick left or right, the drone moves horizontally left or right. When the operator pushes the buttons, the drone turns left or right. In operation method 2, when the operator turns the analog stick, the drone rotates. When the operator pushes the button, it moves horizontally.

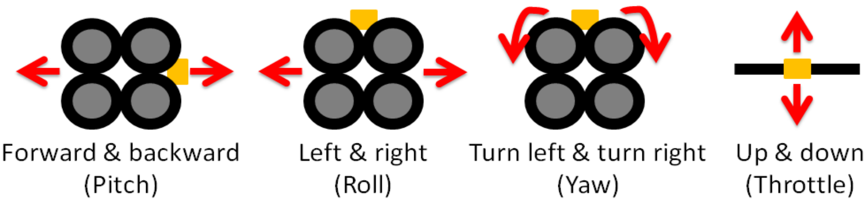

Fig. 2 Drone flight movements

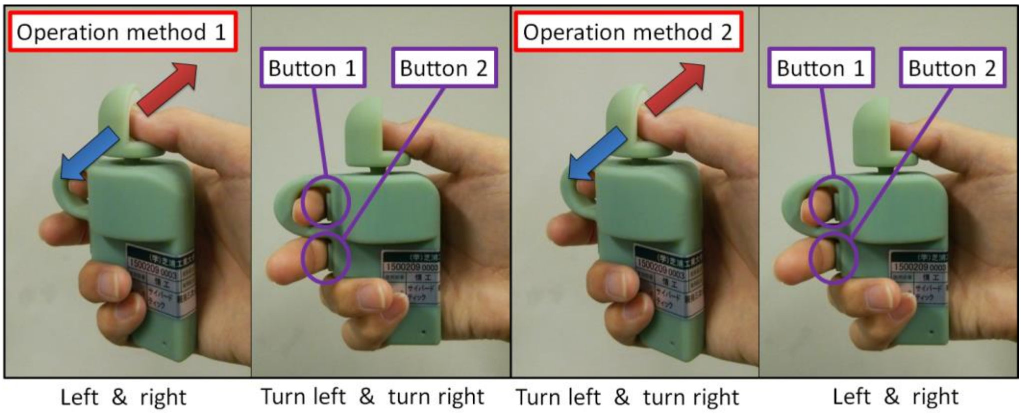

Fig. 3 Differences of operation methods 1 and 2

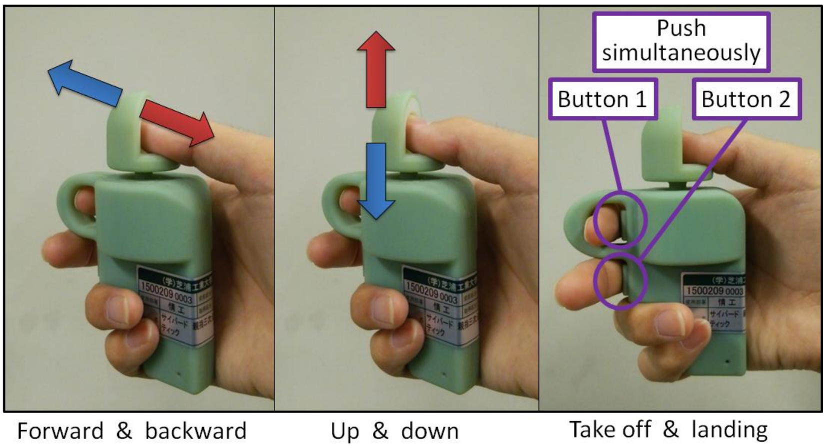

Fig. 4 Common operation in all methods

We designed operation methods (a) and (b). For example, in operation method 1(a), if the operator pushes button 1, the drone turns left, and it turns right when button 1 is quickly pushed twice. In operation method 1(b), when the operator pushes button 1, the drone turns left, and it turns right when button 2 is pushed. We designed four operation methods: 1(a), 1(b), 2(a), and 2(b). Their common operation ways are shown in Fig. 4.

