ELECTRONIC VISION ENHANCEMENT SYSTEM

Peter Mayer, Georg Edelmayer
fortec - Working Group on Rehabilitation-Technology[1)]

Abstract
In this paper we will describe the development of functions and tests for the prototype of a vision enhancement system within the TIDE Project 1211 - "POVES". We will discuss its function, the methodology used for testing and the results obtained from the tests.

1 Introduction

POVES is the acronym for **P**ortable **O**ptoelectronic **V**ision **E**nhancement **S**ystem. POVES tackles visual impairments which cannot be compensated by conventional optical methods.
POVES is a battery operated, portable image processing system consisting of a head worn spectacle part carrying cameras and screen displays and a pocket part containing the image processor, the power supply and the controls (user interface).

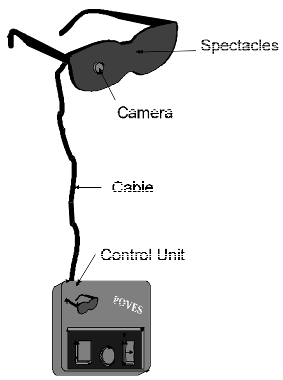

Figure 1: Principle of the POVES Device

As a first prototype a system for night blind persons will be built. This system runs under the acronym NiViS (Night Vision System). The other classes of visual impairment will be tackled in detail in a following project.

[1] Institut für Allgemeine Elektrotechnik und Elektronik, Vienna University of Technology,
A-1040 Wien, Gußhausstraße 27/359-B

2 Potential POVES Users

It is believed that about 80 to 90% of all information that is processed by an individual in everyday life is of visual origin. This clearly indicates the importance of the visual system for independent living in modern society. About six million individuals in the European Community - 2% of the European population, 20% of all the European handicapped - who are considered to be visually impaired, do not enjoy this full personal autonomy and independence (Sandhu and Wood [9]). It is not surprising, therefore, that a FAST-study [3] concludes that among the development of personal assistive devices "aids to mobility in the local environment" should be among the priority innovation areas, in particular for the elderly.

According to a US-project similar to POVES [6], where an estimation of the potential user group has been made, only people within an visual acuity-range (VA) of 20/100 to 20/800 can be helped with electronic vision enhancement systems. Vision of people with a better VA than 20/100 can be improved much cheaper with commonly used devices. For people with VA less than 20/800 no help is possible.

Considering the above mentioned pathologies, the following classes of POVES users were defined:

	POVES classes			
Disorder	**Night blindness (NB)**	**Decrease of visual field** a) tunnel vision **(TV)** b) central scotoma **(CS)** c) irregular scotoma	**Colour blindness (CB)**	**Distortions in** a) contrast vision b) light sensivity c) visual acuity **(CSA)**
Opacities of the refractive media		generalised decrease	(X)	a, b, c
Age-related macular degeneration	(often) X	b	X	c
Juvenile macular degeneration	(X)	b	X	c
Glaucoma	X	a, b, c		
Retinitis Pigmentosa (RP)	X	a, (c)	X	
Diabetic Retinopathy (DR)	(x)	generalised decrease		c

Table 1: Classes of symptoms versus eye diseases

3 The Development Process of the Full POVES

At the start of the project in early 1994 first a market study and basic research was done to define the target groups and their needs. This work was carried out by the two university partners in Brussels (GREN[4]) and Vienna (TUW[6]) and empirica[3]. The results were used to write a first duty catalogue containing the supposed requirements honouring the technical feasibility.
To acquire more precise data a PC-based simulation system was built to be able to evaluate different proposed algorithms in non-real time. For first tests two similar systems were set up by the industrial partner CAE[2] and TUW.
The testing performed at the two universities with a small group of impaired and normal sighted led to a refinement of the duty catalogue forming the basis for the construction of a functional yet provisional system, providing the ability to study the algorithms in real time.
Now another series of tests were done using two different implementations of the functions to be tested, one by CAE and JURCA[1] the other by TUW. These tests were carried out under low light conditions at two test sites at GREN and TUW. The test persons had to perform different recognition, orientation and mobility tasks.
The results which proved the concept of POVES to be realisable led to another revision of the duty catalogue specifying the features of the final prototype currently (June 1996) being manufactured by the industrial partners CAE and JURCA.
Final testing of the prototype will result in the documents for production of NiViS and prototype specifications for the modular full POVES. The project is scheduled to end in July, 1996.

