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Vision Restoration and Vision Chip Technologies

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Abstract

With the help of the bionic devices blind people might regain some of their sight. The main objective of this paper is the presentation of the vision restoration techniques and bionic vision devices. Also, the vertically integrated vision chip technology is bringing a revolution in the design of artificial vision systems. Prospective vision restoration techniques are presented and discussed in detail focusing on retina implants, bionic glasses and on vision chip technologies. Our paper summarizes and details the essence of our successful program, and the knowledge how to build and establish a groundbreaking innovation center.

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1. The Hungarian Bionic Vision Center

The ultimate goal of the center is to help and assist the visually impaired with technical inventions, such as special mobile devices, retina implants and in the future through optogenetic methods. At the Hungarian Bionic Vision Center, founded by two scientific universities, we can observe how engineers and medical doctors can work together.

Presently there are three main programs in the Hungarian Bionic Vision Center: the Bionic Eyeglass, the retina implant project and genetic approaches. All of these need a dedicated, interdisciplinary approach and the previously mentioned close collaboration of experts.

In our first project, we are developing a Bionic Eyeglass that can provide wearable TeraOps visual computing power to guide visually impaired people in their daily life. Detection and recognition of signs and displays in real, noisy environments is a key element in many functions of the Bionic Eyeglass. The paper briefly describes spatial-temporal analogic cellular algorithms used for localizing signs and displays, and recognition of numbers they contain.

Retina implants are being developed and tested in many centers. One of the most innovative and valuable approach is the subretinal implant developed by the Retina Implant AG and Professor Eberhart Zrenner with his group at the University of Tuebingen, Germany. Thanks to our collaboration with them, we expect that the first subretinal implant surgery will take place in Hungary in 2011. The corresponding preoperative and postoperative testing procedures will be also performed in Hungary. Taking into account the high cost and other demands implementing this state-of-the-art scientific innovative technique, we might declare that participating in this multicenter project is a major step forward to any newly established center.

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Nomenclature

BE	Bionic Eyeglass
CMOS	Complementary metal–oxide–semiconductor
LCD	Liquid crystal display
MPDA	Micro-Photodiode Array
TeraOps	Trillion Operations per Second
TSV	through-silicon-via

2. Novel Prospective Research Challenges

2.1. Multi-Layer Vision Chip Implementation Using 3D Silicon Technology

Smart CMOS Imagers adapt their response to the stimuli and correct non-ideal behaviour of sensing and readout circuits. Basic smartness includes functions to improve image quality like high dynamic range acquisition, correlated double sampling, fixed pattern noise attenuation, etc. Advanced smartness includes spatial-temporal processing rendering feature extraction, identification of regions of interest, tracking of salient points, etc. [1]. Real-time vision requires these tasks to be executed at ultra high speed. For that, per-pixel circuitry to support fully parallel processing is employed. As a consequence, the pixel size grows (around 30 µm in state-of-the-art 0.18 µm CMOS vision chips) degrading spatial resolution and image quality. This session addresses new architectures, circuits and methods for smart imagers that use 3-D integration technology to combine large spatial resolution and image quality (using backside illuminated sensors with 4 µm pitch) with advanced intelligent functions.

The future smart 3D image sensor architectures will most probably consist of a sensor layer at the top and various processing layers below. Each layer will be organized into locally connected cellular arrays, with additional global communication/operation mechanisms. Layers will be vertically interconnected using bi-directional parallel channels implemented by through-silicon-vias (TSVs). Images at different scales and abstract information about salient points and features will be transmitted top-down across the stack, while commands will be transmitted bottom-up to support adaptation. Different signal modalities and image representations (multi-scale, binary and gray scale images) will be employed (Fig. 1).

Hence, together with the smartness challenges, these chips will address challenges related to the co-existence and interactions among these different kinds of signals and image representations.

