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English ⅢB

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1. Introduction

When using a drone, it is sometimes required to control the drone to move it and operate the camera at the same time. In many cases, drone operation and camera operation are both performed with a hand-held controller, but when input is concentrated in the hand, there is a problem of confusion between drone operation and control. In aerial photography by a drone, it is difficult to control the drone and operate the camera at the same time, making it difficult to perform aerial photography with free camera work. To solve this problem, there are products in which drone operation and camera operation are shared by two operators, and they are used for aerial photography. However, it is not easy for two operators to work together when they need to work in a highly coordinated manner. Therefore, a drone UI that allows one operator to perform aerial photography with free camera work without confusing drone operation and camera operation is desirable. The objective of this research is to enable a single operator to perform free camera work for aerial photography without confusing drone operation and camera operation. We propose a method in which the operator uses his or her hands and feet to control the drone and operate the camera, respectively, using different interfaces. In this paper, we propose a system in which the feet control the drone, and the hands operate the camera. As a prototype of the system, we developed an interface in which the drone is controlled by the force of foot extension and the camera is operated with a camera-type device held in the hand in a virtual space. As a result of user studies using the prototype, it became clear that participants could control the drone as they wished without confusing the drone control by foot and the camera control by hand. In addition, it was observed that the participants became accustomed to drone operation in about 10 minutes, indicating that the UI is highly intuitive.

2. Foot Controller

The mapping between the inputs to the prototype and the virtual drone operation is shown below. Forward movement: Sum of tension by both toes Backward movement: Sum of tension by both heels Rightward movement: Sum of tension by left toe and heel Leftward movement: Sum of tension by right toe and heel Rise: Sum of tension by both toes and heel Falling: Sum of tension by both toes and heel Right rotation: Sum of tension by left toe and right heel For ascending and descending, the foot rises when the tension applied to the toes and heels of both feet is positive, and descends when the tension is negative. The above mapping is the default setting, and the setting in which the mapping of right-rotation and left-rotation is reversed is the inverted setting. The user can select either one according to his/her preference.

3. Hand Controller

The orientation of the camera mounted on the drone is controlled by the orientation of the camera-type device. The camera mounted on the drone is controlled by the orientation of the camera-type device. The lens part is rotated clockwise to zoom in and counterclockwise to zoom out when viewed from the user's perspective.

4. User Study

A user study was conducted to examine whether a prototype of the proposed system can be used to control a drone and a camera without confusion. In the user study, the drone and camera were controlled in a virtual space generated by Unity.

4.1 Participants

The participants were six university students (three males and three females, mean age 21.2 years). Three of the six participants had experience flying drones or drone simulators, and all had experience using HMDs.

4.2 Evaluation

A questionnaire regarding the controllability of the prototype and a questionnaire regarding VR sickness were conducted. The controllability questionnaire consisted of six questions about drone maneuvering, camera operation, maneuvering and operation errors. The Simulator Sickness Questionnaire (SSQ) was used as the VR sickness questionnaire, and participants were asked to answer the questions before and after the task to check for changes in sickness, and the results were compared.

4.3 Tasks

A task was created to examine whether the prototype could operate a camera while piloting a virtual drone. A dragon was placed in the virtual space. The dragon flew straight toward the target location, which was randomly determined within an area of 250 × 250 × 250 units (1 unit = 1 m in Unity). After reaching the target point, it remained stationary for 2 to 3 seconds to prevent participants from being unable to catch up with it. The next target point was then determined at random from within the range. The participants filmed the dragon for 10 minutes as it continued to repeat the above process. When filming, participants were asked to capture the dragon in the center of the camera's angle of view as much as possible.

4.4 Procedure

The participants sat in the chair of the prototype of the proposed system and performed the task wearing the HMD. Before starting the task, the participants put a board on their feet with their legs naturally extended, so that they could apply force to the cord by extending their legs. Next, they answered the SSQ. After answering the SSQs, the participants received explanations on how to control the drone and operate the camera. After that, the drone control interface was calibrated using the feet, and sufficient practice was conducted. During the practice session, the participants experienced both the default and inverted settings for the left-right rotation input and chose which one they preferred. After completing the task, participants answered the SSQ, followed by a questionnaire about the controllability of the prototype.

5. Results and Discussion

From the results of the user study using the prototype, it is clear that the proposed system allows users to operate the drone as they wish without confusing drone operation and camera operation. In addition, it was shown that the proposed system may not increase the nausea items in VR sickness.

5.1 Drone operation and camera operation

The participants highly evaluated the proposed system for both drone operation and camera operation in terms of two indices: ease of use and ability to move the drone as desired. The participants were able to become accustomed to drone operation within 10 minutes after starting to practice. These results indicate that the proposed system has the potential to be a highly operable and intuitive interface. In addition, the low response rate for confusion between drone operation and camera operation indicates that users are unlikely to confuse drone operation with camera operation. This may be due to the fact that the interface was divided into hand and foot interfaces. In the free response questionnaire, there was a response that the user can concentrate on the camera operation. This indicates that the proposed system has the potential to enable more detailed camera operations. This is expected to enable aerial photography with free camera work, which has been difficult with conventional drones. The results showed that the drone control interface by foot has a possibility of high operability. This suggests the possibility of applications such as controlling a drone with the feet, operating a robot arm with the hands, and using various tools remotely.

5.2 VR sickness

The fact that the score did not increase in the nausea item of the SSQ indicated the possibility that the interface does not increase sickness. It is possible that the camera display shown in the virtual space functioned as a gazing point and reduced sickness. In addition, the virtual space used for the task was an environment with few objects, and the optical flow was small, which may also have had an effect. On the other hand, since the scores increased for the items other than nausea, it became clear that intoxication could not be eliminated.

6. Limitations and Prospects

In this paper, only a task in a virtual space was conducted, so it is not clear whether the findings of this paper can be applied to an actual drone. In the future, we plan to study the effectiveness of the proposed system using actual drones. In addition, since we have not conducted comparative experiments between the proposed system and existing systems, the usefulness of the proposed system has not been quantitatively evaluated. In the future, we plan to conduct quantitative evaluation and comparison experiments on operability and intuitiveness.

7. Conclusion

In this paper, we developed a prototype of a system in which a drone is steered by the force of foot extension and a camera is operated by a camera-type device held in the hand. As a result of a user study using the prototype, it became clear that the drone pilot could operate the camera as he or she wished without confusing the drone operation with the camera operation. The participants became accustomed to the drone operation in about 10 minutes, indicating that the proposed system is an intuitive and easy-to-operate interface. Based on the above, we believe that the proposed system will allow a single operator to operate the drone and the camera as desired without confusion. In addition, since the operator can concentrate on camera operation, it will be possible to perform aerial photography with free camera work, which is difficult with ordinary drones.

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