4 Testing of POVES

4.1 Simulation Tests

The purpose of these tests was to choose among the possible image processing algorithms that should be implemented in the POVES system. At this simulation stage, the tests were carried out with a non real-time processing of the images on a PC running under Windows and so any subject-environment perceptual interaction was made impossible.

4.1.1 Test Subjects

Twelve normally sighted subjects at GREN and 10 at TUW, aged from 12 to 53, with a visual acuity of 20/20 after correction were involved in the different tests. Different visual impairments were simulated on these subjects. In addition, five visually impaired subjects were also involved in these tests: two subjects were belonging to the Tunnel Vision class and three to the Central Scotoma class.

4.1.2 Preference and Performance Tests

A sample of images was chosen and a set of algorithms was applied. The subjects had to decide if the processing led to a more perceptible image. This procedure allowed to select a reduced number of algorithms that were found useful for implementation in the next development phase.
To measure absolute performance, the error rate and the needed time for several defined recognition tasks were measured and evaluated.

4.1.3 Conclusions

Results obtained with the simulation of different visual impairments as well as with visually impaired subjects showed that several algorithms could enhance the performance obtained for various visual tasks. Especially each type of contrast enhancement proved to be valuable. So these algorithms were chosen to be studied further on with the functional system.

4.2 Tests of Functional System

The functional systems built for testing were based on a PC combined with a DSP-system. The images were picked up by a B/W camera and presented on a commercial VR-Display, both of them mounted on a spectacle like head worn device. The camera used was a light sensitive miniaturised CCD module. The images were processed in real time by the DSP system. Parameters like contrast or brightness as well as different algorithms could be altered during the tests.
The processed frame rate was at least 10 frames/sec. These frames were displayed on commercial VR displays at a size of 320 x 200 pixels in 256 grey levels with a resulting field of view of about 30 x 20° giving the impression of an unmagnified image of the environment.

The following algorithms where used during the tests:

- Without wearing the system
- No image Processing: The camera image was put to the display without any changes
- Double contrast: The contrast was enhanced by the grade of the input-output function
- Non-linear Contrast setting: The contrast was enhanced by a non-linear I/O function
- Histogram equalisation: The grey values of the picked up image were recalculated so that the output image always used the whole range of possible grey values.
- Edge enhancement: 4 different edge enhancement algorithms were tested.
- Magnifying: Electronical magnifying of the presented image by the factors 2 and 3.
- Inverting of grey-values: The grey values picked up by the camera where inverted.

5 POVES for the Different Classes

Within POVES all of the impairments mentioned in table 1 were investigated for the possibilities to correct them with a to be defined optoelectronic vision aid. The main result of POVES however, will be a prototype for a night vision aid called NiViS.

5.1 Night Blindness (NB)

Most of the night blind persons suffer from RP. Typical disorders include:

- progressive restriction of visual field: scotoma and tunnel vision
- increasing disability of night vision, night blindness
- disturbance of contrast vision and light sensivity

The impairment of night blindness cannot be tackled by means of conventional (passive) optical aids. In the past there were only few attempts to use active electronical devices.
Solution: The cameras of POVES will still work at illumination levels around 1 lx. The displays of the spectacle part will present the processed scene at a brightness level where photopic perception is possible. Re-mapping of the images can be used to enlarge the visual field.

5.1.1 Past Users of Electronic Night Vision Aids

Among visually impaired persons, in particular RP patients, the ITT night vision aid (NVA) has been developed and sold via the US National RP Foundation (NRPF) during the seventies and eighties. According to Berson [1] the NVA has until now been sold to about 200 to 250 persons in the USA and UK at a prize of 2200 dollars.

