Development of a Flexible 3D Pointing Device with Haptic Feedback

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***Abstract*—With the increasing trend toward diversification of display devices, the development of displays with curved, folded, or spherical surfaces, has become popular in recent years. At the same time, a new Three-Dimensional (3D) pointing device is required to provide effective user interaction for 3D displays. This study attempts to develop a new 3D pointing device with an Inertial Measurement Unit (IMU) sensor, a flexible mechanism, and haptic feedback. For the haptic, we adopt both active and passive haptic feedback. Here, we perform experiments with the prototyped device to verify the effects of the flexible mechanism and haptic on 3D pointing. Experiments confirmed that the haptic has a significant impact on 3D pointing, enabling more accurate input operations. However, the flexible mechanism was not significantly assisting the adjustment of the input to the depth.**

Keywords-haptic feedback; flexible interface; stylush pen; IMU.

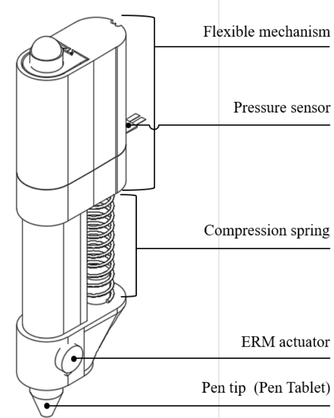

Figure 1. The configuration of the 3D pointing device in this study.

I. INTRODUCTION

The use of virtual contents has become common in recent years, regardless of the field or application, such as entertainment, industry, and education. With the increase in the variety of displays, the interaction with virtual contents is becoming more extensive. Augmented Reality (AR) contents that can be viewed with commonly used mobile terminals, AR glasses, and head-mount displays are attracting attention. These devices have dedicated controllers with motion tracking capabilities and hand tracking that enable users to input operations intuitively without losing the sense of reality of the contents.

In addition to AR devices, multi-view 3D displays are also being developed. These displays create the illusion of 3D content as if it exists in real space. Looking Glass [1] is the first personal holographic flat display that allows 3D content to be viewed at an effective viewing angle of approximately 40-50°. The spherical display [2] uses motion parallax to project 3D images onto the 360° surface of the sphere and renders the images according to the viewing direction to achieve the same effect as the Looking Glass. Unlike AR devices, the surface of these displays can be touched directly, allowing for the adoption of input methods, such as touch and pointing interfaces.

For the input interface of a multi-view 3D display, the use of existing mouse and touch interfaces in its original form is not intuitive. This is due to the limited information that can be input by these input interfaces, which is limited to Two-Dimensional (2D) information, making it difficult to manipulate the contents in depth. Although the 3D pointing device proposed by Prima et al. (2020) was developed for 3D spherical displays, it is difficult for users to sense how much input they are making when performing 3D pointing to depth [3]. Therefore, a mechanism to enable input to the depth is necessary for this pointing device.

This study aims to develop and evaluate a stylus-type 3D pointing device with a flexible mechanism and vibration actuators for intuitive input. Giving a haptic input sensation is expected to enable more accurate input for 3D pointing to depth. In addition, the introduction of a flexible mechanism is expected to make it easier to adjust the depth input.

The rest of this paper is organized as follows. In Section II, we describe the related works of 3D input interfaces. Section III introduces our approach to implement the pointing device. Section IV describes our experiment results. Section V discusses about the further enhancements to the proposed pointing device. Finally, Section VI presents our conclusions and future works.

II. RELATED WORKS

Haptic devices play an important role in human-computer interaction [4]. These devices are often used as interfaces to convey virtual tactile sensations to users using vibration, temperature, and pressure.

There are two types of haptic devices: active and passive [5]. Active Haptic Feedback (AHF) uses the movement of computer-controlled actuators as feedback. The advantage of AHF is that it can be flexibly realized according to the content, such as reproducing the texture of an object or the sensation of collision through vibration. High performance actuators and

