SYSTEM I4CONTROL®: THE EYE AS A NEW COMPUTER PERIPHERY

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Abstract: In this paper we introduce a design of a system for controlling a PC by eye movements. We are witnessing the time of revolutionary introduction of computers and information technologies into daily practice. Healthy people use keyboard, mouse, trackball, or touchpad for controlling the PC. However these peripheries are usually not suitable for handicapped people. They may have problems using these standard peripheries, for example when they suffer from myopathy, or cannot move their hands after an injury. Therefore we are coming with a proposal how to enable the handicapped people to control the PC.

Introduction

The word “communication” origins from the Latin word “communicatio” which means to connect something. In a broader context it means any type of information transmission between individuals (in groups, societies, or populations) mediated by a set of codes (characters or signals) shared by sender (communicator) and receiver (communicant) using communication channels. We can distinguish many types of communication (e.g. direct and indirect). A special category is communication between man and technical systems capable of interaction (e.g. computers), another category is mutual communication between technical systems. Interpersonal communication is realised either in verbal form (using speech), or non-verbal form (using specific expressive means – body movements, gestures, mimics), while communication between a man and a computer is realised using a special device (computer periphery). Input information from the human is transmitted to the computer using one of the suitable interfaces, e.g. keyboard, mouse, trackball, or light pen. However handicapped people may have difficulties when controlling a PC by classical peripheries. This concerns people with a motoric handicap that causes inability to control movements of arms and hands. Such people have problems with grasping a mouse, not speaking about fine manipulation with it. Since the computers have become common tools of work and have started to accompany us even in everyday life it is necessary to ensure for the handicapped people easier communication with the computers. That has been the motivation for us. We have proposed a solution that is based on recording eye movements and using them for communication between a person and a computer.

Methods of eye movement measurement

Observatione of person’s view direction is used not only in medicine, but also in other areas, as for example psychology, ergonomic studies, marketing, arts; this principle may be used for an computer interface that can serve handicapped people. At present the most frequently used methods for recording eye movements are: search coil, electrooculography, monitoring reflected light by a photodetector, and videooculography.

Search coil

It is composed of many turns of a thin wire and attached to the eye by a special contact lens, possibly operatively at animals. There is measured the voltage induced in the coil by homogeneous magnetic field originating from an external generator (Helmholtz coils, see Fig. 1). The method enables to reach precision of the order of hundredths of degree and bandwidth of the measured signal of several kHz. The direction of view is measured in the coordinate system of the generator, the eye must remain during the measurement in the area of linear field. Due to possible problems with lenses application, this method is used purely for research purposes. Another disadvantage is high price of lenses and their fast detrition.

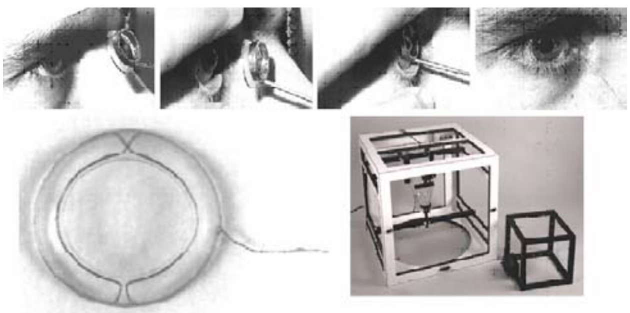

Figure 1: Search coil

Electrooculography

Electrooculography (EOG) uses differences of electric potentials of cornea and retina that cause changes of electrostatic field when the eye changes its position (see Fig. 2). The amplitude is sensed by electrodes attached to the skin close to the eye. Potential of the dipole cornea – retina depends on the position of the eye axis. When the person looks directly ahead then the dipole is placed symmetrically between electrodes and the resulting EOG signal is zero. When looking to the left the cornea becomes positive in the proximity of the left electrode that becomes positive accordingly. Nearly linear dependence between horizontal angle of the optical axis of the eye and EOG signal is approximately in the range ±30º. Measured signal can be significantly distorted by artefacts caused by movements of surrounding muscles and electric background noise. Typical discrimination is about one degree, maximum bandwidth reaches tens of Hz. The direction of view is measured in the coordinate system of the head.

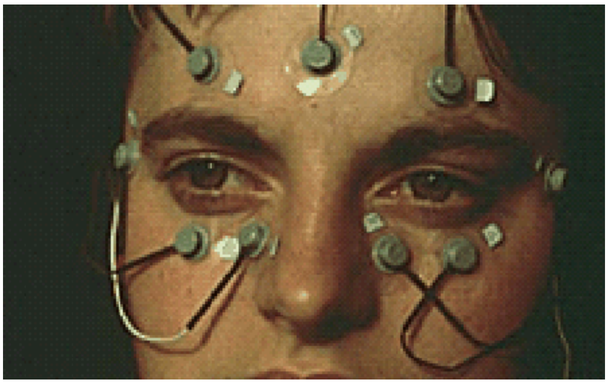

Figure 2: Placement of the electrodes for recording EOG signal

Monitoring reflected light by a photodetector

Monitoring reflected light by a photodetector (IROG, see Fig. 3). The method uses the fact that sclera reflects more of the falling light than cornea. When the eye is lighted the amount of reflected light changes with the angle of turning. With respect to covering cornea with eye-lid, this method can be used only for measurement in the horizontal plane.

