International Congress Series 1282 (2005) 1075–1079

www.ics-elsevier.com

A generic real-time video processing unit for low vision

Fernando Vargas-Martín[a,*], M. Dolores Peláez-Coca[a], Eduardo Ros[b], Javier Diaz[b], Sonia Mota[b]

[a] *Dep. Física, Edificio C, Campus de Espinardo, Universidad de Murcia, 30100 Murcia, Spain*
[b] *Dep. Arquitectura y Tecnología de Computadores, Universidad de Granada, Spain*

Abstract. We describe a generic real-time video processing system for applications in the field of electronic visual aids. A working system has been implemented using a specific hardware (FPGA device) to achieve real-time processing in low cost portable systems. The inclusion of a reconfigurable circuit FPGA allows real-time video processing, the setting control by the user, and personalisation for each individual person in a simple way, resulting in a unique platform to be included in static and portable CCTV systems or in video displays. Several processing algorithms applied to a video source, as digital zoom, edge enhancement or the augmented view scheme are implemented in this device. © 2005 Elsevier B.V. All rights reserved.

Keywords: FPGA low vision; Visual aid; Video enhancement; Video magnification; Visual field expansion; Augmented view; Optoelectronic

1. Introduction

There are several causes of Low Vision (LV) pathologies. These pathologies can be divided into two groups, those that mainly produce a loss of visual acuity (macular degeneration; diabetic retinopathy; optic atrophy; cataracts, and oscilopsy) and those that mainly produce a reduction in the overall visual field–tunnel vision–(retinitis pigmentosa, glaucoma or damage of the brain). Other factors that are also affected include contrast sensitivity, adaptation to light changes (night blindness), color vision.

Some pathologies are characterized by a slow progression leading to eventual blindness. In these cases, the visual rest deteriorates gradually with time; therefore, each patient has different requirements that change as the disease advances.

---

* Corresponding author. Tel./fax: +34 968398317.
E-mail address: vargas@um.es (F. Vargas-Martín).

0531-5131/ © 2005 Elsevier B.V. All rights reserved.

doi:10.1016/j.ics.2005.05.107

Conventional visual aids (optical/electronical) try to restore the lost component by compromising the remaining visual capabilities [1].

In this context, the main contribution of the present work is the implementation of a new optoelectronic platform (based on reconfigurable architecture FPGA) that allows the development of LV aids for a wider range of applications and tasks [2].

2. Motivation

In this work we describe the design of the real-time image-processing device for general visual rehabilitation. Using reconfigurable hardware (FPGA) allows fast image processing algorithms at video rates. The system is able of implementing several processing algorithms without modification. Therefore, a single board could be fabricated for the different impairments, reducing manufacturing costs for a larger user target population, and adapting to possible temporal disease evolution in the patient.

3. Device description

The aid can be described as a CCTV with real-time processing. A FPGA is the core or the proposed aid. We use a low cost prototyping board Celoxica RC100, which includes an on-board video frame grabber, a FPGA Xilinx Spartan II, and a VGA output. This board accepts NTSC/PAL/SECAM and RGB outputs. The FPGA includes 200K gates that are enough to implement different circuits, defined with a high level Hardware Description Language (HDL), Handel-C of Celoxica. The system is easily reconfigurable for the different needs of the subjects by simply modifying the programs stored in the EPROM using the parallel port.

4. Real-time video processing schemes

We have implemented three simultaneous algorithms as example of the capabilities for the FPGA board. Results from preliminary evaluations are shown in Section 6.

