DepthMove: Hands-free Interaction in Virtual Reality Using Head Motions in the Depth Dimension

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Abstract

Hands-free interactions are very handy for virtual reality (VR) head-worn display (HWD) systems because they allow users to interact with VR environments without the need for a hand-held device. This paper explores the potential of a new approach that we call DepthMove to allow hands-free interactions that are based on head motions towards the depth dimension. With DepthMove, a user can interact in a VR system proactively by moving towards the depth dimension with an HWD. We present the concept and implementation of DepthMove in VR HWD systems and demonstrate its potential applications. We further discuss the advantages and limitations of using DepthMove.

1 Introduction

Hands-free interactions are essential for virtual reality (VR) head-worn display (HWD) systems. When a user's hands are occupied, or other ancillary devices (e.g., controllers) are not available or not easily accessible, efficient hands-free interaction techniques become very useful. For example, a user is watching a movie in an HWD-based VR environment but suddenly gets interrupted by a message from an instant messaging app. When watching movies, the user does not usually carry a controller, and it might be inconvenient for her to take down the VR headset to find one. In this situation, a hands-free approach to switch to the messaging interface and send a reply becomes very practical.

Several input mechanisms could be suitable for the above scenario such as speech control and eye-gaze control. However, speech control mechanisms can be disturbing to others in a shared environment [2]—for example, in the above scenario, maybe the user's baby is sleeping near her and could wake her up by making a sound. Eye-gaze control has been shown to be inaccurate at times [1, 4], and it is usually expensive to have gaze trackers embedded into the VR headset—for instance, Pupil Labs offers eye trackers for the HTC VIVE with a cost of around $1600 [5], whereas HTC VIVE VR system costs only $499.

For existing consumer HWD headsets, it may not be necessary to have additional peripheral devices for interaction since the headsets have a number of sensors that can capture head and even body movements [8]. These movements can be translated into commands without needing a handheld device. Current hands-free interaction techniques in HWD are based mainly on the use of the dwell-based approach [3, 7] which tracks the user's head movement. This technique requires users to focus on a target for a certain period of time (dwell time) in order to select and then interact with it. However, it is difficult to determine the dwell time [1] and longer dwell times slow down performance, while shorter dwell times might cause unintentional selections and errors. Moreover, because of the pre-defined dwell time, users are always "pushed" to select a target and quickly move to the next one. The user needs to be very focused and act carefully to avoid making unwanted false selections—this process can make interaction stressful and tiring.

In this paper, we present a new hands-free interaction approach, called DepthMove, for VR HWD. It allows the user to select and interact with objects by making depth dimension movements—that is, moving the head perpendicular to the VR HWD forwards or backwards. We illustrate the concept, present an implementation of DepthMove in VR HWD, and discuss its potential applications for interaction. Next, we consider the benefits of DepthMove over the dwell-based technique which is the most common hands-free interaction method in use, as well as the limitations of using DepthMove. We provide the conclusion and future work as the end.

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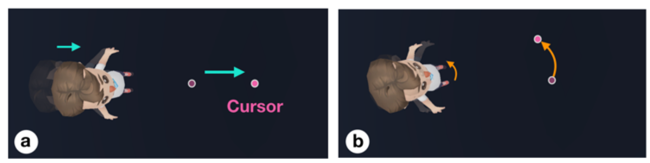

Figure 1: An illustration of the depth cursor movement relative to the user's movement. (a) When a user performs forward DepthMove (b) when the user turns, the cursor also follows the user's rotation but does not go further into (or away from) the virtual environment.

2 Concept and Implementation

From the user's point of view, the basic directions that he or she can move are up/down, left/right, and forward/backward. Movements in forward/backward direction are considered as *depth dimension movements*. Specifically, we define the movements perpendicular to the VR HWD screen as *DepthMove*. As we will be presented in the next section, DepthMove can trigger different interactions by aiming at different targeting objects and moving different displacements in the forward or backward direction.

DepthMove supports both 3 degrees-of-freedom (DoF) and 6 DoF VR headsets. For 6 DoF VR headsets such as the HTC VIVE (a stationary VR system) and Oculus Quest (a standalone VR system), the head displacement in the forward and backward direction can be easily sensed by the HWD headset. For 3 DoF VR systems like Samsung Gear VR (a mobile VR system), we could employee the built-in inertial measurement unit (IMU) sensor of the smartphone to track the head displacement through some advanced algorithms [6]. Alternatively, we could apply DepthMove through depth acceleration, in lieu of the depth displacement, which can be accurately sensed by the IMU sensor.

To provide visual aids while using DepthMove, we could embed a *depth cursor* into the virtual environment (VE). When a user performs DepthMove, the cursor goes deeper into (or moves back from) the VE (see Figure 1a). When the user turns, the

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cursor also follows the user's rotation but does not go into the VE further (see Figure 1b). Movements perpendicular to the depth dimension does not affect the depth of the cursor. Overall, it looks like the cursor is stuck to the canter of the user's visual view. When the user is performing DepthMove, the cursor goes forward or backward according to the user's movement. The gain ratio (i.e., the relative movement of the tracked HWD position to the movement of the depth cursor) can be easily changed.

