VRiAssist: An Eye-Tracked Virtual Reality Low Vision Assistance Tool

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Abstract

We present VRiAssist, an eye-tracking-based visual assistance tool designed to help people with visual impairments interact with virtual reality environments. VRiAssist's visual enhancements dynamically follow a user's gaze to project corrections on the affected area of the user's eyes. VRiAssist provides a distortion correction tool to revert the distortions created by bumps on the retina, a color/brightness correction tool that improves contrast and color perception, and an adjustable magnification tool. The results of a small 5 person user study indicate that VRiAssist helped users see better in the virtual environment depending on their level of visual impairment.

Index Terms: Human-centered computing—Accessibility—Accessibility design and evaluation methods; Human-centered computing—Accessibility—Accessibility technologies

1 Introduction

Vision impairment conditions affect millions of people around the world with an increased prevalence as the population ages. These issues prevent a person from enjoying their normal activities and if the activity is focused on vision, such as a virtual reality experience, it devolves into a negative experience. This problem is further complicated by the dynamic nature of the impairment and how it moves with the gaze of the user, resulting in limited efficacy for static solutions.

There are many forms of vision impairment, and details of the condition will change what is needed for the user to enjoy a virtual reality experience. For example, macular degeneration and central serous chorioretinopathy (CSC) leave the peripheral vision unaffected with only the center of the retina (macula) being affected [6, 9]. With this in mind, one of the main problems with assistive software techniques such as magnifying glasses, color inversion lenses, and contrast enhancers is that they target the whole field of vision which also includes the parts of the vision which are healthy [5]. Moreover, these tools are not reactive to where the user's eye is actually looking, which can create an unpleasant experience as the vision impairment condition follows the user's gaze. One of the best attempts to provide accessibility tools to visually impaired users in VR is SeeingVR which provides multiple tools to tackle different vision problems [10] but they do not integrate eye-tracking for dynamic corrections.

In this paper, we present VRiAssist, a novel approach that dynamically follows the retina with eye-tracking in order to introduce corrective measures and vision enhancing tools to the areas of the user's visual system that need enhancement rather than applying them holistically to the entire eye. By making use of a virtual reality head worn display with embedded eye-tracking, VRiAssist can improve a user's vision in a virtual environment. By using such a device, the eye-tracking component supports dynamic visual assistance as users look around in the virtual environment (VE), and by utilizing the head worn display component, the enhancements can be applied to either eye or both depending on the particular characteristics of the visual impairments for a given user. Using a simple calibration step, VRiAssist provides a distortion correction tool to revert the distortion created by bumps on the retina, a color/brightness correction tool that improves contrast and color perception in dark spots of the retina and a set of adjustable magnification tools. Figure 1 shows how an eye-tracked distortion+brightness can help a user with a retinal problem.

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(a) Healthy eye perception of the image. (b) Visually impaired user perception

(c) Corrected image using VRiAssist (d) User's perception of the image c

Figure 1: An example illustration of the visual correction tools (Distortion+Brightness in the center area).

2 VRiAssist Toolset

VRiAssist tools are overlayed on one or both images (left/right eye) of the graphics shown in a head worn display. VRiAssist's main goal is to provide a non-intrusive approach to vision enhancements for the users without over-processing the image and affecting the healthy parts of the user's eyes.

The three main tools in VRiAssist are Distortion Correction, Color/Brightness Enhancement, and Magnification. For each tool, we use an Amsler Grid [1] to calibrate the system based on the user's visual impairment problem. Usually, people with macular degeneration perceive the image of their environment distorted in the affected area, this distortion is more discernible when looking at an Amsler Grid since the person knows that the grid cells are square.

2.1 Distortion Correction

The distortion lens is used to undistort the user's vision in an elliptical spot. In some conditions such as wet macular degeneration, the fluid under the retina can create a bump in the retina which leads to distorted vision that follows eye movements, making static vision correction, such as glasses, ineffective. Using eye-tracking technology, we create a counter distortion in the image to create an undistorted region for the user.