4.1. Digital zoom

The digital zoom that we use can be easily controlled through switches and the target zone to be amplified can be selected and shifted with a conventional mouse or a head-

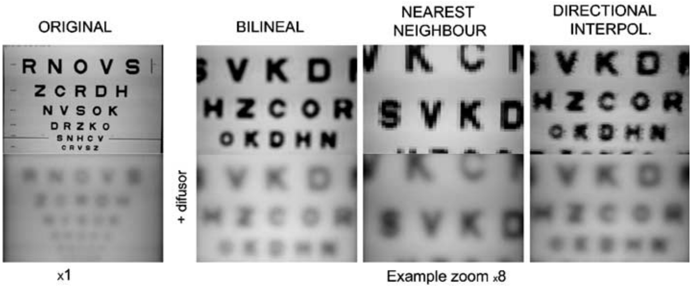

Fig. 1. The top row of images illustrates the different kinds of zoom (×8 in all cases). The bottom row illustrates the simulation of low vision implemented using a filter between the subject and the display at 15 cm of distance from the display.

Fig. 2. Edge enhancement. Image on the left is the original video frame; image on the right is the processed frame by edge enhancement. The example image has been captured from the actual VGA output of the FPGA board.

tracker. The system can be easily adapted changing the output format for different kinds of the displays. We have implemented three kinds of zoom that allow magnifications from ×2 to ×16. Fig. 1 shows examples of the three types of zoom.

4.2. Edge enhancement

As described above, some LV patients perceive foggy or blurred images, hence they are not able to identify objects and faces. An increased gain in the high frequencies can help patients to identify them [1].

The contrast enhancements that we propose consist of extracting the edges and superimposing them with the original image at the same position with a polarity that depends on the context. This means that we redraw a black trace on a light background and a white trace on a dark background, as can be seen in Fig. 2. This kind of edge enhancement has been evaluated by Peli [3].

4.3. Augmented view: superimposing edges of wider visual fields

The patients with tunnel vision can have a very restricted visual field but, sometimes, high resolution. For these patients it is useful to have information about objects out of their central visual field to facilitate orientation, because their capability to walk and navigate in an urban environment is very limited. For this purpose, as an alternative to wide angle lenses, other authors have proposed the possibility of drawing the edges of a wider visual field on the central visual area [1,4]. In this case, the patient can focus his attention on these edges to walk and neglect them or even switch them off for other tasks. An example of the last processing is shown in Fig. 3.

We implement this kind of image processing using the reconfigurable device in real-time. It is important to give the patient the possibility of easily controlling the threshold of

Fig. 3. (Left) Input image to the FPGA generated by a mini-camera with a 50° HF. (Right) Image of the display of the HMD (NOMAD ND2000 16° HF), recorded using a webcam.

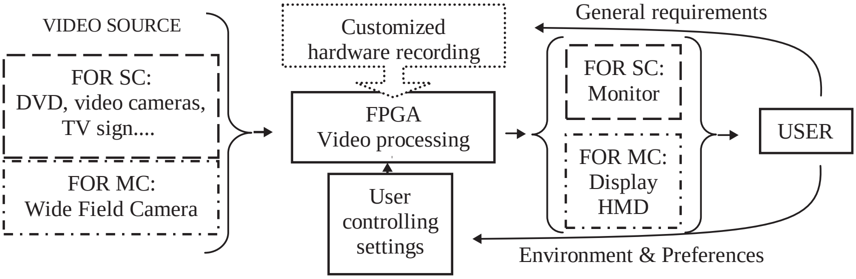

Fig. 4. Working scheme. Elements labelled with SC or MC are only used within the static and mobile configuration, respectively.

the edges (by means of two buttons). In both applications, edge enhancement and augmented view, we use Sobel edge detector to extract edges from the original image.

5. Device configuration

The device can be used with two configurations, a mobile one and another one static, depending on the devices that are connected to the FPGA (Fig. 5d). We can see a scheme in Fig. 4. It is composed of an image acquisition or source device (such as DVD, TV broadcast, mini-camera, etc.), the FPGA device for real-time image processing, and a display dependent on the needs (mobile or static configurations); e.g. Head Mounted Display (HMD) NOMAD ND2000 for portable purpose, VGA monitor, video monitor, etc. The complete setup for the mobile configuration is shown in Fig. 5.