5.1.2 Test Subjects and Procedures

For the NB-tests TUW employed 8 night blind persons, while the partners at GREN performed the tests with 18 night blind persons. The persons involved in the test were all suffering from Retinitis Pigmentosa (RP).
For class NB an obstacle course was built, where the persons had to walk through and fulfil some orientation and object detection tasks. This because the persons belonging to the NB class mainly have problems in orientation under low light conditions..
Major result was that using the system even without any image processing at light levels of only some lx gives a positive effect because without it the night blind persons could not see anything at all. This is typical for people suffering from RP.
Individual contrast and brightness modifications provided the most comfortable image to the persons so they had best performance moving around. On the other hand histogram equalisation provided

best results finding smaller objects as it gives best contrast while at the same time the test persons did not feel comfortable with the image quality.

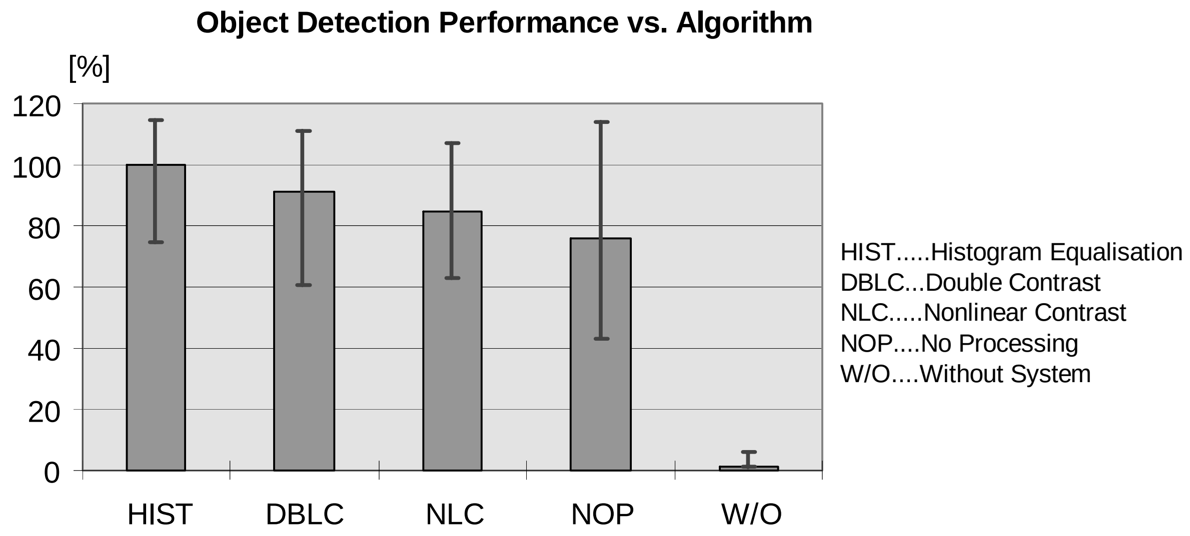

Figure 2: Performance of Object Detection
Mean performances and deviation interval related to mean performance achieved with the HIST-function (100%)

5.2 Decrease of Visual Field by Peripheral Scotoma (Tunnel Vision) and Decrease of Visual Field by Central Scotoma

People with RP suffer from a decreasing visual field leaving only a very narrow field of sight at the later states of this disease. On the other hand Central Scotoma enables the patients to see in the peripheral area but only in a ring-like area with low visual acuity around their scotoma.
The final POVES will re-map the image perceived by the cameras to the still functioning parts of the retina thus enlarging the visual field. Basic tests to evaluate different re-mapping algorithms and their major effects have been done at TUW and GREN. As it is difficult for the test persons to get familiar with an image that is altered in its spatial arrangement, a phase of learning has to be provided. Tests that base on persons who are trained to use the remaped image are yet be done. The possibility of eye-tracking is not used in the POVES prototype, but will be evaluated in a following project.
For these two classes a special re-mapping chip is under development by DICE[5].

