FloatingPad: A Touchpad Based 3D Input Device

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Abstract

In this paper, we present FloatingPad, a touchpad-based input interface for mobile devices for the navigation and the object manipulation in the 3D environment. Many input interfaces for the 3D environment have been proposed, however, most of them were too big to put in mobile devices. We have focused on a touchpad, a popular input interface for laptops, and tried to augment inputs for 3D interaction while keeping its form factor. FloatingPad looks quite similar to a typical touchpad on a laptop computer, but it has higher degree of freedom. Not only can users perform only traditional touchpad actions, but they can also slide, rotate, and tilt the touchpad by exerting force on it. We assigned new actions to yaw, pitch, and roll. Since FloatingPad's translations of yaw, pitch, roll are greatly intuitive, even novice users can naturally navigate the 3D worlds with FloatingPad. Hereby we show our FloatingPad concept, its hardware design, the software developed for the evaluation, results of the evaluation, and our findings from the study.

1. Introduction

With the increase in the computing power, even the small mobile devices like cell phones are capable of the 3D graphics. Mobile devices are rather small than non-mobile devices, and they are often packed in a bag, moved to other places, unfolded in a small, sometimes unstable space. Considering those characteristics of use of the mobile devices, it is clear that we need different input interfaces for them.

The touchpad has good characteristics to be used for mobile devices. It is thin and flat, so it does not need a big space. It is embedded on the device, so users do not have to set up/place or pack/unpack to use it. It is also stable in posture since users can rest their hands by leaning on the device. However, it lacks of the ability to deal with the 3D environment from the root because it is a 2D interface.

We imagined a flat board floating on the elastic material. The flat board which is a touchpad can be slid, rotated, and tilt by the force. It is a touchpad that is not strictly fixed on the device, but is more flexible and elastic to the device. The touchpad on the elastic material can be tilt, rotated The pad itself is a touchpad, but if a user exerts more force, it could be slid. The user also can rotate the pad by twisting his/her fingers or can tilt it by pushing the edges of it. In their behavior, these actions are very similar to the common 3D movements; Yaw, pitch, roll. As you see in the figure 1, we assigned rotating to yawing and tiling to pitching, rolling.

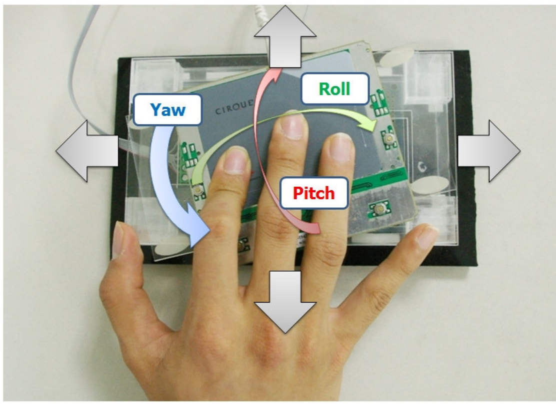

Figure 1. FloatingPad Prototype

The current prototype of FloatingPad consumes more space than the traditional touchpads due to the size of the potentiometer. However, by changing the potentiometer to the smaller one, the size of the FloatingPad can be reduced and can be embedded to the portable/mobile devices with the similar form factor to a traditional touchpad.

In this paper, we will describe the FloatingPad implementation, the demo software, and the evaluation we did.

2. Related Work

There have been many researches on the input devices to enhance the interaction with the 3D environment. Hachet et al.[7] presented a classical circular table sized freestanding input device that has both 2D and the 3D interaction. It provides the 3D interaction with six degree of freedom and 2D interaction by using the pen tablet. Fröhlich and Plate

