P-16: Augmented View for Tunnel Vision: Device Testing by Patients in Real Environments

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Abstract

An augmented-vision device for patients with severely restricted peripheral visual field (tunnel vision) was proposed, combining a see-through HMD and minified contour detection. Implemented commercial off-the-shelf (COTS) configurations were tested in real environments by Retinitis Pigmentosa patients and normally sighted subjects.

1. Objective and Background

In normal vision two different subsystems operate: wide angle peripheral vision (in low resolution) and central vision (with high resolution). The perception of a wide field with high resolution vision is achieved by scanning saccadic eye movements (~3saccades/sec). Several eye diseases such as Retinitis Pigmentosa (RP) and Glaucoma produce a severe restriction of the peripheral visual field (tunnel vision), though the patient may maintain their central vision (with high resolution) [4]. Tunnel vision limits patient's mobility because of a reduced ability to spot obstacles and difficulties in navigation. Current visual aids increase the field of view by minification but thus compromise the resolution of the remaining central vision [1][2].

The requirements from tunnel vision visual aids are:

- To provide information about objects in the peripheral field.
- To be compatible with the remaining visual capabilities (resolution and visual field).
- To be compatible with natural eye movements.
- Ability to function in light and dark (important when the disease causes night blindness).
- To permit use of spectacle correction
- To be portable, low weight, long lasting operation, and cosmetically acceptable.
- To use COTS design preferably, due to the small size of the market.

An Augmented Vision device has been proposed and implement as a new approach to visual aid design for severe loss of peripheral visual field [5]. The proposed Augmented Vision principle provides a visual multiplexing of the high-resolution vision and the wide field of view. This approach consists of a combination of a see-through HMD, a wide-angle video camera and an image-processing unit. The head-mounted video camera provides an image of a wide field (up to 75 deg.). The image-processing unit creates a "cartoon" of the scene by using a contour (edge) detection algorithm. Contours are presented as bright lines and shown on the see-through HMD with a scene reduction (minification) of 3 to 5 times (Fig. 1). Also, see video simulations in our website [6].

2. Methods and Results

Several combinations of COTS components were used to create the proposed augmented vision system and were evaluated with normally sighted people and two RP patients with severely reduced visual field (5-10 deg). Initial evaluation was carried out in the lab. When the devices were modified to be portable, walking evaluations were performed indoors, including stair climbing in light and dark rooms, and outdoor walking on the street under daylight and at night (Fig. 2)

Figure 1: Augmented Vision simulation showing the instantaneous patient view with the device

Figure 2: Patient Evaluation at night shown here with the MicroOptical ClipOn system

Two cameras were tested:

- The **Mitsubishi M64283FP CMOS Artificial Retina** has 128×128 B/W pixels. This camera includes in-chip images processing and edge detection. Using a PC as a controller, we obtained 5 frames-per-second (fps) in the Edge Detection mode. With the appropriate lenses, the horizontal fields were 58° and 78°.
- The **MicroOptical USB ClipOn Camera** (Fig. 3) is a color web-cam with 640×480 pixels that attaches to ordinary eyeglasses temples. It has a high sensitivity at low illumination level, and auto-gain control based on the final image. We obtained 59°, 72°, and 97° horizontal fields with the appropriate lenses. The edge detection was performed by software-based processing. In this mode, the frame rate was 5 to 22 fps depending on the light level.

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Also we tested six commercially available and prototype HMD's (see tables in next section for technical details):

- The **Sony Glasstron PLM-50** is a binocular device that displays color a NTSC signal with a continually selectable see-through density.
- The **Virtual Stereo I-O HMD** displays a color NTSC signal in see-through with an open peripheral design.
- The **Olympus Monocular Eye Trek** is a VGA color display (800 x 600 pixels), see-through.
- The **MicroOptical Integrated EyeGlass** (monocular) is a built-in-spectacle QVGA see-through display [6].
- The **MicroOptical ClipOn** (monocular) is an opaque color QVGA display that attaches to ordinary eyeglasses or safety glasses.
- The **MicroOptical VGA ClipOn** (monocular) similar to previous with higher resolution and field (Fig.3).