5.3 Colour Blindness

Solution for persons with different kinds of colour perception problems: POVES can represent colours in different formats depending on which colours or contrasts are perceived best. There were no further studies on this class because the functional prototype only supported B/W images.

5.4 Impairments in Contrast Vision, Light Sensitivity and Visual Acuity

To tackle these impairments POVES will offer different possibilities for adjustment of brightness and contrast, filtering and magnification of the image.

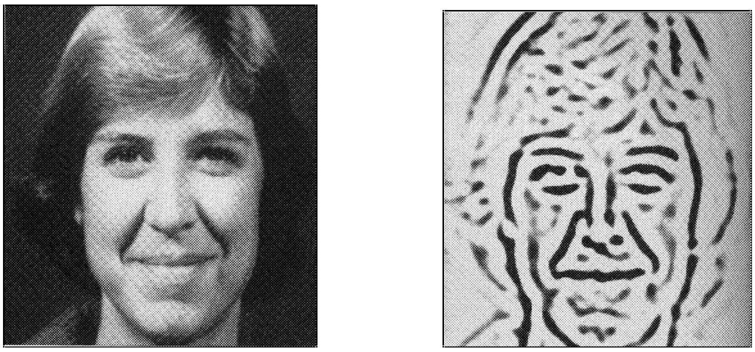

Figure 3: Example of Enhancement of Face-characteristics by Filters [6]

For the class CSA TUW did the tests with 12 persons. All persons were suffering from different eye-diseases that lead to a general loss of visual acuity or difficulties in contrast sensitivity. (e.g. glaucoma, cataract congenita). For the persons in the CSA class object detection and object recognition tests were performed. The test persons usually have not much problems in orientation but in detecting specific objects or perform reading tasks. Two of the 12 employed persons where unable to fulfil the tests because their vision was already too low.

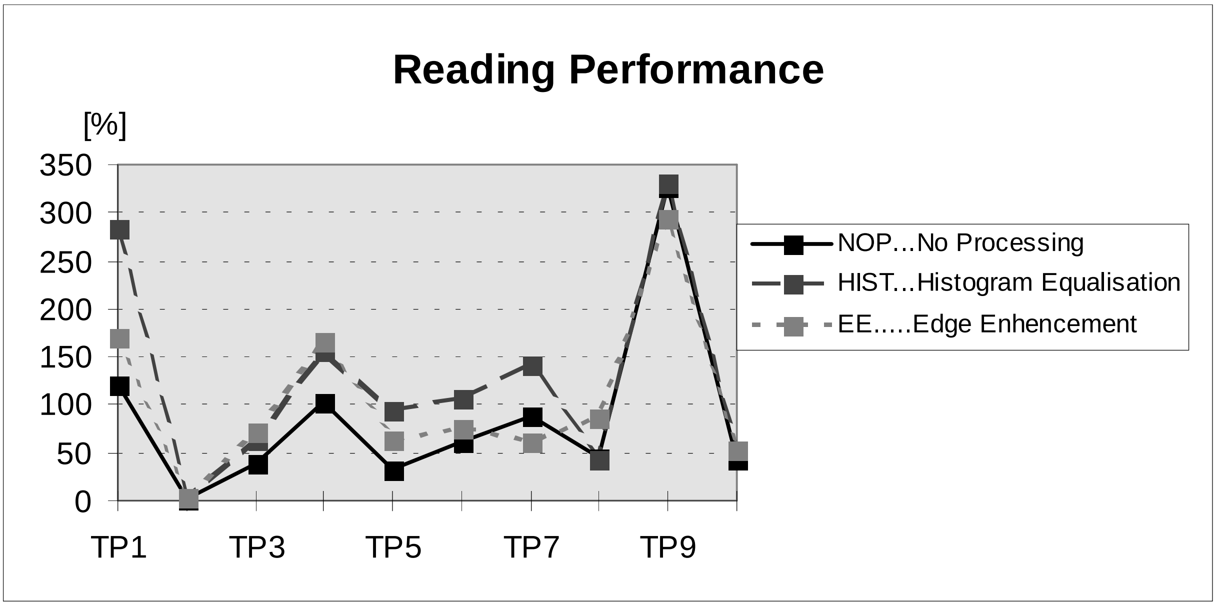

Figure 4: Reading Performance
Performance = (errors * time) without system / (errors * time) with the system [%]