3. EVALUATION EXPERIMENT

3.1 Experimental System Configuration

Our system's diagram is shown in Fig. 5. The drone we used is the AR.Drone 2.0 (Parrot, AR.Drone 2.0. Parrot new wi-fi quadricopter, 2015). The PC is connected to Cyberbird by a USB and to the AR.Drone 2.0 by Wi-Fi. The AR.Drone 2.0 has a front camera and underneath cameras; we used the front camera whose images appeared on the PC. The operator manipulates the drone using Cyberbird while looking at the image on the PC. The system sends control commands to the AR.Drone 2.0 based on input from Cyberbird. The library we used for controlling the drone is ARDroneForP5 (Engineering Navi, 2011).

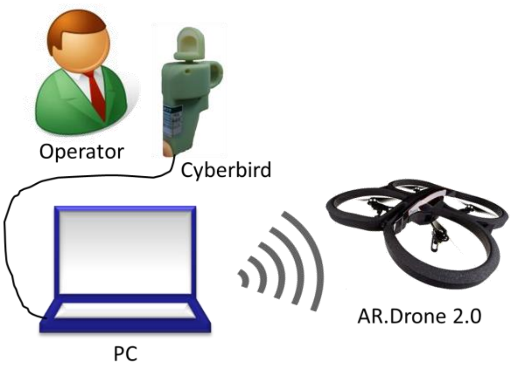

Fig. 5 System diagram

3.2 Experimental Content

The operator sequentially captured four markers using the drone camera. Fig. 6 shows the numbered markers targeted on a pole extending to the ceiling. The height of each marker was between 70 to 200 cm, and the markers shown in Fig. 6 were used for both operation methods. The operator also confirmed the position of the markers before starting the capture operation.

First, the operator controls the take-off the drone from about 2.1 meters away. A few seconds later, the operator starts to capture the markers. In the normal state, the image from the drone's inner camera with the black square is shown on the PC (Fig. 7). When the marker is in the black square and the drone is in the marker's range, a green box is displayed on the marker (Fig. 7). This is the successful-capture state. After the operator successfully captures the marker, he starts to capture the next marker. After capturing the fourth marker, he lands the drone. This experiment's content is based on Higuchi & Rekimoto, 2013.

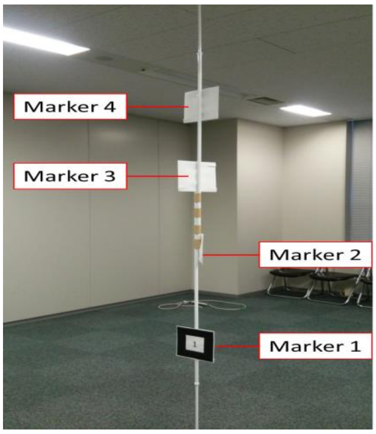

Fig. 6 Marker positions and orientations

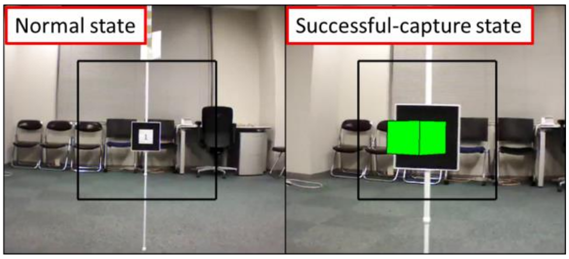

Fig. 7 Capturing markers

3.2 Evaluation Method

An example of our experimental procedure is shown in Fig. 8. We divided our experiment into parts 1 and 2. At the end of part 1, the participants answered questionnaire 1. After finishing part 2, they answered questionnaire 2. Table 1 shows the items of questionnaire 1. We also changed the combination of operation methods in each part for every participant. In questionnaire 2, participants explained which operation method they preferred and explained why.

