Augmented Edge Enhancement for Vision Impairment using Google Glass

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Abstract

Google Glass provides a unique platform for low vision aids. We have implemented an augmented vision enhancement with Glass, by overlaying enhanced edge information over wearer's real world view. Contrast enhanced central vision can be naturally scanned over the ambient scene.

Keywords

Google Glass; HMD; vision enhancement; vision rehabilitation; contrast enhancement; low vision.

1. Objective and Background

Most people with impaired vision experience reduced visual acuity (VA) and contrast sensitivity (CS). These reduced visual functions have a large impact on their quality of life [1, 2, 3].

Various augmented vision - head mounted display (HMD) systems have been proposed and prototyped as aids for a variety of vision impairments [4]. Luo and Peli developed a see-through HMD for people with restricted peripheral vision by displaying a minified and cartoonized edge view of the scene on the HMD [5]. The device was shown to significantly improve wearer's search performance (e.g. reducing search time up to 74%). Using similar hardware configuration, they also developed a see-through augmented image enhancement device that superimposed edge image over a wearer's see-through view [6]. Visibility enhancement depends on the high contrast edges being aligned precisely with the see-through view. However, because the camera and HMD's virtual display do not share the same axis, parallax makes alignment of edges for different distances difficult. On-axis HMD-camera configuration was prototyped and achieved good alignment across a range of distances [7]. However, the brightness of the augmented edges was severely reduced by the optical combination system, such that the edges were too dim to provide significant visibility boost.

Commercial HMD type vision aids were usually bulky, requiring separate image processor and battery/power units, were not comfortable to wear, and were not attractive. For that reasons, these systems were not widely embraced by people with visual impairments.

Google Glass provides a unique development platform (both hardware and software) that can be easily extended to vision enhancement devices for visually impaired people, in a package that is attractive and substantially more comfortable than prior HMDs, and more suitable to social interactions. Google Glass has a wide angle camera, a narrow see-through display, and enough mobile CPU/GPU power to handle required image processing. Although a Glass specific API has not been provided yet, the android based operating system supports OpenGL ES and camera API. We explored the possibility of using the Google Glass, as a visual aid for people with impaired vision, by providing augmented edge enhancement.

2. Results

To provide an augmented vision, which overlays enhanced edge information over the wearer's real world view, the spatial alignment between the augmented and real-world view must be resolved. The inherent parallax is smaller than in earlier devices because the camera is located close to the display (horizontal displacement of 16 mm). Edge enhancement method and range of contrast strength to be enhanced should be user selectable because these factors depend on the individual's visual impairment, and user's anticipated task at hand. The user interface design for controlling enhancement parameters must be simple and intuitive.

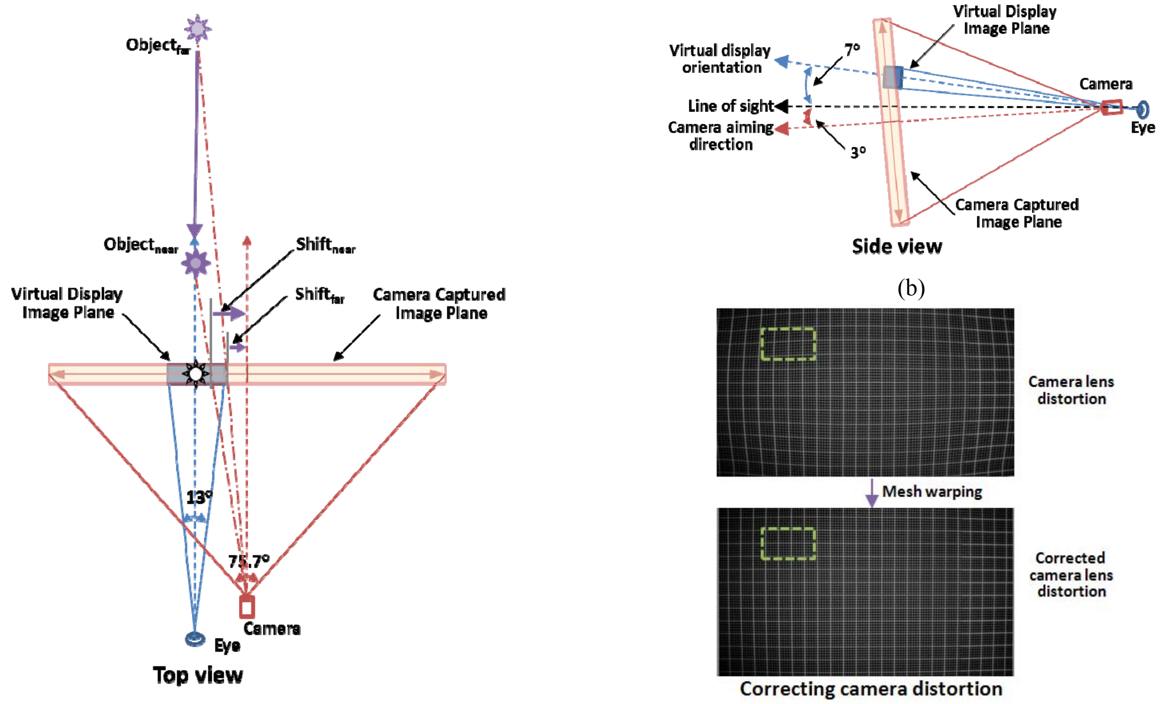
<u>Google Glass Hardware Information:</u> The Google Glass camera has a relatively large field of view (75.7˚ x 58.3˚) with 2528 x 1856 pixel resolution. During video recording, upper and lower portion of the captured image is cropped to the conventional, 16:9 screen ratio, and encoded to 1280 x 720 pixels at 30fps (720p).