3 POTENTIAL APPLICATIONS

After presenting DepthMove, we can revisit our example in the introduction: A user is enjoying watching a movie using a VR HWD late during the night. Her baby is sleeping, and any voice could wake the baby up. Suddenly, a message comes in, and the notification is displayed on the screen. She then performs a long-range DepthMove [*Mode Switching*] to switch from the movie interface to the chat interface. She then performs several short-range DepthMove to type a short message on the virtual keyboard and taps the "send" button [*Target Selection*]. Next, she performs another long-range DepthMove to switch back to the movie interface and resumes playing the movie. At this moment she feels like the volume is somewhat high, so then she performs a continuous DepthMove to lower down the volume [*Item Scaling*]. She then can continue enjoying her movie.

Mode Switching. The long-range DepthMove allow users to switch between different workspaces or applications with 2D UI. For example, as shown in Figure 2a, performing long-range DepthMove with different depths could help the user switch to different interfaces. Moving the cursor back to the original depths indicates selection confirmation.

Item Scaling. The continuous DepthMove enables users to scale the item continuously which can be used, for example, to turn down/up the sound and scale down/up the size of the target. As shown in Figure 2b, the user places the depth cursor "on" the sound symbol and performs continuous DepthMove to turn the sound down/up.

Target Selection. The short-range DepthMove allow users to perform simple selection tasks, such as keyboard typing. As shown in Figure 2c, a user performs short-range DepthMove to enter a simple message "hi". In this case, the user needs first to position the cursor on the letter 'h' (lateral movement) then perform a short-range DepthMove to confirm its selection. Then she moves to where the character 'i' is located (lateral movement), and finally perform another DepthMove confirm the selection.

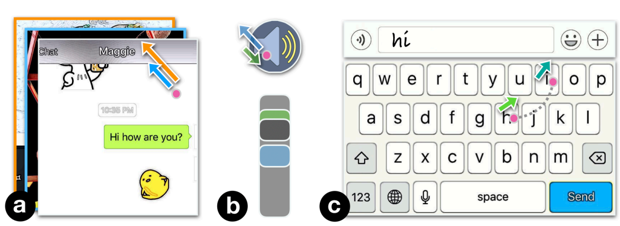

Figure 2: Potential applications of DepthMove: (a) Mode Switching, (b) Item Scaling, and (c) Target Selection.

4 ADVANTAGES AND LIMITATIONS OF DEPTHMOVE

We identified several benefits of DepthMove over the traditional dwell-based technique.

- With DepthMove, the user could be able to select fully-occluded target (like multiple occluded 2D UIs), whereas this might be difficult when using the dwell-based technique.
- DepthMove allows the user to interact with targets proactively. She can interact with a target at any point and her own pace. In contrast, the dwell-based techniques will "push" the user to select a target and then quickly move to the next one while avoiding making unwanted false selections.
- DepthMove allows continuous interaction like continuous item scaling, while the dwell-based technique could not offer.

We also have to consider the following limitations when applying DepthMove as an interaction technique.

- Some users might not be willing to performing DepthMove in public places.
- Prolonged interaction with DepthMove could be tiresome.
- DepthMove could increase body collisions and danger risks for users when interacting with VR HWD systems.

5 CONCLUSION AND FUTURE WORK

In this paper, we have presented DepthMove, a new hands-free interaction approach for VR HWD. It allows users to select and interact with objects by moving the head forward or backward perpendicular to the VR HWD. We demonstrate the concept of using DepthMove and how it can be implemented in VR systems. We propose the potential applications of DepthMove and discuss its advantages and limitations. We envision more specific applications using the DepthMove to be introduced and evaluated in the future.

REFERENCES

[1] A. M. Feit, S. Williams, A. Toledo, A. Paradiso, H. Kulkarni, S. Kane, and M. R. Morris. "Toward everyday gaze input: Accuracy and precision of eye tracking and implications for design." In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, pp. 1118-1130. ACM, 2017.

[2] J. Grubert, L. Witzani, E. Ofek, M. Pahud, M. Kranz and P. O. Kristensson, "Text Entry in Immersive Head-Mounted Display-Based Virtual Reality Using Standard Keyboards," In *Proceedings of the 2018 IEEE Conference on Virtual Reality and 3D User Interfaces (VR)*, Reutlingen, 2018, pp. 159-166.

[3] R. J. Jacob. "What you look at is what you get: eye movement-based interaction techniques." In *Proceedings of the SIGCHI conference on Human factors in computing systems*, pp. 11-18. ACM, 1990.

[4] M. Kytö, B. Ens, T. Piumsomboon, G. A. Lee, and M. Billinghurst. "Pinpointing: Precise Head-and Eye-Based Target Selection for Augmented Reality." In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*, p. 81. ACM, 2018.

[5] Pupil Labs. HTC Vive Binocular Add-on, 2018. [Online]. Available: https://pupil-labs.com/store/#vr-ar. [Accessed: 27-Nov-2018].

[6] J. Windau and L. Itti, "Walking compass with head-mounted IMU sensor," In *Proceedings of the 2016 IEEE International Conference on Robotics and Automation (ICRA)*, Stockholm, 2016, pp. 5542-5547.

[7] C. Yu, Y. Gu, Z. Yang, X. Yi, H. Luo, and Y. Shi. "Tap, dwell or gesture?: Exploring head-based text entry techniques for hmds." In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, pp. 4479-4488. ACM, 2017.

[8] B. Zhang, Y. H. Chen, C. Tuna, A. Dave, Y. Li, E. Lee, and B. Hartmann. "HOBS: head orientation-based selection in physical spaces." In *Proceedings of the 2nd ACM symposium on Spatial user interaction*, pp. 17-25. ACM, 2014.