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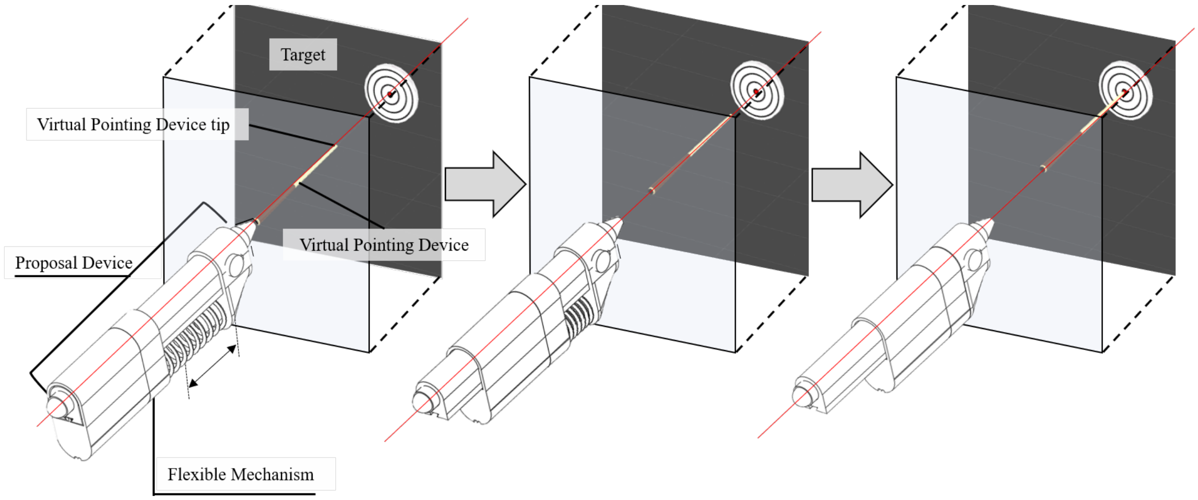


Figure 2. Depth input operation by pushing the pointing device with the flexible mechanism.

complex controls can be used to generate high quality sensory feedback. In contrast, Passive Haptic Feedback (PHF) is a haptic that uses a real object to provide haptic feedback. The advantage of PHF is that it can easily generate high-quality sensory feedback at a lower cost than AHF because it uses physical properties such as the shape and weight of the object. However, it has the disadvantage of not being able to respond flexibly to content due to its strong dependence on physical properties.

A haptic stylus with a flexible mechanism was presented as an interaction device for manipulating small-sized virtual reality contents on mobile devices [6]. To manipulate 3D content, the stylus needs to be tilted and rotated. However, these functions are not implemented.

III. Flexible 3D Pointing Device with Haptic Feedback

In this study, we modified the stylus with flexible mechanism proposed by Choi et al. (2021) [6] and implemented AHF and pose orientation feedback to create a 3D pointing device. Therefore, our pointing device will have both AHF and PHF when manipulating 3D content in virtual space. To simplify the design of the device, we used Wacom Intuos Pros to detect the position of the pointing device tip relative to the touch point and the orientation of the device. The PHF is generated by the change in the length of the device due to the flexible mechanism and the repulsive force of the spring. AHF is implemented by Eccentric Rotating Mass (ERM) actuators that generate pulsing vibrations when the tip of the device touches a visual target in virtual space. PHF is intended to influence the perception of the amount of input, while AHF is intended to influence the perception of completion.

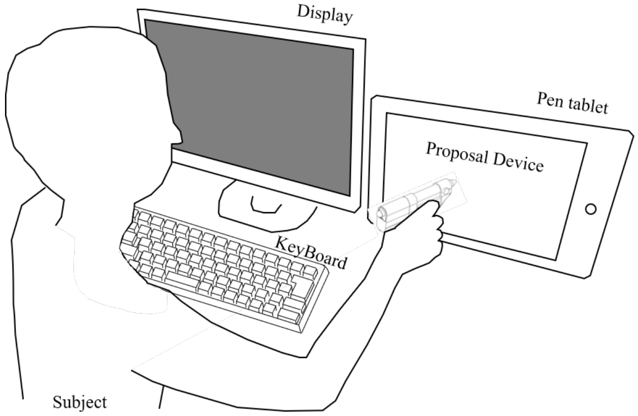
Figure 1 shows the configuration of the 3D pointing device in this study. The device vibrates the haptic motor to provide AHF to the user when the device tip hits with the 3D content in the virtual space. To implement the flexible mechanism, we used a spring and a pressure sensor. The pressure value changed by the compression coil spring when the user pushes in is treated as the input value to the depth. Figure 2 shows an example of depth input operation by pushing the pointing device with the flexible mechanism. Here, the pressure and AHF sensors are controlled by M5Stick-C, which communicates with the software via Bluetooth Serial. M5Stick-C and the AHF sensor is attached to the user's arm using a band. The total cost of the proposed 3D pointing device is about $100.