Figure 3: ClipOn HMD (left) and Camera (right)

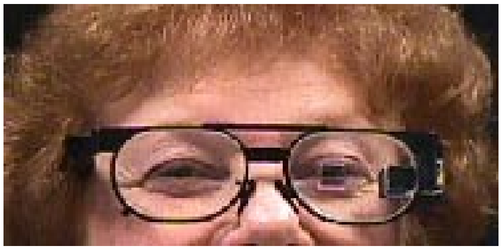

Figure 4: Integrated EyeGlass Display

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The values of visual field and fps rate provided in the tables are from experimental measurements. They depend on the anatomy of the subjects and the illumination level and control system.

A laptop PC was necessary for the camera control (and is not expected in a final product). An 8 neighbor point gradient algorithm for edge detection algorithm was applied and a saturated look-up-table was used to binarize the final image (by hardware or software). Minification values were controlled by display software as well.

3. Patients' preferences for HMD's and cameras

In addition to the tabulated preferences shown on the next page, patients had the following comments:

- **Color** display may help with the correspondence between the displayed and the real world (if Augmented Vision not used)
- **Binocular** displays were preferred, even though **monocular** HMDs have advantages (field, transparency, weight, cost, clearance).
- Preferred using own **spectacle correction**.
- **Clip-on** concepts were preferred (Fig. 3). Patients can use them in either bioptic or central position by choice.
- **Integrated Eyeglass** design was attractive to subjects due to its aesthetic look and the open field around the display (Fig. 4).

Our assessments for further design requirements of Augmented Vision aids are:

- **Small HMD size** is not a limitation. Patients preferred smaller displays. This is supported by Preliminary measurements showing that their fixation field is narrower (50%) than that of normally sighted people.
- **Minification** should be close to 5 times. This values permits providing a wide field of camera (~75º) in a small display. Therefore, patients don't need to scan with large eye movements in order to obtain information of the wide field. However, one of the subjects, who presents less than 10 deg visual field, shows strong preference having a configuration such as a display field slightly smaller than his visual field (as 2/3 ratio) with a minification factor up to 10 times. This configuration allows him to notice the whole outlined scene in once glance, still being able to process the information displayed on the display. With higher minification factors, the image becomes too small and busy.
- It is necessary to **improve camera sensitivity**: IR illumination should be provided to supplement signal in darkness for edge detection performance. For Augmented Vision neither color camera nor high resolution are necessary, so camera pixels can be larger sized and IR sensitive, improving light efficiency.
- **Controlled brightness:** High brightness is needed in sunlight while in dim illumination reduced brightness prevents dazzle. Patients with night blindness require more display brightness in the dark. In addition, manual control of display brightness in dim illumination is desirable.
- **Video rate** display and acquisition are needed. If the frame rates are slowest, patients need to stabilize their head before an image can be viewed, due to the delay.
- Avoid need for **focusing:** patients would prefer an auto-focus system or a large depth-of-field. Further, edge detection requires well-focused images.

4. Expanded Field of View

The main purpose of the visual aid, the expansion of the visual field, depends strongly of devices parameters such as contrast, brightness, and ergonomics such as stability and adjustment features. Hence, explicit measurement of the expanded visual field is need in the evaluation of the device. We present, as example of this, the measured expanded visual field of a tunnel vision patient using two different HMDs and we compared the results with those with his unaided visual field.

The systems evaluated were the Sony Glasstron HMD and MicroOptical Eye Glass HMD, both in conjunction with the Mitsubishi Artificial Retina camera. The Glasstron's system had a minification factor 2.6 while the EyeGlass' had a mification of 5.

The visual fields were measured using a clinical device the Auto-Plot perimeter (Bausch & Lomb) in dim room illumination, with white light target of 3mm and 6mm diameter at 1m. As a fixation target we used a laser pointer spot.

Display	Bi / Mo -nocular		Visual field (Horiz.)		Clearance		See-through transmittance	
Sony Glasstron	Bi	xx	22°		39° Binoc.		variable	
Virtual IO	Bi	xx	22°		~Full	xx	5%	
Olympus Eye Trek	Mo		21°		26° Mono.	x	15%	xx
MicroOptical EyeGlass	Mo		17°	xx	~Full	xx	47%	xx
MicroOptical ClipOn	Mo		7.5°	x	~Full	xx	Opaque	NA
MicroOptical VGA ClipOn	Mo		16°	xx	~Full	xx	Opaque	NA

(x) It represents preference by a subject; (NA) Not Applicable

Clearance means the visual field not blocked by the HMD frame. This aperture implies a limitation to the scanning of peripheral visual field through the display and may be larger than the displayed image size.