For the mobile configuration we have selected the camera PC180XS Exview CCD (40° V, 50° H). High IR light efficiency allows night vision capabilities. ND2000 has been chosen due to its transparency, high contrast and brightness, and barely null blocking of the visual field. It also permits visual eye contact and is aesthetically tolerable. (HMD Field: 13° V, 16° H).

6. Preliminary evaluation

To evaluate the efficiency of the aid as zoom and augmented view, we measured equivalent visual acuity and field in two simulated low vision subjects. Different VAs were simulated by means of a translucent diffuser placed at three randomised distances from a PC generated chart (ETDRS like). A severe restriction (4°) was also simulated by means of

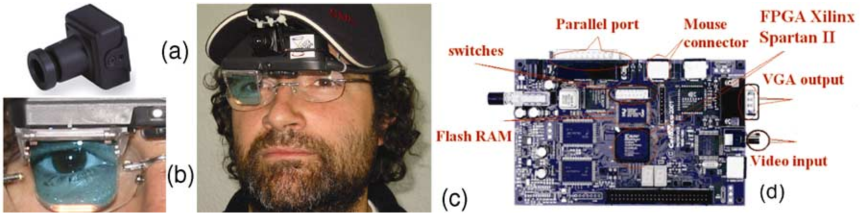

Fig. 5. Elements of the whole device: (a) camera ex-view, (b) detail of NOMAD, (c) aspect of the actual prototype in mobile configuration., and (d) board RC100 by Celoxica.

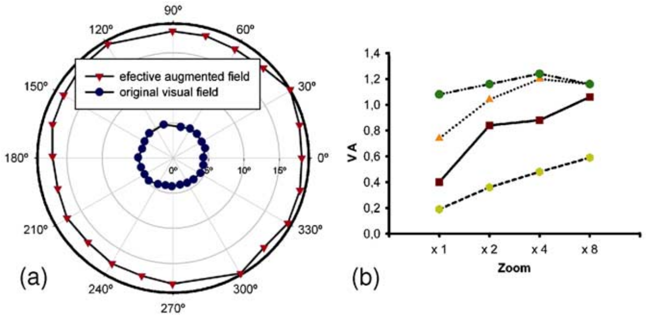

Fig. 6. (a) Simulated tunnel vision (4°). Expansion ×4.5. Expanded visual field is limited by the cam/HMD. (b) Effective VA obtained with the Bilineal zoom for several simulated VA saturation is due to the subpixel limitation in conventional video signal to the zoom factor.

an estenopeic hole. Kinetic perimetry was performed at 1 m distance. Fig. 6 show the increase in visual field obtained with the Augmented View algorithm, using as HMD the NOMAD ND2000 (Fig. 6a) and the increase in equivalent acuity obtained with the Bilineal Zoom, for the different VAs (Fig. 6b).

7. Conclusions

A visual aid has been developed with a notable characteristic to be applied flexibly to a great variety of needs. This visual low vision aid does not compromise the visual rest of the patient. The programs loaded in the EPROM of the FPGA can be easily updated to adapt to the requirements of the different users. The diverse elements that can be connected to the FPGA in static or mobile configuration allow the aid to be used in very varied circumstances without need to acquire specific helps for each situation; this enables economic saving for the user.

Acknowledgments

Supported by grants IST-2001-32114 and FIS- PI021829, and FUNDALUCE (Fundación contra la ceguera).

References

[1] E. Peli, Vision multiplexing: an engineering approach to vision rehabilitation device development, Optom. Vis. Sci. 78 (5) (2001) 304–315.

[2] F. Vargas-Martín, et al., Optoelectronic visual aid based on reconfigurable logic for severe peripheral vision loss rehabilitation, Ophthalmic Res. 36 (S1) (2004) 60.

[3] E. Peli, et al., Wide-band enhancement of television images for people with visual-impairments, J. Opt. Soc. Am. A 21 (6) (2004) 937–950.

[4] F. Vargas-Martín, E. Peli, Augmented-view for restricted visual field: multiple device implementations, Optom. Vis. Sci. 79 (11) (2002) 715–723.