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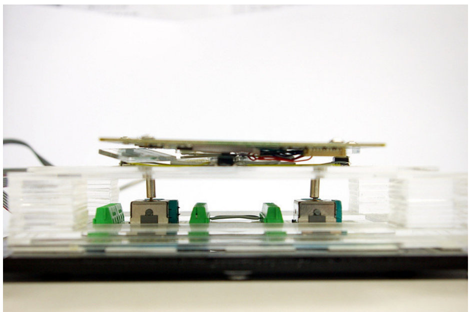
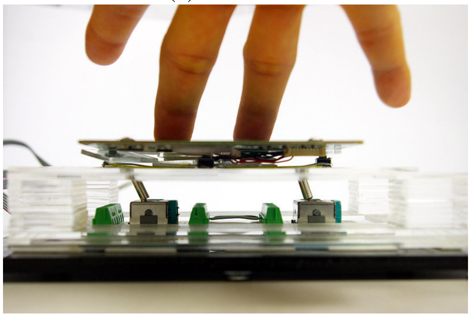
[5] presented a cube shaped 3D input device. It is a hand-held device that has a six degree of freedom tracker and three rods and six buttons for navigation and object manipulation. Geiger [6] suggested TubeMouse which is a tube shaped two-handed input device with optical markers and input buttons. Interactions are performed by moving and bending the device. Casiez [3] suggested a 3D input device called DigiHaptic which can provide three degree input and haptic feedback and found that separating degree of freedom increases the control accuracy. Fröhlich et al.[4] developed two six degree of freedom input devices using the trackball and compared it with the SpaceMouse with a 3D docking task experiment.

There were trials to modify the general pointing device for 3D input. Balakrishnan et al. [1] presented a mouse based novel device for 3D manipulation. They made the bottom of the mouse round to enable the tilting. By tilting the mouse, users can have both 2D and 3D interaction. Balakrishnan and Patel[2] introduced a mouse with a touch pad attached on it. It has four degree of freedom, two degree of freedom from the mouse movement and two from the touchpad.



(a) Side view



(b) Slide left

Figure 2. Movement of the Potentiometer by the user's operation

3. FloatingPad Prototype

FloatingPad consists of three main parts - the upper, lower, and controller parts.

The upper part consists of the commercial touchpad and four buttons. As we mentioned before, our goal is to provide a user with more intuitive and effective 3D interaction by moving the touchpad itself. To archive this goal, the upper part is designed to move based on the users hand actions.

The lower part detects the movement of the upper part. To track the movement of the upper part, the lower part has two joystick-typed potentiometers and the upper part has two holes at the bottom which are fit to the tips of the potentiometers. Figure 2 shows the side view of the FloatingPad and the movement of the potentiometers.

The rotation of the upper part for the y-axis can be obtained from the movement of the z-axis of the upper part which is derived from the measured values of the potentiometers of the lower part. When the user rotates the upper part for y-axis, the two potentiometers of the lower part move to different directions.

For example, if a user rotate the upper part to the right, the potentiometer of the left moves to the upward but the potentiometer of the right moves to the downward. Based on this difference between the z-axis values, the rotation value for y-axis can be derived. Other rotations like x- or z-axis can be collected with the buttons of the upper part. When the user pushes the top, bottom, left or right side of the upper part to rotate, the buttons of the upper part turn on. It is simple binary actions, but still can obtain the rotation of the x- and z-axis.

The lower part and the upper part are connected to the controller part. The controller part uses PIC16F73 microprocessor to process the signals from the device, and this part sends processed data to the computer via RS232 serial communication.

To evaluate the three-dimensional interactivity of the FloatingPad, we developed a navigation and object manipulation applications which can be controlled in three dimensionally.

4. Experiments

4.1. Experiment 1: Navigation Task

The navigation environment needs two main components: transformation of the view and reference 3D objects. In our navigation application, the transformation of the view is controlled by FloatingPad. We mapped the horizontal translation of the upper part to the translation of the view in the XZ plane and the rotation of FloatingPad to the rotation of the view. Figure 3 shows the navigation environment. The environment consists of two different reference objects: XZ plane and the pillar-shaped objects. The XZ plane is a horizontal plate positioned below of the view in y-axis. There are 16 pillar-shaped objects and they stand 10m apart about x- and zaxis. All of the pillar-shaped objects are placed on the XZ plane.

