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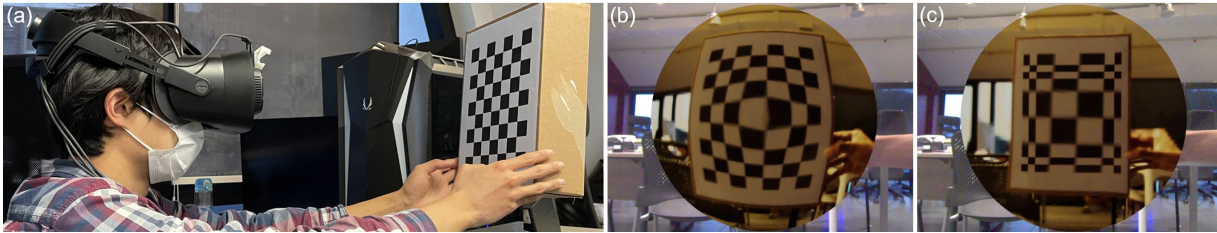


Figure 1: (a) Video see-through HMD with virtual magnifiers (b) Fisheye magnification (c) Rubber sheet magnification

ABSTRACT

Fisheye and rubber sheet are common magnifying methods in information visualization. In this paper, we present two experiments about their performance in AR scenarios: visual search and fine motor manipulation. Also, a baseline test without any magnification will be conducted as a reference. Users finish some tasks with a restricted region of interest and we evaluate the result based on time to completion and accuracy. Our results show that visual distortion of different magnifiers does not have significant debuff on visual search and fine motor skills. These results can be a reference to projects that need enhancement of visualization in AR.

Index Terms: Computing methodologies—Computer graphics—Graphics systems and interfaces—Mixed / augmented reality

1 INTRODUCTION

Magnifying a region of interest is a commonly used method to improve accuracy in visual tasks. Normally, we use different algorithms or real magnifiers for text or pictures to emphasize or assist users in reading tasks. In Augmented Reality (AR), we also have similar scenarios that users need to magnify some regions of interest. However, if the magnified area includes users' working area, their interaction will be influenced because of the distortion of magnifiers. Research [1, 3] has shown that redirected touching caused by the distortion of the observation area will even change the haptic perception of users. We conducted this study to evaluate two common magnifying algorithms in AR. We test how much these two magnification methods support visual search and interaction in this study.

2 RELATED WORK

Researchers have developed the fisheye magnification method for information visualization [2] a long time ago. Although the distortion of the fisheye view is unnatural to humans, this magnification method still improves visual input a lot in suitable areas. Also, this magnification method is similar to a real loupe, which makes this magnification method one of the most classical methods in information visualization. We would like to evaluate how much this distortion will influence the users' interaction.

Research [6] about rubber sheet magnifiers shows promising results when dealing with enlarging regions of interest in information

visualization. This kind of magnifier can keep a straight line straight when magnifying a region. Similar to the fisheye magnifier, this method also prevents losing context when magnifying a region.

Redirected touching [1, 3] proves that visual shape can influence human's haptic shape sensing. Based on this theory, we assume the distortion will have a strong influence on users' performance when they interact with the system.

Some works have been done in AR about magnification. In the medical area, researchers have designed a hybrid magnification method [4]. Another work contained a calibration method to make an optical see-through head-mounted display worked with real medical loupe [5].

3 METHODS

3.1 Magnifying without losing context

Normally, direct magnification is a good solution especially when users need to interact with magnified regions. However, direct magnification will occlude content around and cause visual inconsistency. In this paper, we conduct this two experiments with magnification solutions without losing context to better simulate how these two magnifiers perform in information visualization.

Fig. 2 shows the setup of the AR system with fisheye magnifier as an example. The magnified display is based on the frustum and camera parameters of the region of interest. So the magnified part will have visual consistency with the remaining part. This also assures that the baseline test is the same as the original view.

3.2 Fisheye and rubber sheet

- The mapping equation of the fisheye magnifier is

$$\begin{cases} u = (x^2 + y^2)^{\frac{3}{2}} \cdot x; \\ v = (x^2 + y^2)^{\frac{3}{2}} \cdot y. \end{cases} \quad (1)$$

- The mapping equation of the rubber sheet magnifier is

$$\begin{cases} u = \frac{x}{2} \cdot (1 + \text{smoothstep}(0.25, 0.5, x)); \\ v = \frac{y}{2} \cdot (1 + \text{smoothstep}(0.25, 0.5, x)). \end{cases} \quad (2)$$

(x, y) is the original coordinate of the image plane, (u, v) is the target coordinate of the magnified display plane. $\text{smoothstep}()$ is the smooth Hermite interpolation between 0 and 1 when $0.25 < x < 0.5$.

