HoloCMDS: Investigating Around Field of View Glanceable Commands Selection in AR-HMDs

Rajkumar Darbar*
Inria Bordeaux, France

Arnaud Prouzeau†
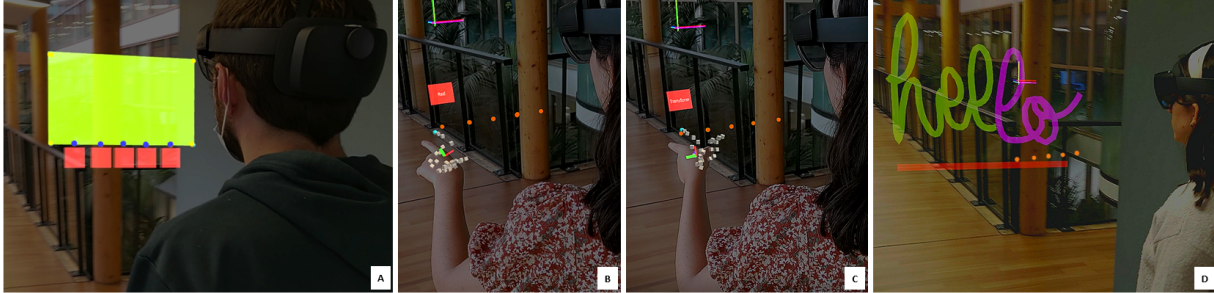Inria Bordeaux, France

Martin Hachet‡
Inria Bordeaux, France

Figure 1: HoloCMDS working prototype running on HoloLens 2. (A) Rectangular area in green color represents FOV of the HMD at a certain depth. Blue colored dots at the bottom FOV border are visual cues corresponding to the spatial location of each button (in red color) situated outside around the FOV. Note that, buttons are shown here for illustration purposes only, not visible to users. (B) A user long presses on the first button, then the associated command name is displayed in a pop-up text. (C) She long presses on the same button by rotating her wrist 90° anticlockwise to invoke a different command. (D) We developed a mid-air drawing application where users access different commands quickly using the HoloCMDS technique.

ABSTRACT

Augmented reality merges the real and virtual worlds seamlessly in real-time. However, we need contextual menus to manipulate virtual objects rendered in our physical space. Unfortunately, designing a menu for augmented reality head-mounted displays (AR-HMDs) is challenging because of their limited display field of view (FOV). In this paper, we propose HoloCMDS (see Section 2) to support quick access of contextual commands in AR-HMDs and conduct an initial experiment to get users' feedback about this technique.

Index Terms: Human-centered computing—Mixed Reality; Human-centered computing—User Interface Design

1 INTRODUCTION

Recently, optically see-through (OST) augmented reality head-mounted displays (AR-HMDs) have evolved rapidly in terms of display resolution, form-factors, weight, battery life, and sensing capabilities. These devices allow users to augment their physical space with virtual objects, and they can also manipulate (i.e., create, delete, rotate, translate, change color, etc.) these objects by invoking contextual commands. Unfortunately, executing commands in AR-HMDs is not trivial due to mainly two reasons. First, most of the commercial HMDs have a limited field of view (e.g., Hololens 2 has a 43° horizontal and 29° vertical FOV [3]). Displaying menus in an already narrow FOV always creates visual occlusion. Second, users often need to go through multiple intermediate steps to issue a command. For instance, in Hololens 2 hand menu [1], users first raise their hand, then gaze at it to activate the hand-attached menu UI, and finally tap on the desired menu item with the other hand to select it. This overall process breaks the interaction flow of the ongoing

*e-mail: rajdarbar.r@gmail.com
†e-mail: arnaud.prouzeau@inria.fr
‡e-mail: martin.hachet@inria.fr

task. To enable quick command selection in AR-HMDs, researchers proposed several menu interaction techniques. For example, users can access menus through various hand postures [4], but such an approach suffers from unintentional activation of commands [2]. On the other hand, Yan et al. [6] studied eyes-free target acquisition around the body in virtual reality by leveraging our spatial memory and proprioception. It was faster but more error-prone than eyes-engaged selections. However, such a technique can not be directly applied to AR devices because of their limited egocentric tracking volume. Prior work also explored the potential of the smartphone for menu selection in AR-HMDs [5], but it requires extra hardware.