Based on the implemented virtual 3D environment, we arranged a navigation task to evaluate the interactivity of

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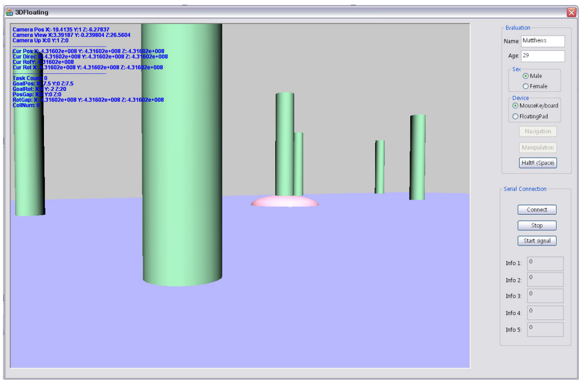

Figure 3. FloatingPad Evaluation Program: Navigation Task

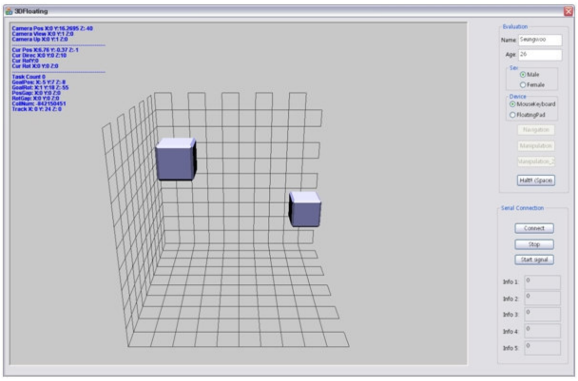

Figure 4. FloatingPad Evaluation Program: 3D Docking Task

the FloatingPad. The task is simple: reach the goal pillar without touching other pillars as fast as you can.

In the virtual 3D environment, the goal pillar-shaped object was highlighted with a small red sphere. The goal pillar-shaped object was randomly chosen among the 16 pillar-shaped objects, and the start position of the view was always same position where all the pillar-shaped objects can be seen. The distance between start position and goal pillar-shaped object could be different among the tasks, so the application keeps the total amount of the distance for each ten tasks to be equal.

In the evaluation procedure, we compared the performance of FloatingPad and keyboard/mouse combination. For the control of the keyboard/mouse combination, we adopted universal controlling method: W,A,S andD for translation and mouse movement for rotation.

There were five subjects, four men and one woman, who have no deficiency in 3D object perception and manipulation. Every subject performed the task ten times with FloatingPad and keyboard/mouse combination. Before start the tasks, all subjects had training time for each devices.

