The Design of Video See-Through Window for Manipulating Physical Object with Head-Mounted Display

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CCS CONCEPTS

• **Human-centered computing → User studies**;

KEYWORDS

HCI, VR/AR, User Study

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1 INTRODUCTION AND MOTIVATION

In general, highly-skilled manipulation without instruction is difficult. Recently there are some works which apply the manipulating guidance by a Virtual Reality (VR) or Augmented Reality (AR) head-mounted display (HMD) to keep the user hands-free. Henderson et al. [Henderson and Feiner 2009] applied AR to armored vehicle turret maintenance. With a head-worn display, the mechanic could acquire steps in the form of texts, images and animations. Our previous work (My Tai-Chi Coaches) [Han et al. 2017] used optical see-through HMD for Tai-Chi Chuan (TCC) augmented learning tool. Although it can provide the user visual hints such as virtual coaches, the visual hints which the user can see are constrained to the small augmented FOV of the HMD.

Another work (AR-Arm) [Han et al. 2016] used video see-through HMD for guiding arm movement in first-person perspective. Because of the mobile VR display, the user could see more augmented visualization with large augmented FOV. However, it suffers from the problem of motion-to-photon latency which increases and causes motion sickness due to the low FPS of camera in mobile device. To solve this, Fernandes et al. [Fernandes and Feiner 2016] proposed a way for combating VR sickness in Computer Graphic based by reducing the FOV while the user is moving, and revealed that small FOV could reduce the VR sickness. However, the small FOV may decrease the manipulation performance, and how to choose a better FOV sizes remains unknown. In terms of rendering, video see-through and immersive VR are similar. In this paper, we adopt different see-through window sizes (i.e. FOV) to find the balance between motion sickness and the manipulation performance in video see-through AR.

2 IMPLEMENTATION

Our system is mainly developed on a mobile VR HMD (Gear VR) with a compatible smartphone Galaxy S7 edge which has a 12-megapixel primary camera on the rear with 96° FOV. For the purpose of creating video see-through HMD, the rear camera is used to capture the wearer's field of view. However, the field of view of the camera is not wide enough for video see-through HMD. Therefore, we attached a conversion lens to acquire a wider view (approx. 150°). The system is developed in the game engine UNITY 5.3 and the camera is calibrated in advance.

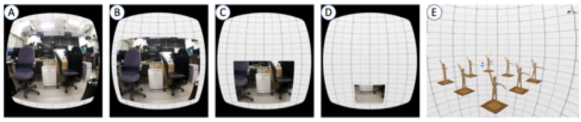

Figure 1: Different size of see-through windows. (a) original window (fit the HMD screen WFOV), (b) 75% width and height of the origin, (c) 50% width and height of the origin and (d) 25% width and height of the origin. (e)Virtual Environment in HMD.

For the user study, we build a simple scene with a see-through window. In order to balance with FPS quality (less than 30 FPS), the resolution of the video is set to 1024 by 768 pixels.

3 USER STUDY

We conduct a study to compare different sizes of the monocular video see-through window to evaluate the tradeoff between FOV and motion sickness. There are four interfaces: the original window (fit the HMD screen WFOV), 75%, 50% and 25% width and height of the original window, as shown in Figure 1 (a)-(d), respectively.

Participants in this study are asked to adjust a wooden mannequin which is used for drawing. They are asked to observe surrounding eight virtual wooden mannequins, which are all doing the same action and facing the same direction, and then apply the motion to the real one in 30 seconds, as shown in Figure 1 (e). It requires the participants to recognize the specific human body posture then present it on the trunk and limbs of a wooden mannequin.

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In this experiment, we invite twelve people (eight males and four females) in 18-26 years old (mean: 23.17 years). Each participant should finish indicated task for every interface in different orders. We design eight target postures with a different number of joints needed to be adjusted for the user to apply. Besides, participants are asked to finish questionnaire and SSQ after each interface.