In this work, we propose HoloCMDS to facilitate fast command selection in AR-HMDs (see Section 2 for details). Compared to previous work, our technique provides the following advantages — commands are always available in the user's FOV (i.e., head referenced) with a very minimum occlusion and can be issued anytime with a single tap; there is no need to switch attention explicitly from the ongoing task; it does not require any external device except the AR-HMD having hand tracking available.

2 DESIGN AND IMPLEMENTATION OF HOLOCMDS

In currently available AR-HMDs, the FOV of the depth-sensing camera, which is used for hand tracking, is comparatively bigger than the display FOV. As a result, virtual content placed outside the display FOV is still interactable. We exploit this fact to design HoloCMDS. In our proposed technique, we position virtual buttons outside around the display FOV (i.e., left, right, top, and bottom). While placing buttons outside the FOV allows us to reduce visual occlusion, clicking buttons accurately becomes harder as we can not see them anymore. To overcome this, small dots are shown at the display border as visual cues to understand the spatial location of each button outside FOV. Figure 1(A) shows an example of visual cues at the bottom part of the display FOV. In this way, users are able to tap easily on buttons to trigger commands with the index finger. Note that, users are required to make a pinch gesture with their thumb and middle finger before tapping a button with their index finger to prevent unwanted button activation. When a successful button clicked event happens, they receive audio feedback as a confirmation.

Moreover, users need to spend some time initially to build the spatial memory of which command is associated with which button as they can not see the button name directly. To explore this, users long press on a button, and a pop-up text representing the associated command name with that button appears in their view (see Figure 1(B)). Once they remember button-command mapping, they quickly tap on the button to trigger the command like a shortcut on the desktop. In our approach, we map two commands to each button by distinguishing two different tapping postures - tap a button with 0° wrist rotation (see Figure 1(B)) and tap a button with 90° anticlockwise wrist rotation (see Figure 1(C)). Therefore, HoloCMDS is a 1D menu where each button supports two commands.

To prototype HoloCMDS, we used Microsoft HoloLens 2 as an AR-HMD, and Unity3D (2018.4) and Mixed Reality Toolkit were used as a software framework.

3 USER STUDY

In HoloCMDS, buttons with visual cues can be placed at four different sides (left, right, top, and bottom) of the display FOV with different arm-reachable depth levels. For our study, we consider two depth levels from the user's eyes: near (40 cm) and far (60 cm). While selecting a button at near depth, users can keep their arm close to the body. Whereas they need to extend their arm fully for the far depth. We conducted a short user study to understand users' preferences about FOV sides and depth levels.

Following HoloLens design guidelines, we set each button size of 4.5 cm × 4.5 cm × 1.5 cm to ensure that users get enough space to tap it successfully with their index finger. HoloLens 2 provides an approximate display area of 30.5 cm × 21 cm at 40 cm depth. This allows us to accommodate 5 buttons at the top, 5 buttons at the bottom, 3 buttons at the left, and 3 buttons at the right side of the FOV. On the other hand, this display area becomes slightly bigger (i.e., approximately 45 cm × 31 cm) at the depth of 60 cm, and it accommodates 8 buttons at the top, 8 buttons at the bottom, 4 buttons at the left, and 4 buttons at the right side of the FOV.

We recruited 10 unpaid participants (4 males + 6 females) from a local university campus. Their ages ranged from 24 to 32 years (mean = 27.54, SD = 4.61). Three were left-handed. All were daily users of smartphones and desktops. Five of them had experience with AR/VR-HMDs. We first introduced them about the experiment background. Then, we showed them a virtual button with a visual cue (i.e., a dot) on the top of that button in their view and asked them to tap it. After that, we only showed them the dot in their view without rendering the button and told them to imagine that there is a button below this dot and tap it. Finally, we informed them that HoloCMDS works the same way like the previous step, but the difference is that they will see dots at each side of the FOV border, and buttons are located outside the FOV next to those dots. Their task was to tap each button sequentially with two different hand postures as described in Section 2. There was no restriction on which hands to use to click a button. We suggested that it would be comfortable to use the left hand if buttons are located on the left side of the torso and vice versa. We randomized the order of depth levels and sides of the FOV across all users. There were 80 button tapped events ((total 16 buttons at near depth x 2 hand poses) + (total 24 buttons at far depth x 2 hand poses)) for each participant. At the end of the experiment, we did an informal interview to understand their preferences about depth levels as well as sides of the FOV. This study was carried out in standing condition and took approximately 20 mins to complete for each participant.

