Real Time Image Processing on a Portable Aid Device for Low Vision Patients

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Abstract. Low vision patients are subjects with very restricted visual fields or low contrast. There are different pathologies affecting this kind of patients. From a functional point of view the residual vision can be classified in three categories: low contrast vision, tunnel vision and peripheral vision. This contribution describes simple real-time image processing schemes that can help this kind of patients. The presented approaches have been implemented in specific hardware (FPGA device) to achieve real-time processing with low cost portable systems. This represents a very valid alternative to optical aids that are widely used in this field.

1 Introduction

There are several kinds of low vision patients suffering pathologies that reduce their visual fields. The pathologies can be classified in two types:

- Degenerative: in this case the visual capability gets degraded progressively.
- Post-traumatic: the visual field restriction has been produced by an accident, and the damage is permanent but stable.

The residual vision can have different characteristics. There are patients that loose their peripheral vision (they suffer from tunnel vision). These patients are able to read and watch TV, because both tasks require a very small visual field (fovea vision). However, their capability to walk and navigate in an urban environment is very limited. Other patients loose their fovea vision (due to macular degeneration for instance); they suffer from peripheral vision. In this case, the subject loses his central visual field; they can walk easily and avoid objects but they can hardly read and watch TV. Finally, there are other pathologies (such as retinitis pigmentosa) that produce low resolution vision. The prevalence of these different kinds of anomalies is very low (about 17 per thousand). Normally these patients use lenses based devices [1], [2] to partially compensate this restricted vision, although different research groups explore the possible use of electronic technology for real-time image processing in this field [3], [4], [5]. There are also commercial products [6] but they are video magnifiers, with low portability and only providing zooming capabilities.

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The motivation of using reconfigurable hardware (FPGAs) in this application can be summarized in the following points:

1. The population suffering these pathologies is reduced and very diverse. Each patient has his own requirements: tunnel vision, peripheral vision, low contrast, etc; furthermore each patient may suffer from a kind of limited vision in different degrees. Therefore, instead of developing a different platform for each of these visual restrictions, a single hardware platform can be customized for different image processing tasks.
2. Temporal disease evolution. The systems need to be adapted to the pathology evolution in the degenerative cases.
3. Portability. The image processing device needs to be carried by the patient in order to be used for walking and similar tasks.
4. Low cost: these devices represent only aids, in the absence of a definitive solution to their limited vision. Each patient has different requirements, which make the system difficult to be used by different subjects without reconfiguring it.

The complete system for low vision aids is shown in Fig. 1. It is composed of a camera (image acquisition), a FPGA device (for real-time image processing) and a portable display (HMD: Head Mounted Display) NOMAD ND2000 16 º HF.

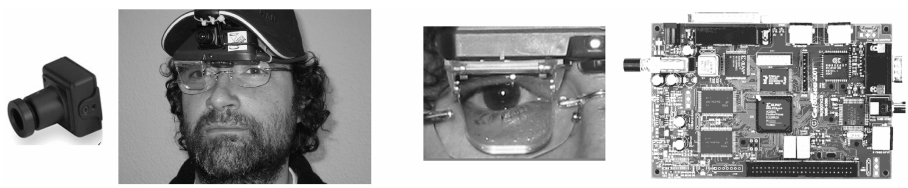


Fig. 1. Low vision aid composed of a camera, a FPGA prototyping board and a HMD

In this work we describe the design and hardware resources cost of a real-time image processing device for this kind of application. We use a low cost FPGA prototyping platform (RC100 of Celoxica [7] shown in Fig. 1) that includes video input and VGA output.

2 Real Time Image Processing

We have focused on the implementation of three simple image processing algorithms that are useful for the described pathologies. In this way, a single board could be fabricated for the different pathologies. The medical specialist only needs to program the configuration EPROM with the proper file to adapt the device to a specific pathology and a restriction degree.

The three developed applications are: Contrast enhancement. For patients with low contrast vision, edges multiplexing with the original image in the central visual field (useful for patients with tunnel vision) and digital zoom of the image for patients with peripheral vision.

2.1 Contrast Enhancement

The contrast enhancement that we have implemented consists in extracting the edges and superimpose them with the original image at the same position with a polarity that depends on the context (this requires a not transparent HMD). That means that we redraw a black trace on a light background and a white trace on a dark background, as it can be seen in the marked area in Fig. 2.a. After testing different contrast enhancement algorithms we have chosen this approach due to its high quality and low computational requirements. The patient can control the relative intensity of the re-drawn edges with two buttons.