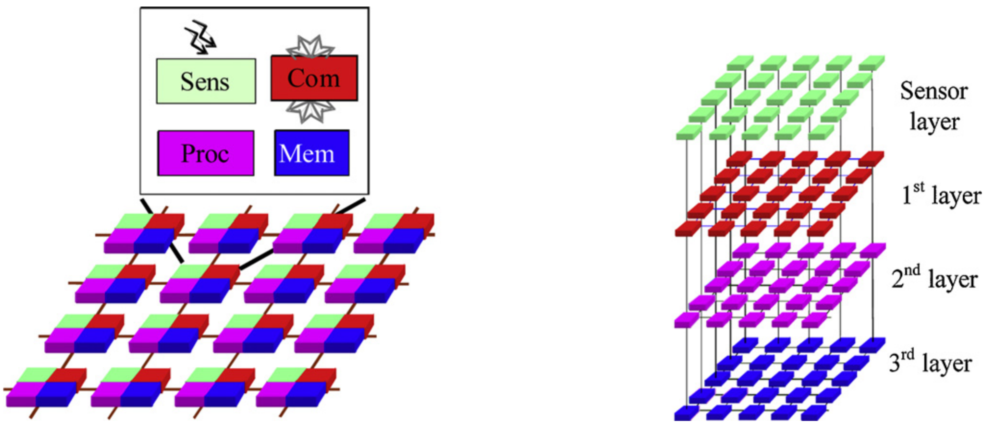

Fig. 1. (a) Embedded sensor and processor layers. In the conventional planar silicon implementation the different functional units are merged on the same plane, hence the areas of the resulting cells are large [1,2]. In the 3D silicon implementation; (b) the different functional blocks can be placed to different layers. In this way, each functional layer is implemented on the most suitable technology, hence the performance will increase and higher resolution (megapixel or higher) can be reached [4,5].

2.2. Bionic Eyeglass

The Bionic Eyeglass, a portable device, has been proposed recently to help patients in everyday navigation, orientation and recognition tasks that require visual input. Presently blind and visually impaired people rely on sighted people's help in such cases. Exact identification of these situations help determining useful functions of the Bionic Eyeglass; this process is being performed by continuous consultations with potential users through different organizations representing blind and visually impaired people. Although requesting personal help has social aspects for them, there is a clear demand for the Bionic Eyeglass, which can be explained by its following significant aspects:

- it can increase the user's freedom and decrease his dependence on other people's help
- it works without external infrastructural requirements
- it will be available for end users in the near future
- it does not pose health risk to the user.

The key challenge in creating the Bionic Eyeglass is to be able to process video flows in the selected situations in real time on a mobile device, where mobile refers to the following requirements: (i) portable, (ii) small form factor, (iii) autonomy of at least 6-8 hours. In order to satisfy these requirements we need a computational platform that has high computing power as well as low power consumption. Cellular visual microprocessors possess both of these properties [6] (Table 1).

Our recently developed function that was also demoed at our exhibition booth is banknote recognition, which is a prevalent problem for blind and visually impaired people. Relevant shapes are extracted from the image flow of the banknote shown to the mobile camera using adaptive thresholding and morphological shape filters. In a two-level classification scheme different classifiers are used for different categories of patches (portrait, denomination, tactile marks), and the votes are combined through an ensemble decider. The confidence of the decision is established if the same class recurs through several frames. This device communicates with the user through speech. The system has been tested on blind subjects using a cell-phone based prototype, and the results showed that they quickly became confident using it [7].

2.3. Retina Implant Technology

Up to now there has been no obtainable cure for diseases causing the permanent impairment of retinal photoreceptors. at present the development of the retinal implant is the earliest to promise a result that can be implemented in the clinical treatment of these patients. Implants with different operating principles and in various stages of progress are presented in the provided session in details, highlighting the characteristics, as well as the Hungarian aspects of the development. Advance in microelectronics in recent years made it possible and proved to be feasible to replace the degenerated elements in the retina with electrical stimulation [8]. Numerous comparable approaches are running simultaneously. Two types of these implants are directly stimulating the remaining living cells in the retina [9]. Hitherto the best

Table 1
Typical tasks considered for the (BE) Bionic Eyeglass.

	Home	Street	Office
User-initiated functions	*Color and pattern recognition of clothes*	*Recognition of crosswalks*	*Recognition of control signs and displays in elevators*
	Bank note recognition	*Escalator direction recognition*	*Navigation in public offices and restrooms*
		Public transport sign recognition	*Identification of restroom signs*
		Bus and tram stop identification	*Recognition of signs on walkways*
		Recognition of fluorescent displays	
	Recognition of messages on LCD displays		
Autonomous warnings	*Light left on*	*Obstacles at head and chest level (i.e. boughs, signs, devices attached to the wall, trucks being loaded)*	
	Gas oven left turned on		

resolution has been achieved with the subretinal implants. Although the epiretinal prosthesis offer lower resolution, but requires shorter surgery for implantation. Retinal implants in certain retinal diseases such as retinitis pigmentosa are proved to be capable of generating vision-like experiences. A number of types of retinal implants can be expected to appear in clinical practice a few years after the successful conclusion of clinical trials. Our goal is to perform the very first successful human implantations in Central and Eastern Europe with the necessary evaluation tests of the retina implant in 2011. (Find out more on www.vision-center.hu)

2.4. Copyright

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Further reading

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