4 RESULTS

Most of the participants preferred near depth as it allows them to keep their arms close to the body for comfortable interaction. On the other hand, the top side of the FOV was their least preferred option as they need to raise their hand each time to click a button.

Among the other three sides, clicking buttons located at the bottom side were comparatively fast and accurate for all users. Although everyone appreciated the left and right sides for placing buttons, they had difficulties to see visual cues clearly there in HoloLens 2. As a result, more attention was required to estimate the button position outside FOV and it was visually fatiguing to them. Furthermore, they were frustrated to click a button on the left and right sides as hand tracking was not working accurately in that area. Our participants also confirmed that visual cues were not disturbing to their main task as they stay in the near periphery, not in the central view.

5 DEMO APPLICATION

In HoloLens 2, we developed a mid-air drawing application where users were able to invoke different commands using our HoloCMDS concept (see Figure 1(D)). There were a total of ten commands distributed in five buttons. Informed by our user study, all buttons were placed at the bottom side of the FOV with a near depth distance. Initially, they long pressed each button to remember the spatial locations of each command. Once remembered, they were using their dominant hand to draw strokes in the air while issuing commands quickly with their non-dominant hand.

6 CONCLUSION, LIMITATION, & FUTURE WORK

In this paper, we introduced HoloCMDS, a novel approach for executing commands in AR-HMDs. In HoloCMDS, we placed buttons outside around the display FOV and showed visual cues (i.e., dots) corresponding to these buttons at the FOV border. With the help of these visual cues, users were able to tap buttons easily using their index finger to invoke commands while keeping their focus on the main task. Our initial user study confirmed that users prefer to place buttons and their corresponding visual cues at the bottom side of the display FOV with an approximate depth of 40 cm.

The primary objective of HoloCMDS is to support command shortcuts in AR-HMDs similar to desktop and mobile interfaces. We took the first step towards that. In the future, we will compare HoloCMDS with the hand menu [1] in terms of time, accuracy, and users' preferences. Currently, we are only providing auditory feedback when users tap a button. It would be interesting to support visual feedback by animating the visual cue (i.e., dots) corresponding to each button. For instance, moving the dot in the z-dimension while tapping a button to emulate pushing a button effect. Further, we need to investigate how HoloCMDS can help users to memorize commands by utilizing different colors and shapes of the visual cues.

We envision that the hand menu will be used to support all commands required in an application, whereas HoloCMDS will be the gateway to access frequently used commands quickly.

REFERENCES

[1] Hand menu in hololens 2. `https://docs.microsoft.com/en-us/windows/mixed-reality/design/hand-menu`. Last accessed: January 05, 2022.

[2] I. Golod, F. Heidrich, C. Möllering, and M. Ziefle. Design principles of hand gesture interfaces for microinteractions. DPPI '13. doi: 10.1145/2513506.2513508

[3] D. Heaney. Hololens 2's field of view revealed. `https://uploadvr.com/hololens-2-field-of-view/`, February 25, 2019. Last accessed: January 05, 2022.

[4] C. Park, H. Cho, S. Park, Y.-S. Yoon, and S.-U. Jung. Handposemenu: Hand posture-based virtual menus for changing interaction mode in 3d space. ISS '19. doi: 10.1145/3343055.3360752

[5] H. Saidi, E. Dubois, and M. Serrano. Holobar: Rapid command execution for head-worn ar exploiting around the field-of-view interaction. CHI '21. doi: 10.1145/3411764.3445255

[6] Y. Yan, C. Yu, X. Ma, S. Huang, H. Iqbal, and Y. Shi. Eyes-free target acquisition in interaction space around the body for virtual reality. CHI '18. doi: 10.1145/3173574.3173616