(a) **(b)**

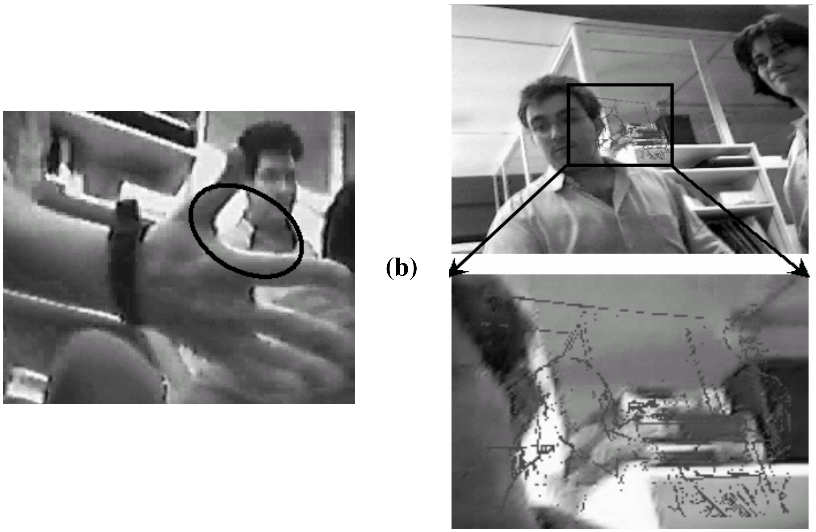


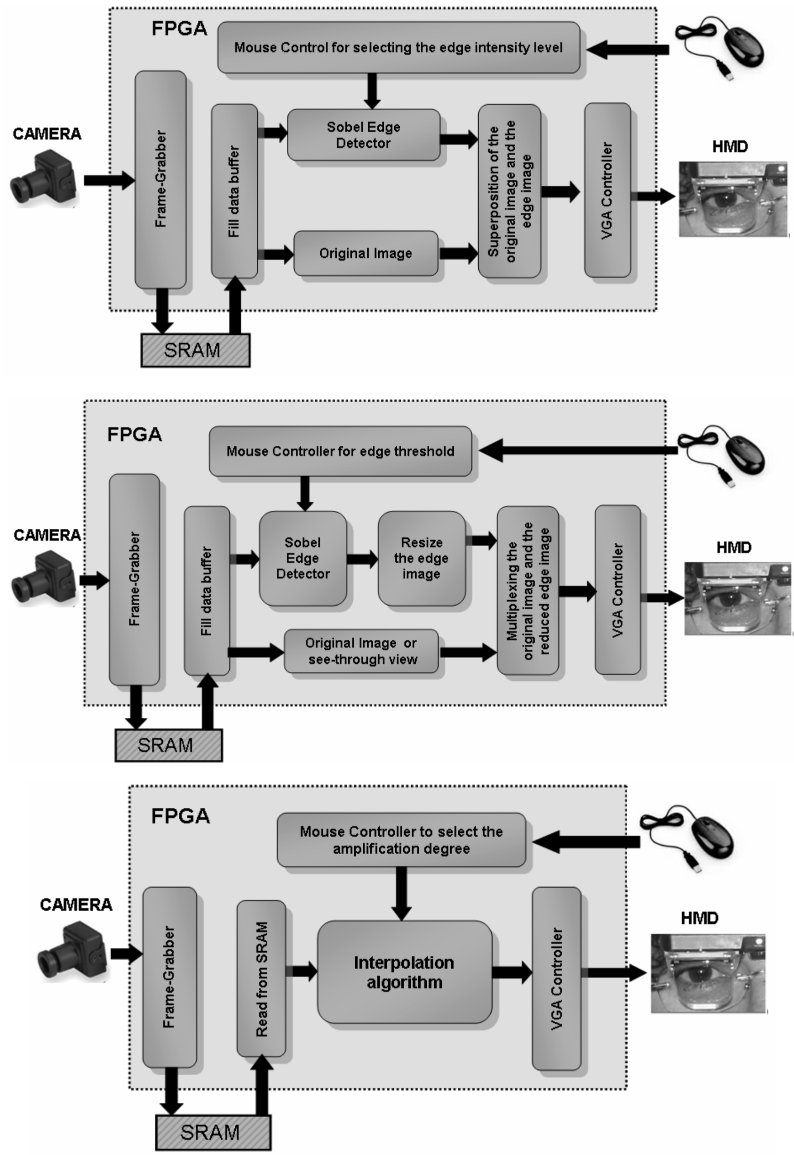
Fig. 2. (a) Contrast enhancement. (b) Global scene structure multiplexing (edges multiplexed in the central visual field). The bottom figure shows a detail of the patient's visual field.

2.2 Global Scene Structure Multiplexing

The patients with tunnel vision have a very restricted central visual field but of high resolution. For these patients it is useful to have information of a wider visual field to be able to walk easily. For this purpose, as an alternative to wide angle lenses [8] other authors have proposed the possibility of drawing the edges of a wider visual field on the central visual area. In this case, the patient can focus his attention on the edges to walk and neglect them or even switch them off for other tasks. This kind of image processing is shown in Fig. 2.b. This application requires a see-through HMD as shown in Fig. 1. It is important to give the patient the possibility of controlling easily (with two buttons) the edges threshold. In this way, he controls the amount of information that is displayed on the top of the central visual field.

2.3 Digital Zoom

The patients with peripheral vision have a wide visual field but with low resolution. Currently, telescopic devices (based on lenses) are being used as aids [9] to read. For this kind of pathology we have implemented a digital zoom, in this way the patient can control easily (with two buttons) the zoom used in each moment.