IV. Experiments and Results

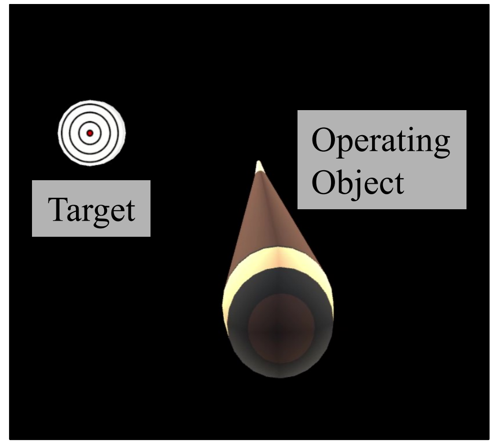
The use of haptic feedback in input operations to virtual contents is expected to enable more accurate 3D pointing by improving the input sensation. In this experiment, we will evaluate to what extent the input sensation improves 3D pointing and verify the effects of the flexible mechanism and haptic on the operation. In this experiment, we measure the accuracy and precision of 3D pointing to a visual target using the proposed device and evaluated its stability for depth input. Figure 3 shows our experimental environment. The pointing system was implemented in Unity3D. The pen tablet was mounted on a wall and the touch coordinates were obtained so that the front of the real world was the front of the content.

Five subjects (male) between the ages of 23 and 27, participated in the experiment. Subjects were seated in front of a display while holding the proposed device. At first, the experimenter provided the subject with instructions on how to use the device to virtually touch the presented visual target. Next, subjects were given the opportunity to practice pointing the target using the device. The experiment was started after the subject were sufficiently familiar with the operation of the device.

Figure 4 shows the procedure of 3D pointing in this experiment. At first, the experimenter presents the visual target on the display. Next, the subject touches the tablet with the proposed device and adjusts its angle toward the visual target. After feeling that the angle has been adjusted properly,



(a) Equipment layout



(b) A visual target and the virtual pointing device

Figure 4. Environmental experiment for this study.

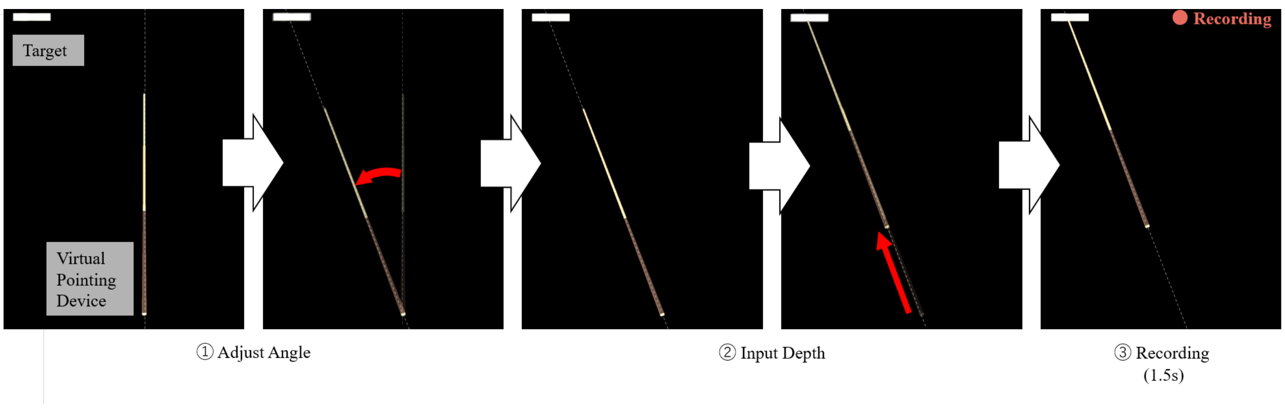


Figure 3. The procedure of 3D pointing in this experiment.

TABLE I. 3D POINTING PRECISION AND ACCURACY.

Condition	Mean [mm]	SD [mm]
None	7	5.3
PHF	8.2	6.3
AHF	4	3.3
PHF and AHF	4.7	4.3

the subject presses the device and make a depth input, trying to make the tip just touch the center of the visual target virtually. The subject records the position of the tip by pressing a button on the keyboard when he felt that this operation was successful.

