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Video Guides on Head-Mounted Displays: The Effect of Misalignments on Manual Task Performance

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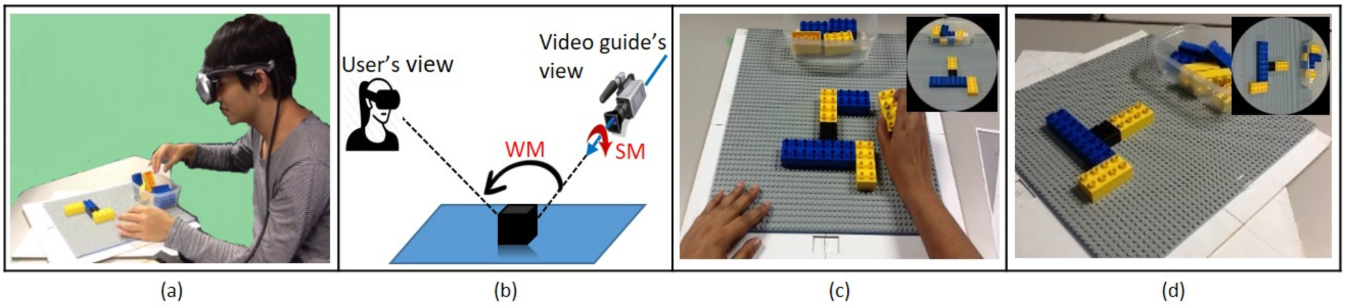

Figure 1: *(a) A participant of our experiment (re-enacted) performing a lego placement task following a video guide on his Video See-Through Head-Mounted Display (VST-HMD). (b) We investigate the impact of two different misalignments: First, between the HMD's and the video guide's view-plane normals* (WM)*; Second, between the HMD's and the video guide's up vectors* (SM)*. (c), (d): Example of a participant's view from our experiment; (c):* $WM = 0°, SM = 0°$*, (d):* $WM = 45°, SM = 90°$.

Abstract

Head-Mounted Displays (HMD) are becoming widely available at affordable prices. A typical application of HMDs is supporting users when perform manual tasks. However, displaying information on a HMD without any registration with the environment lead to misalignments and reduced task performance. The goal of our investigations is to quantify how increased misalignments impact the performance. We conducted two experiments and we found that task completion time is significantly affected by World space Misalignment and a significant correlation of the absolute difference between World space Misalignment and Screen space Misalignment to the task completion time.

Categories and Subject Descriptors (according to ACM CCS): H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems—Video H.5.2 [Information Interfaces and Presentation]: User Interfaces—Training, help

1. Introduction

Video See-Through Head-Mounted Displays (VST-HMDs), e.g., Canon MREAL HMD, and Optical See-through HMDs (OST-HMDs), e.g., Google Glass, are becoming widely available at affordable prices. A common application of such HMDs is manual task support. There are two fundamental ways of displaying instructions on HMDs; registered to the real environment, following the Augmented Reality (AR) paradigm or unregistered, following the Wearable Computing paradigm. A previous study [RMW08] found that registered AR performs better than unregistered graphics. However, AR does not perform better when the content is not properly aligned with the environment. Therefore, the system must be accurately calibrated with the environment to obtain the desired performance. This is often a very complex, expensive and time consuming process. Instead, graphical instructions such as video and pictures can be displayed on the HMD without any registration and tracking, which is much faster and easier to accomplish.

Video guides are one of the most common ways to present instructions for manual task support. In addition, a large number of 2D video guides already exists and are freely available in various forms. These existing video guides can be displayed on an HMD without further preparation or registration to the environment, thus greatly reducing the required preparation time. However, unregistered techniques might present the information from a different perspective than the angle the user is looking from and create a misalignment. This misalignment can manifest in two ways (Figure 1b). First, between the HMD's and the video guide's up vectors (*SM*: Screen space Misalignment); Second, between the HMD's and the video guide's view-plane normals (*WM*: World space Misalignment). Because of these misalignments, users will have to

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mentally rotate the guide to align the video instructions with their workspace. This results in reduced task performance [SM71].

In this work, we evaluate the effect of misalignment of the video guides using HMDs on manual tasks. We conducted two experiments to identify how task completion time is affected by the misalignment of the video guide. We found a significant effect of *WM* on task completion time and a significant correlation of the absolute difference between *WM* and *SM* to the task completion time.