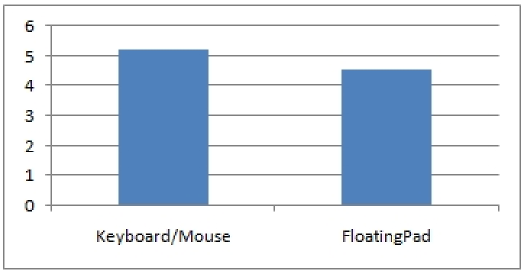

Figure 5. Elapsed Time for Navigation Task

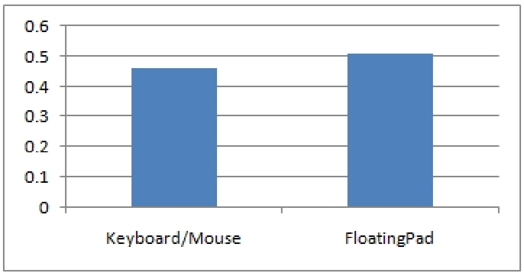

Figure 6. Collided Number of Time for Navigation Task

4.2. Experiment 2: 3D Docking Task

To evaluate the 3D manipulation performance of the FloatingPad, we arranged a simple 3D environment with two box-shaped objects and reference grid. Figure 4 shows the 3D environment for the 3D docking task. The 3D docking task a little differs from the navigation task since it needs both of the 3D interaction and 2D interaction. To complete the task, a user has to move the controllable object to the position of the goal object. The user can rotate the view of the camera by controlling FloatingPad, and move the controllable object by touching the touchpad which is placed on the FloatingPad. The distance between the start position of the controllable object and the goal object was controlled to keep certain amount of distance. To evaluate the task performance, keyboard and touchpad combination was applied as a comparison pair. The common W, A, S and D was adopted to rotate the view of the camera. The subjects who performed the former task were also performed the manipulation task. Every subject performed the task ten times with FloatingPad and keyboard and touchpad combination. Before start the tasks, all subjects had training time for each devices.

5. Results

5.1. Results from Navigation Task

We collected the elapsed time as the efficiency of the FloatingPad and collided number of time as the accuracy. Figure 5 and figure 6 show the average values of the elapsed time and the collided number of time. While the Float-

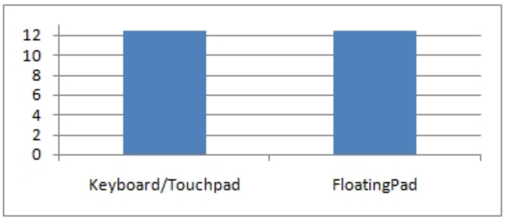

Figure 7. Elapsed Time for 3D Docking Task

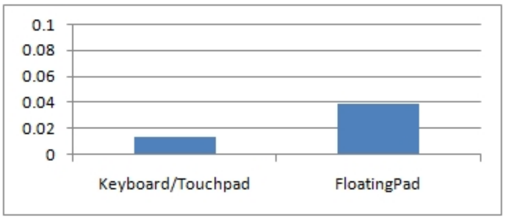

Figure 8. Mean Error Distance for 3D Docking Task

ingPad shows better result about the elapsed time, keyboard/mouse combination shows better result about collided number of time.

At the early stage of the experiment, we assume that the FloatingPad will overcome the keyboard/mouse combination at efficiency and accuracy. However, the results show that our hypothesis was corrected only about the efficiency. We assume that these results were caused by the subjects who are very skilled at keyboard/mouse control. Especially, those who are familiar with First Person Shooting game showed a proficient performance using keyboard/mouse. In this point of view, we can assume that the performance about accuracy could be enhanced if a user got used to the FloatingPad.

5.2. Results from 3D Docking Task

For the 3D docking task, we measured the elapsed time and the error rate with the FloatingPad and the keyboard and touchpad combination. Figure 7 and figure 8 show the average values of the elapsed time to complete the task and the distance from the controllerable object to the goal object. There was no significant difference in completion time between the FloatingPad and the keyboard and touchpad combination and keyboard and touchpad combination had lower error distance value.

After the experiment, subjects were asked to answer the questionnaires. Subjects answered that the FloatingPad is more intuitive than the keyboard and touchpad combination. Four of the six subjects answered that they would use FloatingPad rather than the keyboard/touchpad interface for the 3D docking task. One of the participants reported that using the touchpad for both 3D camera rotation and the 2D object manipulation caused a problem when the finger slips on the touchpad.

6. Conclusion and Future Work

In this paper,we introduced FloatingPad, a touch pad based 3D input device using floating metaphor, suitable for mobile devices. We also developed software to evaluate the interactivity and usability of FloatingPad.

The experimental results showed that FloatingPad outperforms the keyboard/mouse combination for the navigation task on the aspects of the efficiency. Based on comments of the subjects, we found that the FloatingPad is more intuitive than the keyboard/touchpad combination for the 3D docking task. We also found that problems can occur with the FloatingPad when the finger slips on the touchpad.

In the future, we are planning to adopt the floating metaphor into mobile devices like a mobile phones with touch screens.

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