The distortion lens contains the ability to have either a positive distortion, coming out of the screen, or a negative distortion, going into the screen. The distortion edges gradually morph into the image plane. A positive distortion is used for a dip in the retina while negative distortions handle bumps in the retina. To compute the distortion, we use the technique described by Gribbon et al [4].

2.2 Color/Brightness Enhancement

The Color/Brightness tool is the name for our visual enhancement tool that supports a variety of different enhancements including brightness, contrast, color saturation, hue, grayscale, light sensitivity mode, and color inversion. The tool can be applied to one or more spots on the retina depending on the type and severity of a user's visual impairments. For example, for a user with macular degeneration, we can apply a color/brightness enhancement to an elliptical region in the center of the retina while a user with diabetic retinopathy [3] might require enhancements to multiple spots across the retina. The tool also supports enhancements for a user's whole field of vision.

The tool can then be used to adjust the brightness and color properties of the image. Brightness can be adjusted in spots to accommodate users who experience dark spots in their vision. Contrast can be increased for users that experience foggy vision. Hue/saturation can also be adjusted for those that have color vision deficiency. Furthermore, the tool allows for the compression of higher intensity lights to help users with photophobia [2]. The difference between the light-sensitive mode and the brightness adjustment is that the light-sensitive mode will restrict the dynamic range of images so that higher intensity lights are compressed into less bright colors, while the brightness adjustment will only make the image darker. Finally, VRiAssist can invert the colors for the whole screen for better reading of texts. Similar to the Distortion Correction tool we use the Amsler Grid for calibration of brightness/contrast in the image.

2.3 Magnification

The magnification lens allows for dynamic magnification that can be elliptical or rectangular. To adjust the magnitude of the magnification lens, the user looks at a paragraph of text which is located on a wall in the virtual environment. They are then provided with the option of using a magnification lens and if requested the moderator will add the tool to the image and adjust the location, magnitude and shape of it based on the user's preference. Users are then able to choose whether the magnifier is attached to their gaze location or pinned to a location on the screen.

3 VRiAssist Evaluation and Results

To determine the effectiveness of VRiAssist we ran a small exploratory within-subjects user study to gather feedback and performance measures on how the tool works with users with a variety of visual impairment problems. We recruited 8 (2 males, 6 females) participants from a blind assistance center. Out of the 8, two were completely blind and would not benefit from VRiAssist and one participant was not able to finish the experiment given her severe visual impairments. Thus, we were able to successfully run 5 (1 male, 4 females) participants through our study. We collected demographic information on each participant including age, gender, whether they were legally blind, their visual impairment diagnosis, visual acuity, field of view, color vision and light sensitivity. It was important to gather this level of detailed information about each participant so we could determine how well VRiAssist would work with people with varying levels of visual problems.

Participants were randomly chosen to use VRiAssist first or second. The study had participants conduct tasks including a Snellen eye chart test [8], a simple reading task, a Landolt C eye test [7], and an interactive book sorting task with decreasing readability of the book titles. These tasks provided insight on user performance, eyesight improvement, and overall user experience to capture the strengths and limitations of VRiAssist.

Additionally, qualitative data such as perceived usability and quantitative data such as task accuracy were gathered and analyzed. Qualitative data was gathered from a post-questionnaire that included a Likert scale ranging from (1 = Bad or Strongly Disagree) to (7 = Perfect or Strongly Agree).

While statistical significance is provided, we note that the sample size is small. For the qualitative data we used the Mann–Whitney U test and found the overall experience with VRiAssist was significantly higher (Md=7, n=5) compared to without VRiAssist (Md=2, n=5), $U = 0.5, p < 0.02$. No significant statistical difference was found on frustration or performance. However, comments from individual users showed the tool worked well, and most importantly participants enjoyed the experience even if they did not have a significant increase in performance.

4 Conclusion

We have presented VRiAssist, a series of tools that allows dynamic corrections for distortion, brightness and color properties, and magnification via eye tracking technology built into the VR headset. While our initial user study contains a small sample size, the results show promise for VRiAssist in expanding VR accessibility to those that would otherwise be frustrated with their experience. We intend to move forward with our novel solution in both a more expansive user study and to show its potential for correcting real-world imagery via a see-through device.

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