The Glass' virtual display spans 13˚ x 7.3˚ at 640 x 360 pixels and is only available for the right eye. The camera and virtual display are encased in a single rigid compartment, so that adjusting the virtual display position (*e.g.*, by tilting or rotating the head) also changes the camera aiming angle. The camera is set to aim 10˚ downward relative to the display direction, and the virtual display is positioned 7˚ above the wearer's line of sight. Therefore, when a Glass wearer looks straight ahead through the display, the camera aims 3˚ downward, providing a natural camera picturing angle (see Fig. 1a-b). Note that the optics for the virtual display is angled at 7˚ downwards (delivering a small eye box), thus the virtual display is not visible if the display is not positioned at the designated location (7˚ above the wearer's natural line of sight).

<u>Assumptions for Augmented Vision Alignment:</u> The alignment process becomes simpler if we assume that the virtual display plane is always perpendicular to the line of sight. For Google Glass to be used as an augmented reality device, a user has to tuck his/her chin down, and look 7˚ upward. With this head/eye positioning, the wearer's head movements will naturally align the virtual display at the center of the wearer's visual field, bringing the display plane perpendicular to the wearer's line of sight.

<u>Correction of Camera Distortion:</u> The Glass's large field of view inevitably introduces camera distortions, which become larger at the periphery. For that reason, image alignment starts with correcting the distortion, which makes the captured image correctly represent the orthogonal projection of the scene. We measured the camera distortion by taking a picture of a square grid, and comparing the intersection positions to the locations where they should be to generate a corrective mesh. This mesh was used to warp the captured image to the ideal image plane projection (see Figure 1c).

<u>Correcting Image Zoom and View Point:</u> The camera captured image covers 75.7˚ x 42.6˚ field of view with 1920 x 1080 pixels. Since the virtual display covers 13˚ x 7.3˚ field of view with 640 x 360 pixels, only a portion of the image (330 x 186 pixels) is cropped and scaled up (1.94x) for the virtual display (see Figure 1c). The clipped image is projected onto the display plane rotated 10˚ counter clockwise around the x-axis to compensate for the



(a) (b) (c)

Figure 1. (a) Illustration of the 2D translation of projected image dependence on distance to the aimed object. (b) Schematic of Google Glass hardware configuration (not to scale): specifying the angular compensation needed between the virtual display orientation and the camera aiming direction. (c) Correction of Google Glass camera lens distortion. Note that only small portion of the captured image needs to be rendered.

relative angular difference between the camera direction and the virtual display orientation. Then, an additional 2D translation must be applied to bring the center of the captured image to the center of the display (see Fig. 1a). Note that the horizontal displacement between the camera and display causes parallax, thus the amount of misalignment between projected and captured images depends on the distance to the photographed objects. Since most visually impaired people are able to recognize near objects (less than 10ft away), the default parallax correction is set to 10ft. Users may adjust parallax correction with the Google Glass touchpad.

Implementation: Google Glass currently runs on Android 4.03 and fully supports OpenGL ES 2.0. Our application utilizes the 3D graphic hardware pipelines by implementing the necessary graphic processes algorithms on vertex and fragment shader levels. Camera distortion correction (*i.e.*, warping), image projection correction (*i.e.*, rotation and translation), and viewpoint control (*i.e.*, image clipping and zooming) are modulated by vertex shaders. The edge enhancement was implemented on fragment shaders, so that only the visible portion of the captured image (about 330 x 186 pixels out of the original captured image, 1920 x 1080 pixels) is processed. This effectively reduces overall image processing load by a factor of 33.8 and allows the system to achieve acceptable real-time frame rate.