In this experiment, 18 indicators were placed at equal intervals on the screen. During pointing, four patterns of combinations of with and without AHF and PHF were set up. The pointing precision and accuracy were evaluated with and without AHF and PHF. In case of using PHF, the pointing depth is adjusted by the flexible mechanisms of the device. On the other hand, when PHF is not used, the standard functions of the pen tablet are used for the input.

Table I shows the accuracy and precision of 3D pointing for each pattern of AHF and PHF. The results show that more accurate 3D pointing can be achieved by using AHF. Figure 5 shows a histogram of the resulting pointing z-scores for each pattern. Here, a negative Z-Error indicates that the pointing position is short, while a positive Z-Error indicates that the pointing position is longer than the target. Figure 5 (b) shows that the AHF allows pointing closer to the target. However, when both AHF and PHF were used, the pointing tended to be longer than when only AHF was used.

V. CONCLUSION

In this study, we have developed a flexible 3D pointing device with haptic feedback to evaluate the extent to which input sensation improves 3D pointing and to verify the influence of flexible mechanisms and haptics on the operation. Our experiment shows that the active haptic feedback enables pointing closer to the target.

In the future, we would like to install an IMU on the developed device to obtain rotation and stretching information by itself to be used in actual 3D displays.

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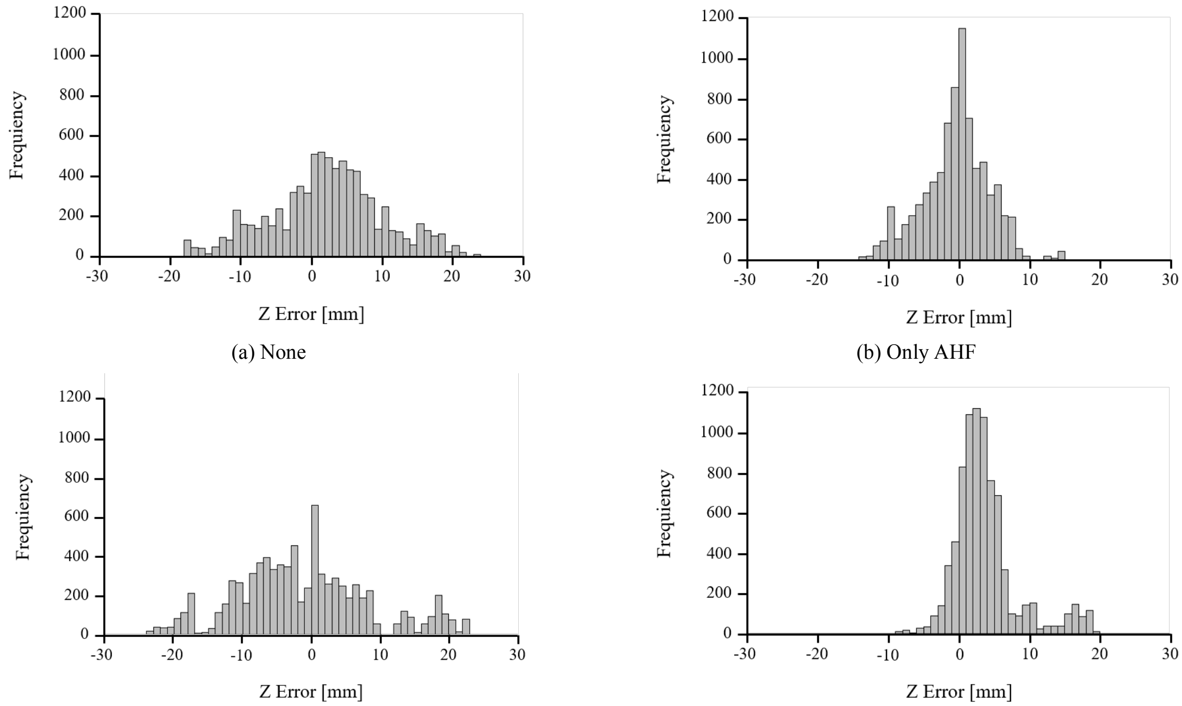

(a) None (b) Only AHF (c) Only PHF (d) AHF and PHF

Figure 5. Histogram of the resulting pointing z-scores for each haptic pattern.

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