4 RESULTS AND DISCUSSION

We adopt the simulator sickness questionnaire proposed by Kennedy et al. [Kennedy et al. 1993] to evaluate the level of comfortable in each interface, and the preference results on the questionnaire. Figure 2 (left) shows the result of user preference for each interface, all participants have positive comments on 75% length and width of original size of see-through window, which is considered as the best size. In addition, Figure 2 (right) shows that observing and recognizing the position of hands and mannequin are both easier with larger FOV. Due to the small size of window, most of the participants spend more time on adjusting the wooden mannequin and realizing the correct distance between them and the wooden mannequin. In terms of the time for adjusting the mannequin, the performance of 75% and 100% window size are similar, and it shows that 75% window size is enough for manipulation.

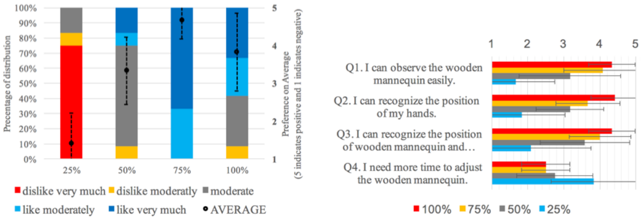
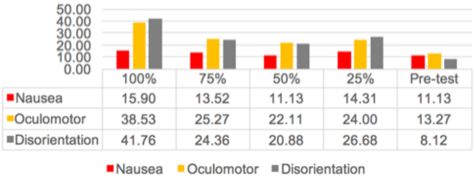


Figure 2: (left) Preference for Interface. (right) Questionnaires of each interface which use 5-point Likert scale (5 = totally agree, 1 = totally disagree).

Figure 3 shows the results of SSQ. Original size leads to the highest SSQ in three subscores and total scores. It reveals that larger FOV of see-through window would cause serious sickness because of the low camera FPS. However, the score does not decrease as the window size getting smaller, because the user will need more head-turning due to the limited FOV of the smaller see-through window size. After the experiments, four authors score each wooden mannequin adjusted by the participants with a random order in 1 to 5 points, where 1 point represents the worst and vice versa. According to the number of the joints needed to be adjusted, we divided the target postures into two kinds of tasks: simple (2-6 joints) and hard task (7-11 joints). Figure 4 shows the distribution of average scores of different tasks with different window size. The score of 25% window size is the worst, and the average scores increase as the larger FOV in all interfaces for both simple and hard tasks.

5 CONCLUSION AND FUTURE WORKS

In our work, we utilized a video see-through HMD with a low FPS camera (less than 30 FPS), which provides monocular vision for user. Our current study shows that 75% and 100% of the original window size lead to similar performance in terms of manipulation, but the motion sickness could be reduced with 75% window size. In the future, we will conduct an advanced user study using VICON to evaluate the physical object, head-turning and head-moving for exploring the relation between manipulation performance and the motion sickness.



	100%	75%	50%	25%	Pre-test
🟥 Nausea	15.90	13.52	11.13	14.31	11.13
🟨 Oculomotor	38.53	25.27	22.11	24.00	13.27
⬛ Disorientation	41.76	24.36	20.88	26.68	8.12

Figure 3: Result of SSQ (Simulator Sickness Questionnaire).

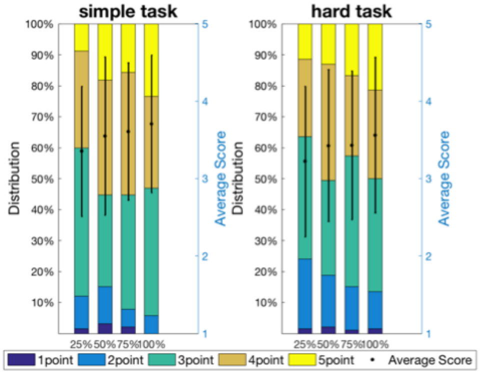


Figure 4: Result of user performance.

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