Magnification Vision – a Novel Gaze-Directed User Interface

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ABSTRACT

We present a novel magnifying tool for virtual environments, where users are given a view of the world through a handheld window controlled by their real-time eye gaze data. The system builds on the optics of real magnifying glasses and prior work in gaze-directed interfaces. A pilot study is run to evaluate these techniques against a baseline, that reveals no significant improvement in performance, though users appear to prefer the new technique.

Index Terms: Human-centered computing—Human computer interaction (HCI)—Interaction paradigms—Virtual reality;

1 INTRODUCTION

Eye-tracking is becoming more common in consumer-class virtual reality systems. We demonstrate a novel interaction mechanism that uses interaction between the user's gaze and hand motion to create a magnifying lens. Our interface is related to metaphors in visualisation such as toolglasses or magic lenses [3]. These metaphors implement virtual versions of lenses so that a user can explore detail in a visualisation or rendering while retaining context of where they are. While originating in 2D user interfaces, they can now be found in a wide variety of user interface contexts, as discussed in recent surveys of the field [8, 9]. Looser et al. were possibly the first to introduce the concept of lenses to a 3D user interface context, supporting augmented reality interaction with volumes that acted as lenses [6]. Our magnification context will be a 2D window, but this is shaped by the user's hands in 3D space. Ashmore et al. investigated the interaction between eye-gaze and lenses [2], though only in a 2D context. Our implementation will act more like a real lens or a camera view that is shaped by the hands.

2 SYSTEM DESIGN AND IMPLEMENTATION

2.1 Designing the MagRect

The key interaction concept is that the user holds both hands in front of her face and focuses her gaze on the space between them to activate magnification. Once activated, a rectangular screen appears to fill the gap between her hands, displaying a magnified view of the environment on the other side. We refer to this rectangle as the *MagRect*. As the user shifts her gaze around on the surface area of the MagRect, the view zooms in in real time on the object being gazed at. In other words, looking through the MagRect at an object far away from the user increases magnification, whereas looking at an object close by decreases it.

The magnitude of virtual magnification ($\mathscr{M}$), is controlled by adjusting the FOV of the virtual camera that renders to the MagRect. Real-time eye gaze data is retrieved through the Tobii XR SDK using the Vive Pro Eye head-mounted display.

We created two variations on the magnification technique, one of which would zoom in on objects purely based on where the user was looking, and another which allowed her to modulate the zoom manually by moving her hands back and forth.

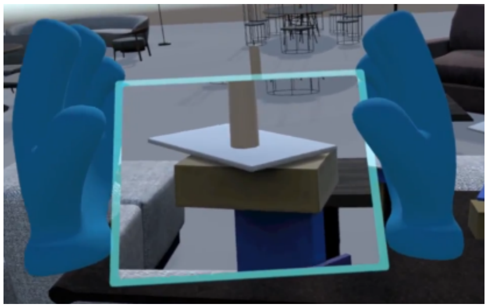

Figure 1: Interacting with the MagRect.

2.2 Gaze magnification

Every frame (t), the user's gaze intersects some object in the virtual environment – call the intersection point the ”target position”. As a visualisation aid for the user, the *GazeDot* was created: This is a small 2D circle sprite that displays on top of the target gaze position so long as the MagRect is active (see the item labelled ”Target” in Figure 2). The position of the GazeDot is set to a moving average of the last n gaze target positions, (similar to the “inertial reticle” detailed by [7]).

The aim was to make the magnitude of magnification a function of the user's gaze distance. Wanting to avoid the ”Midas touch” problem [4] while also keen to leverage the speed of eye gaze for fast interaction, we made the distance function an exponential moving average of the GazeDot's position over some buffer size m ($m > n$).

$$Dist(t) = \alpha \sum_{i=t-m}^{t} \frac{d(i)}{m} + (1-\alpha) Dist(t-1) \tag{1}$$

Where $d(t)$ is the straight-line distance from the user's head to the GazeDot in frame t, and $\alpha \in (0, 0.5)$ is the weighing coefficient. We thus set Gaze-based magnification to:

$$\mathscr{M}_{gaze}(t) = 1 + \lambda Dist(t) \tag{2}$$

i.e. the magnification factor scales linearly with gaze distance (adjusted by parameter λ), and is capped to a minimum value of 1.