2. Related Work

Previous studies of misalignments can be divided into three groups, human perception of misalignment, misalignment evaluation and misalignment elimination.

Human Perception of Misalignment Shepard and Metzler [SM71] (1971) conducted an experiment to identify the effect of mental rotation of three-dimensional (3D) objects. They found that reaction time increases linearly with the rotation angle.

Misalignment Evaluation Stephen R. Ellis et al. [ETKS91] conducted two experiments where they examined the 3D pursuit tracking when operators of teleoperation simulations are faced with misalignment between the display and control frames of reference. They combine both human perception and action to evaluate the effect of misalignment. The results show that the error increases to a maximum at about 125°then, decreases to 180°.

Misalignment Elimination Macedo et al. [MKE*98], proposed an automated compensation method to reduce misalignments between operator of teleoperation and controller orientation. Results show a significant improvements in operator performance with automatic compensation under some conditions. Goto et al. [GUS*10] proposed an AR based task support system that uses instructional videos. The proposed system transforms instructional videos according to the user's view and overlays them onto the user's view to eliminate the misalignment. Their evaluation results confirmed that displaying the instructional video according to the user's view is effective for improving the user's understanding of the instructions. However, there is no previous work that quantifies the effects of misaligned video guides on HMDs.

3. Experiments

We conducted two experiments to identify the effects of misalignments on users. In both experiments, users were asked to place Lego blocks according to a video instructions displayed on a Canon VH2002 VST-HMD. In the first experiment we evaluate the effect of *WM* on task completion time. Twelve voluntary participants (9 male, 3 female) with ages ranging 23 to 43 years (mean=28.83, sd=5.27) took part in the experiment. In the second experiment we evaluate the effect of both *WM* and *SM* on task completion time. Fifteen participants (10 male, 5 female) with ages ranging 23 to 44 years (mean=29.53, sd=5.01) were took part in the experiment.

In both experiments we displayed the video guide in a fixed position in the top right corner of the HMD view (Figure 1 c,d). The video guide was rendered on the HMD with OpenGL and the instructions were displayed step by step. Whenever the user completed a step, the supervisor switched the guide to the next step with a key press. Both experiments were within group evaluations. In the first experiment each participant participated in 12 trials and in the second experiment in 25 trials.

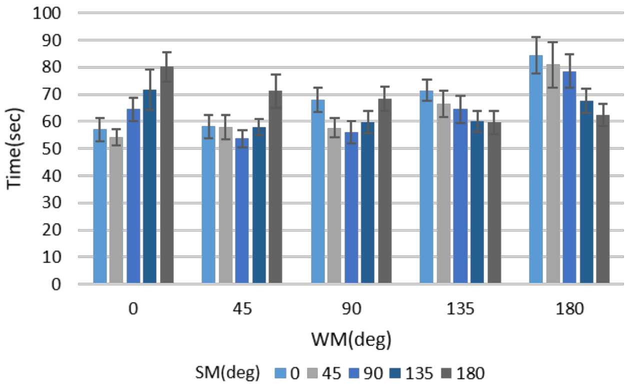

Figure 2: *Experiment 2 mean task completion time for different* WM *and* SM. *Whiskers represent ±standard error (SE).*

Results Analysis of the results of Experiment 1 with two way repeated measures ANOVA showed that task completion time was significantly affected by *WM* [F(1,132)=6.6, p<0.001]. It increases from *WM* 0°to 180°and decreases from *WM* 180°to 330°. Peak task completion time is at *WM* 180°. This result supports the observations by Shepard and Metzler [SM71].

Analysis of results of Experiment 2 with two-way repeated measures ANOVA showed that task completion time was significantly affected by *WM* and *SM* interaction [F(16,308)=8.413, p<0.001]. We observe that task completion time varies with the absolute difference between *WM* and *SM* (Figure 2). Therefore, we analyzed |*WM-SM*| with one-way repeated measures ANOVA and the task completion time was significantly affected by |*WM-SM*| [F(4,56)=21.72, p<0.001].

4. Conclusions

We have evaluated the impact of misalignments of video guides with the user's workspace on user performance. Our experiments show a significant effect of WM and |WM-SM| on the task completion time. In the future we want to use the observations made in our experiments to improve the presentation of video guides in support systems, e.g., by determining if correction of the video-guide alignment is required, or determining how existing guides can be warped to best match the user's perspective.

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