(a)

(b)

(c)

Fig. 3. Block diagrams of the different systems. (a) Contrast enhancement. (b) Global scene structure multiplexing. (c) Digital zoom.

3 Image Processing Implemented in Specific Hardware

The three designs have been included in an EPROM memory on the RC100 prototyping board shown in Fig. 1. In this way, the platform can be configured for each particular task For the three algorithms, the FPGA (Spartan-E 200K) of Xilinx [10] included in the board is configured with an embedded frame-grabber as front end, that receives the images from the camera. After this stage the image processing module depends on the algorithm, and finally the output stage generates a VGA format image. The FPGA includes 200K gates that are enough to implement the three described applications.

Fig. 3 shows the block diagrams of the three processing schemes, which have been implemented in the circuits. Table 1 indicates the characteristics of the circuits designed for the image processing tasks described above. All of them include the input (frame grabber) and output (VGA signal generator) modules. The frame grabber has been used in the three designs and requires 757 slices (32% of the device).

Table 1. Hardware resources cost using a FPGA Spartan-E 200K of Xilinx

	Number of Slices	**Device use (%)**	**Frames/sec**
Contrast enhancement	1319	56	25
Edges multiplexing	2350	99	25
Digital Zoom	948	40	25

4 Discussion

We have described an aid platform for low vision patients based on real-time image processing. Three simple image processing algorithms have been adopted for the three described pathologies: tunnel vision, peripheral vision and low contrast vision. The circuits implemented for these processing tasks have been described, and the implementation costs (in terms of the device usage) have been evaluated. Taking into account that we have used a very low cost FPGA, the results are very promising. The complete platform is composed of a camera, a processing board (with a FPGA device as processing chip) and a HMD. Currently the described platform is being evaluated with real patients in different tasks. A preliminary evaluation has produced promising results: a) we are able to expand the actual visual field of tunnel vision patients by a factor of 4.5 using the global scene structure multiplexing without significantly degrading the visual acuity, b) although their ability to walk in environments with obstacles experimentally remains constant, it increases considerably the users confidence, c) the visual acuity increases linearly using the digital zoom application with different augmentations (x2 steps) up to a level of 0.6 where it saturates towards a value of one [11], and d) the contrast enhancement application has been evaluated by [12]. We also have tested the system autonomy. The nomad HMD uses its own batteries with about 8 hours of autonomy. We measured the current consumption of the FPGA platform which is 410 mA (80 mA coming from the camera). We use a standard Ni-Mh battery of 2400 mA, providing a total system autonomy of five and half hours.

The main contribution of the presented work is the implementation of specific hardware for simple real-time processing tasks for specific visual pathologies. Other simple image processing tasks (image polarization inversion, contrast inversion) have already been implemented and are also being evaluated for different diseases. The great variability in the pathology affection levels and also the gradual evolution of the pathology makes reconfigurable hardware a very appropriate technology for this kind of applications.

Acknowledgments

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References

1. Peli, E.: Field Expansion for Homonymous Hemianopia using Prism and Peripheral Diplopia. Technical Digest on Vision Science and it Applications, Vol. 1. Optical Society of America, Washington, DC (1999), pp. 74-77
2. Kozlowski, J.M., Mainster, M.A., Avila, M.P.: Negative-lens field expander for patients with concentric field constriction. Arch. Ophthalmol, Vol. 102, (1984), pp. 1182-4.
3. Vargas-Martin, F., Peli, E.: Augmented view for restricted visual field: multiple device implementations. Optometry and Vision Science, Vol. 79, 11, (2002) pp 715-723.
4. Toledo, F. J., Martínez, J. J., Garrigós, F. J., Ferrández, J. M.: An Augmented Reality Visual Prothesis for People Affected by Tunneling Vision. LNCS, Vol. 3561, (2005) pp. 319-326.
5. Venkatachalam, R., Strong, J.G., Wong, W., Hornsey, R.: Digital Zoom for Low Vision Enhancement Systems. IS&T/SPIE Sym. on Elec. Im., San Jose, USA (2004), pp. 18-22.
6. Clarity company web site: http://www.clarityusa.com/products.htm
7. Celoxica company web site: http://www.celoxica.com.
8. Peli, E.: Vision multiplexing: an engineering approach to vision rehabilitation device development. Optom Vis Sci 78, 5, (2001) pp. 304-315.
9. Cohen, J.M.: An overview of enhancement techniques for peripheral field loss. J Am Optom Assoc, Vol. 64, (1993) pp. 60-70.
10. Xilinx company web site: http://www.xilinx.com.
11. Vargas-Martín, F., Peláez-Coca, M. D., Ros, E., Diaz, J., Mota, S.:A generic real-time video processing unit for low vision. ICS, Vol. 1282, (2005), pp. 1075-1079.
12. Peli, E., Kim, J., Yitzhaky, Y., Goldstein, RB., Woods RL.: Wide-band enhancement of television images for people with visual-impairments. J Opt Soc Am A, 21, 6, (2004) pp. 937-950.