2.3 Combined magnification

To see whether our new magnification technique could be improved by a degree of manual control, we implemented an alternative version of the MagRect that would behave more like a real magnifying glass. We implemented this based on optical formulae relating the distance of the lens from the user and from the virtual image displayed to the magnitude of magnification (referred to here as $\mathscr{M}_{manual}$) [5]. This produced an effect similar to a real-life magnifying glass, where moving one's hands back and forth increased and decreased magnification.

We proceeded to combine our Gaze magnification with this Manual magnification into a final technique we refer to as ”Combined” magnification:

$$\mathscr{M}_{combined}(t) = \beta \mathscr{M}_{manual} + (1-\beta) \mathscr{M}_{gaze} \tag{3}$$

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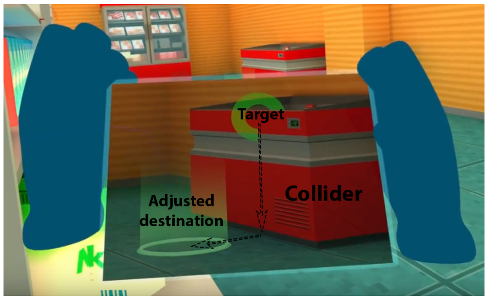

Figure 2: Gaze teleportation, where the user selects a teleportation target with the GazeDot, and has the final destination adjusted.

Figure 3: Screenshots from the trial scene, showing a hidden item on a shelf (left) and a shopping list display to guide subjects (right).

The resulting effect (depending on parameter $\beta \in [0,1]$), is one where the MagRect's magnification is determined partially by the user shifting her gaze around the view, and partly by moving her hands back and forth.

To allow users to move around a larger environment without distracting from the use of the MagRect, we also implemented a technique for gaze-based teleportation, as seen in Figure 2. Here the user would select a target destination with her gaze and warp to an adjusted floor-level position by holding down a controller button.

3 USER STUDY DESIGN

In order to assess the utility of magnification vision, we conducted a study to investigate whether users found the system useful and whether it improved their performance in a cognitive task. We also wanted to see which of our two techniques were most effective. This entailed designing a puzzle-based scenario where subjects could use the MagRect freely, and performance could be measured in terms of time taken to complete the task.

18 subjects (5 female; median age 23) were recruited as volunteers to participate in the study. The study was approved by the UCL Research Ethics Committee. The task designed was a simple object-search game, where five items were hidden in disparate sections of a supermarket scene. The subjects' task was to walk around the supermarket and find these special items, as shown in Figure 3. Item placement was randomised between trials.

Each subject performed the task three times using different implementations of the MagRect: Once with pure Gaze magnification, once with Combined magnification, and once with no magnification at all. This third technique was used as a control condition, in which the magnification factor is always set to 1, and the MagRect is only used to direct the GazeDot for gaze-based teleportation. After each trial, subjects completed a series of questionnaires, including a System Usability Survey (SUS).

4 STUDY RESULTS

Session data were parsed from session logs and compared using a one-way ANOVA (repeated measures), which found no significant difference in any performance measure between conditions (with $\alpha = 0.05$). SUS ratings also did not indicate any significant utility of one technique over another. From multiple choice responses (also compared with a one-way ANOVA), Combined magnification was rated significantly better than the other techniques only in its ability to correctly focus on objects users wanted to look at ($p = 0.0025$). Asked to rank the techniques in order of preference, Combined magnification was highest, but this was not significant ($p = 0.10$).

5 DISCUSSION AND CONCLUSION

The lack of statistical difference in performance is likely explained by the coupling between magnification and teleportation. In the described study, there was no clear way to tell whether a user was activating the MagRect and directing her gaze around it to zoom in on an object or to select a teleportation target, making interpreting data about just one of the two use cases difficult. Since teleportation around the supermarket scene is necessary to complete the task, but magnification is not, subjects likely behaved similarly across conditions, even when the MagRect did not zoom.

One can imagine more significant results might be gleaned from tasks where locomotion is constrained, such that magnification is essential. Examples could include looking at objects from a vehicle, inspecting multi-storey buildings while constrained to the floor, or exploring very large environments (using magnification as a telescope). We could also imagine using magnification-contingent LOD rendering for small scale inspection to reveal finer details in objects in a smaller viewport that would not be computationally feasible to render normally. A more comprehensive discussion of the MagRect and the study described here is provided in [1].

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