Display	Contrast		Brightness		Brightness control		Resolution		
Sony Glasstron	N/A	xx	N/A		Full	xx	262 x 230		x
Virtual IO	87%	xx	N/A		No		262 x 230		x
Olympus Eye Trek	63%	xx	N/A	xx	3 Levels	xx	800 x 600		xx
MicroOptical EyeGlass	30%		N/A		No		320 x 240		x
MicroOptical ClipOn	N/A	xx	N/A	x	No		320 x 240		x
MicroOptical VGA ClipOn	N/A	xx	N/A	x	No		640 x 480	xx	xx
								Gray scale	Edge

(Edge) Augmented Vision presentation; (N/A) Not measured

We were unable to measure effective retinal illumination (brightness) because of the interaction between the display exit pupil and the luminance meter aperture [3]. This will be addressed in the future.

Display	Image position		Ergonomic confort	
Sony Glasstron	4m	xx	Helmet	
Virtual IO	4m	xx	Head Band	
Olympus Eye Trek	0.5m		Head Band	
MicroOptical EyeGlass	1m	x	Build-in-spectacle	xx
MicroOptical ClipOn	1m	x	ClipOn	x
MicroOptical VGA ClipOn	1m	x	ClipOn	x

Camera	Auto Gain Control			Light Sensitivity			
Mitsubishi Artificial Retina	Yes / No	x	No auto		x		
MicroOptical ClipOn camera	Yes	xx	xx	xx	xx	x	
		Gray scale	Edge	Gray scale	Edge	Gray scale	Edge
				High/Dim Illumination		Dark	

Camera	Frame Rate			Color / BW			Resolution		
Mitsubishi Artificial Retina	5 fps			B/W		xx	128 x 128		x
MicroOptical ClipOn camera	6 - 20 fps	xx		Color	xx	xx (B/W)	640 x 480	xx	xx
		High/Dim Illum.	Dark		Gray scale	Edge		Gray scale	Edge

Camera	Field (Horizontal)	
Mitsubishi Artificial Retina	58°	x
	78°	xx
MicroOptical ClipOn camera	59°	x
	72°	xx
	97°	x (distorsion)

Minification	
1:2	
1:3	x
1:4	xx
1:5	xx
1:10*	x

Potential Focusing	
Fixed	
Manual	x
Auto	x
Large depth of field	x

Table: Specifications and results

The Figure 5 shows the perimetry results for the two systems (only the result of the 6mm target are plotted, the results with the 3mm target were not different).

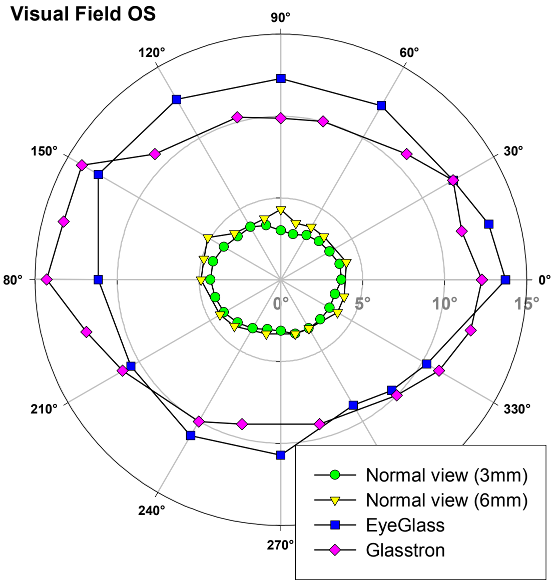

Figure 5: Visual field of a RP patient with normal view and Augmented Vision.

The expanded field using the Glasstron fulfilled the expectations. However, the field was only doubled using the EyeGlass despite the minification factor 5. This was probably due to the low contrast, primarily as result of a poor light extinction of the LCD in our system. The low contrast affects the patient's detection of the target. In addition, users with tunnel vision may have more difficulties adjusting HMD's with maxwellian view, such as the EyeGlass. Therefore, such systems need to be better equipped for adjustment and remain more stable on the head.

5. General concept opinion

Patients consider Augmented Vision useful for navigating, obstacle avoiding, and hazard prevention. Training may be necessary to gain veridical perception of visual direction and correspondence between the real world and the displayed contour image.

6. Acknowledgements

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