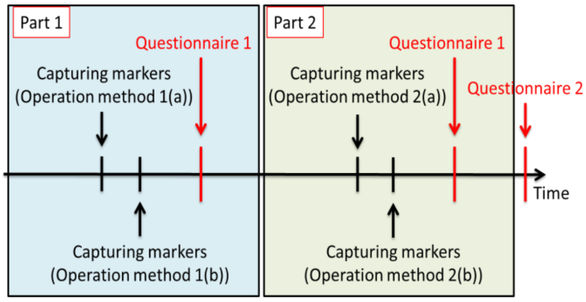

Fig. 8 Experimental procedure

Table 1 Items for questionnaire 1

Number	Question
Q1	Which operation method was easier to understand?
Q2	Which operation method was simpler to use?
Q3	Which operation method did you operate most confidently?

3.3 Experimental Result

Our participants were 12 male students of the Shibaura Institute of Technology in their 20s. Fig. 9 shows the results of questionnaire 1. Operation method 1(b) showed the best score among the four methods because it is more intuitive to operate rolling with an analog stick than with buttons. It is also easier to assess left or right using both buttons 1 and 2.

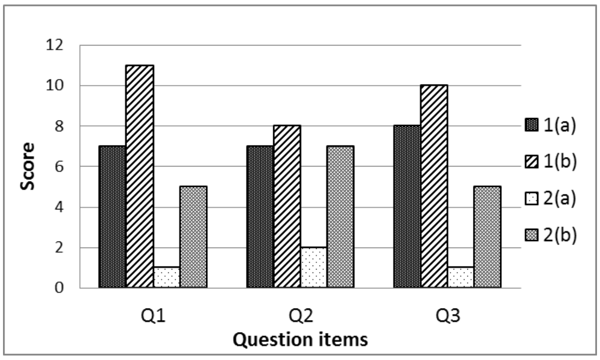

Fig. 9 Questionnaire 1 result

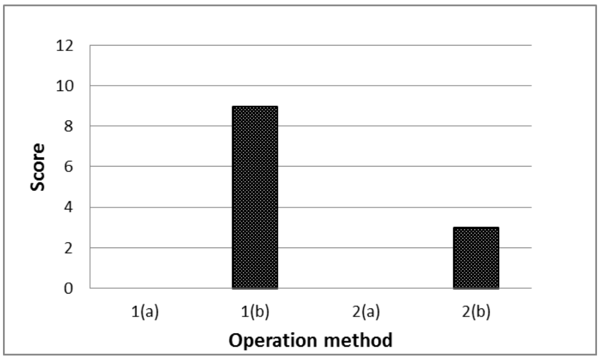

Fig. 10 Questionnaire 2 result

The questionnaire 2 result is shown in Fig. 10. All participants chose either operation methods 1(b) or 2(b). 9 of 12 chose 1(b). Operation method 1(b) has more general versatility than operation method 2(b).

From the results of questionnaires 1 and 2, we chose operation method 1(b) as the best combination of drone movements and Cyberbird operations. In operation method 1(b), when the operator turns the analog stick left or right, the drone moves horizontally left or right. When the operator turns the analog stick forward or backward, the drone moves horizontally forward or backward. When the operator moves the analog stick upward or downward, the drone moves horizontally upward or downward. Also if the operator pushes button 1, the drone turns left, and it turns right when button 2 is pushed. And if the operator pushes button 1 and 2 simultaneously, the drone takes off or lands.

CONCLUSION

Based on improvements to our prototype developed in 2003 as an input device suitable for VR space, we decided to evaluate its intuitive operability for operating a drone. However, first we must identify the best combination of drone movements and Cyberbird operations. Therefore, we experimented with our four operation methods to determine the optimal method. From our experiment results, we adopted operation method 1(b). In the future, we will evaluate the intuitive operability of Cyberbird with other devices, including game controllers.

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