Control of edge enhancement: Usual implementation of edge detection algorithm enhances all edges in the scene, in proportion to the local contrast (luminance gradient). As a result, clearly visible edges of the scene are often over-emphasized, and low level noise is visible, interfering with natural scene interpretation. This does not provide practical improvement and is not preferred by users [8]. Applying a single threshold to the edge strength for enhancement only solves half of the problem (e.g. high contrast threshold to prevent 'over-enhancement', or low threshold for 'noise removal'). Selective edge-strength range for enhancement results in better performance for some tasks (e.g. face recognition) [9][10], and increased preference towards the edge enhancement. Therefore, the user should be able to choose the range of contrast strength of the image to fit his/her needs.

Our edge enhancement algorithm currently has a built-in double thresholding such that user can select a particular contrast strength range by applying a two-finger gesture on the touch pad, where two-finger pinching sets the width of contrast-strength range, and two-finger sliding sets the average contrast to be enhanced (see Fig. 2b-c). With optical see-through system, such as Google Glass, edge enhancement can only be implemented using with bright/white light, contributing to visibility enhancement mostly over darker portions of the scene. Note that dark/black edges on see-through systems are essentially invisible [7]. As a result, current edge enhancement shows minimal effect over brighter areas of the ambient scene (see Fig. 2e-f, for the apparent lack of contrast enhancement on the mug handle, compared to the rest of the mug).

3. Discussion

The small span of the virtual display limits the angular extent of the augmented edge enhancement, but may not limit the effectiveness of the device. Most users with impaired vision retain normal peripheral vision, which supports natural guidance of the virtual display and augmented edges to the objects of interest, and enables scanning through the scene with head movements. This enables a mode of operation similar to those with normal sight,

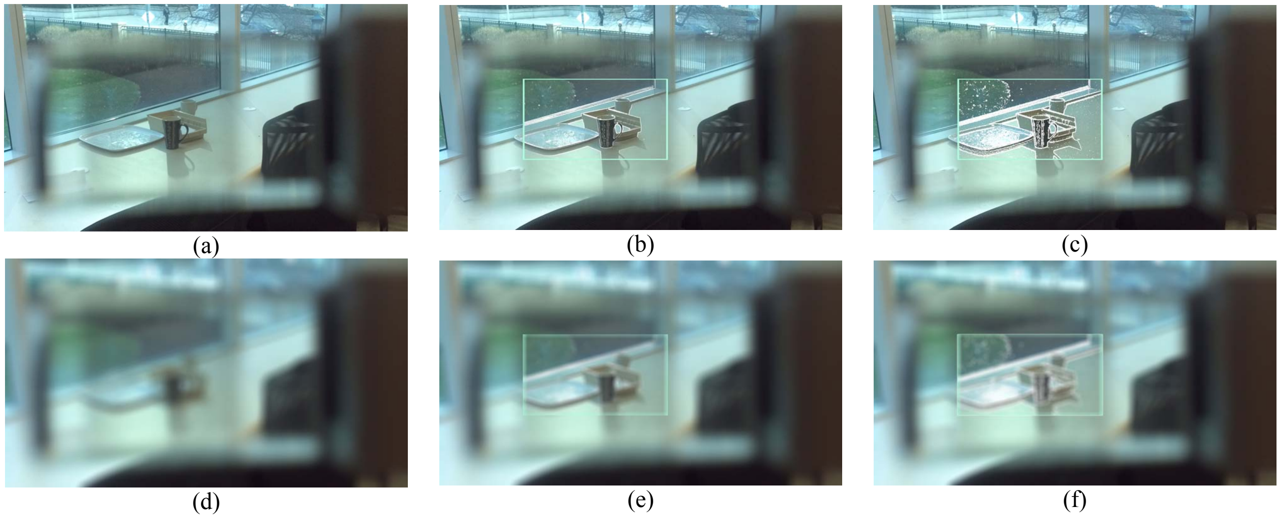


Figure 2. (a)–(c) Photo of a scene taken through Google Glass, simulating the scene viewed by normal vision (NV): (a) without augmented edge enhancement, (b) with medium strength edge enhancement, (c) with full strength edge enhancement. (d)-(f) Corresponding simulated views of the scenes in (a)-(c), seen by impaired vision (IV) (blurred). Note that visibility of details is improved with strongly enhanced augmented edges (e), compare to (d), but over-enhancement (f) may reduce object recognition, compare to (e).

where peripheral vision, which naturally has low VA and CS, guides foveal gaze [11], and performs ego/exocentric motion perception [12]. Once the target of interest is selected, detailed inspection is mainly carried by the foveal area which has high VA and CS. In our application, the contrast of the patient's foveal area is enhanced by augmented high-contrast edge.

4. Impact

We demonstrated that augmented vision enhancement can be efficiently implemented on Google Glass, providing a visual aid for people with impaired vision. The effectiveness of the contrast enhancement, termed *wideband enhancement* [9] has been previously shown to improved performance on visual tasks. Most importantly, Google Glass's appealingly and compact design opens new possibilities of developing acceptable HMD-based vision aids for people with impaired vision at reasonable cost.

5. Acknowledgements

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