The results of the reading tests can be seen in Figure 4. It has to be mentioned that using the system most often worse results were achieved than not wearing the system (no system = 100% performance). The object detection and face recognition tests gave similar results. Therefore the following conclusion referring class CSA can be made: The system as it is now, gives too little acuity for this class of diseases. Although the test persons have acuities below the systems inherent acuity, the performanc using the system was worse than with not using it. Best results were reached with the histogram equalisation. The lack of colour may be a reason for the worse performance too, because some information is lost when reducing the colours to grey-values.

6 Results and Conclusions

It could be shown that the functional system is a good basis for the NiViS prototype as it gives a possibility to orientate at light levels that normally are too low for people suffering from RP. For reading tasks it would be better to provide higher resolution.

For the class CSA it would be preferable to provide the spectacles with a display that has higher resolution and which gives colour images. This means a colour camera has to be used instead of the B/W camera that is used in the functional system now. These requirements also must be taken care of in a follow-up project where the classes Tunnel Vision and Central Scotoma will be tackled.

The design of the functional system (spectacle and pocket part) was well accepted by all test persons. Nevertheless they would prefer a much smaller and lighter device.

Currently (June 1996) the NiViS prototype is tested.

7 The POVES Consortium

[1] JURCA Optoelektronik GmbH (Eschborn, Germany)
[2] CAE Electronics GmbH (Stolberg, Germany)
[3] empirica GmbH (Bad Nauheim, Germany)
[4] Université Catholique de Louvain/GREN (Brussels, Belgium)
[5] Université Catholique de Louvain/DICE (Louvain-la-Neuve, Belgium)
[6] Vienna University of Technology - fortec (Vienna, Austria).

Authors' Addresses

fortec - Working Group on Rehabilitation-Technology
Institut f. Allg. Elektrotechnik u. Elektronik (IAEE)
Vienna University of Technology
Gusshausstrasse 27/3593
A-1040 Wien, Austria
Tel: +43-1-504 1830/31, Fax: /12
e-mail: poves@fortec.tuwien.ac.at

The Austrian part of the POVES project was funded by the Austrian Industrial Research Funds „FFF“.

8 Literature

[1] Berson E., Harvard University Medical School; personal communication, 1973 and 1976

[2] Brabin, J. Problems to be Overcome in High-Tech Devices for the Visually Impaired
Optometry and Vision Science 1992, Vol. 69, No 1, pp 42-45

[3] FAST project: Technology and the elderly, Dublin 1991, p. 113

[4] Grignolo F.M., Fea A. Samuelly R., Bazzano G., Abattista I.G., Night Vision goggles to improve mesopic visual acuity and visual field in RP patients, 1. ECORA Meeting, Bonn, October 1993, Vol. , 1993-10

[5] Loshin David S., Juday Richard D., The Programmable Remapper: Clinical Applications for Patients with Field Defects, Optometry and Vision Science, Vol. 66, 1989, pp. 389-395, No. 6

[6] Massof Robert, High-Tech Help for Low Vision, NASA Tech Briefs, Vol.17, 1993-02 pp. 20-22

[7] Peli Eli, Difficulties and Roadblocks in Applications of Hi-Tech to Low Vision
Optometry and Vision Science, Vol. 69, 1992, pp. 1-2, No. 1

[8] Roche-Lexikon, Urban&Schwarzenberg; Leydhecker, Augenheilkunde, Springer Verlag 1993

[9] Sandhu and Wood 1990