4 PILOT STUDY

4.1 Experiment design

To improve the visual quality of the magnified display, we choose video see-through AR equipment to do the experiment. The first stage of this project is a pilot study using tablets to test visual search and indirect interaction. We will conduct a user study to test direct interaction with more magnifying solutions in Video See-Through Head Mounted Display (VST-HMD) in the future.

In the pilot study, users finish two tasks in three different display conditions – fisheye, rubber sheet, and no magnification.

- The first task is to find the virtual object with the wrong real label in a group of nine objects. The label is printed on paper using Times New Roman with font size 3. Each user does the visual search for 4 groups of objects with one magnification solution.
- The second task is to finish a mini hot wire game for each of the three conditions. Users use the control panel on tablets to control the ring go along the wire. If the ring touches the wire, the move forward button will be disabled and users need to adjust the ring to make it work again.

4.2 Participants

8 participants (3 female and 5 male) joined this experiment. We counterbalanced the order of the tasks to prevent a possible carryover effect. We also randomized the order of the conditions in each tasks (no magnification, fisheye and rubber sheet).

5 RESULTS

Fig. 3 shows the task completion time for both tasks. For task 1, we also measured the accuracy of each condition. Surprisingly, the median accuracy for each condition is 100%.

Based on the non-normal distribution observed in the data collected and considering the within-subject nature of the user study, we used Friedman tests with $\alpha = 0.05$ for the assessment of the experimental variables. However, the Friedman test reveals no statistical significance. The result of task 1 shows that the rubber sheet magnifier non-significantly decreases the readability of text. This result shows that visual distortion did not influence on users' visual search ability in our experiment. For task 2, the final result shows that there is non-significant drawback on interaction when we need to magnify something with distortion. However, interaction with rubber sheet performs worst in these three scenarios, which shows opposite result to our hypothesis. We assume that the rubber sheet magnification was too unfamiliar to most participants.

6 GENERAL DISCUSSION

6.1 Limitations

For task 1 of this pilot study, the limitation is that we designed only one mislabeled object in each group. This increases the users' accuracy and randomness because users may be able to find the wrong label without checking all objects. In task 2, although the final result shows that fine motor skills will not be influenced a lot by the distortion, we need to do more experiments with HMD and direct interaction between users and target objects to support this conclusion.

6.2 Future Plan

In the next stage, we will use some algorithms to improve the magnified video quality of VST-HMD and conduct a user study with more specific tasks.

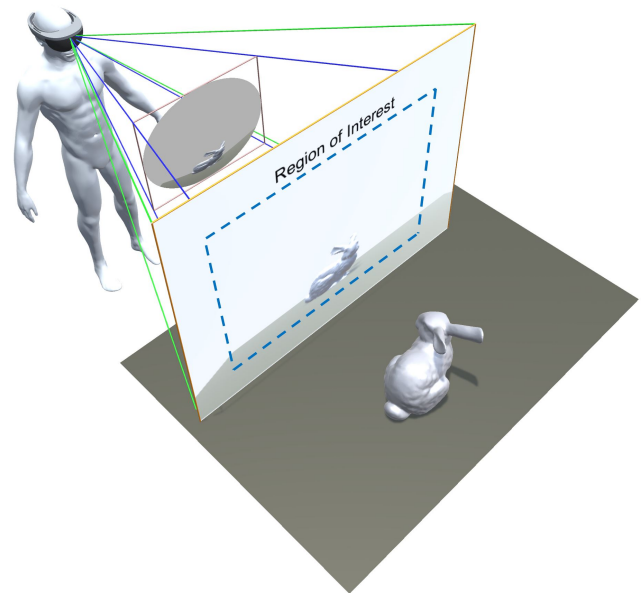


Figure 2: AR system set up

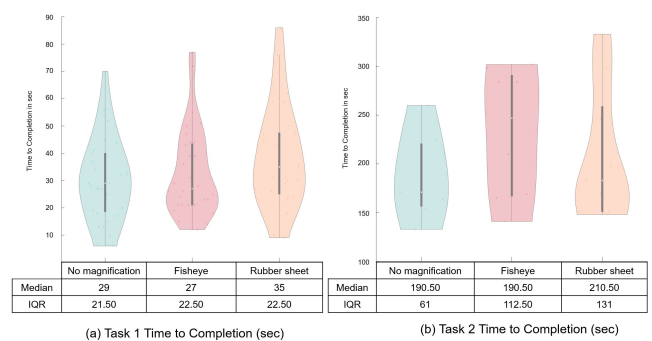


Figure 3: Task completion time in sec for task 1 (left) and task 2 (right).

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