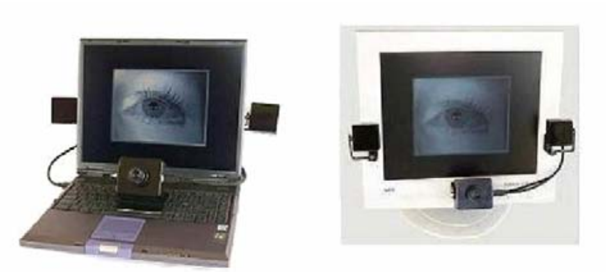

Figure3: System for monitoring reflected light by a photodetector

Videooculography

Videooculography (VOG) uses a camera for following eye position. If the camera is attached directly to the head of the subject eye position is measured relative to the head and for determination of absolute direction it is necessary to measure the head position as well. If the camera is placed somewhere in front of the face it is necessary to keep the eye in its field of vision and at the same time to distinguish the eye rotation from translational head movements. Monitoring algorithms are currently based on digital image processing. The discrimination of tenths of degree and sampling frequency of hundreds of Hz are reached.

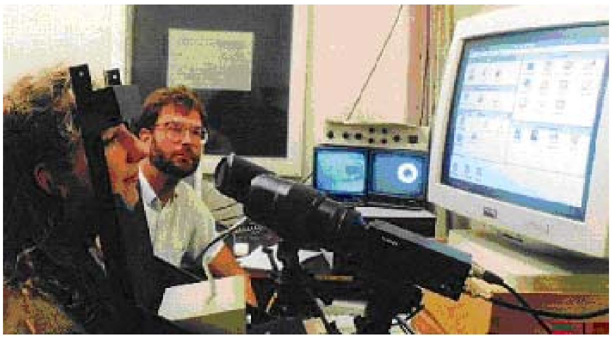

Figure 4: System for videooculography

Review of existing technical solution

Control of a computer's functionality by eye control has been a practical possibility for several years. Let us describe briefly several existing solutions. The LC Technologies Eyegaze System [1] provides an eye-controlled human-computer interface (HCI), using a video camera mounted below the computer monitor that observes the user's eye and specialised image processing software analyses the video images of the eye and determines the eye's gazepoint on the monitor screen in real time. QualiEye [2], part of QualiWORLD, gives simple, efficient, hands-free control of the PC using a standard USB web cam for tracking eye movements. Electrooculography is used at Boston College in the project called EagleEyes [3] for moving cursor at the computer monitor. Great disadvantage of this method is the necessity of correct sticking the surface electrodes and removal of artefacts originating from eye blinking or movements of face muscles. Another disadvantage is the necessity to use special software products that can help a handicapped person to control the PC. At the Cambridge University [4, 5] the project Dasher uses a IR camera that detects the eye position based on the contrast between the light absorbed by the pupil and the reflected light. Each of the presented systems has its advantages and disadvantages. Some of them are already fully developed and commercially available. However, most of these commercially available systems are very expensive, mostly having a single function, namely control of a PC mouse, frequently no head motion is required (position of head is fixed) because the camera is mounted on the PC monitor. That has been the motivation for us. Our goal has been the development of a simple and inexpensive system that is not mind head motion and that may provide more functions depending on the software it is equipped with.

Controlling a PC by eye movements

We have proposed a solution that is based on recording eye movements and using them for communication between a person and a computer. System I4Control® is a simple device for that purpose.

The basic idea is fixing a small camera to the head of a person (see Fig. 5) and recording the eye position in the coordinate system independently on the head movements (evaluation of the eye movements is based on the deviation from balanced position). That means that the eye position has no direct influence on the cursor position on the monitor but it will determine the direction of its movement (as the joystick). To enable usage of the system by persons with a disorder of equilibrium organ manifested as fast involuntary eye movements (nystagmus) it is necessary to introduce an insensitivity zone at detection of deviation. This zone must be adjustable individually according to the patient's handicap.

Figure 5: Location of the camera in the system I4Control®

Using this "free" placement of the camera we remove the disadvantage, namely requirement of fixed head position. The camera is connected to the PC using standard communication interface (USB) equipped with corresponding software and enables the handicapped person to control the PC simply by eye movements referred to rest position (looking directly ahead).

The system I4Control® is designed in such a way that the camera is another input periphery of the PC. The resulting device can be linked to any PC and used for control of all programs. In principle the camera simulates a classical PC mouse extensible by an intelligent keyboard using a special user interface. Using this communication module the problem of compatibility of drivers between individual versions of systems or hardware platforms does not appear. The main advantages of our system are low price, simple installation and simple control.

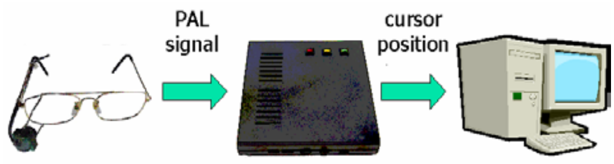

Figure 6: Basic block structure

The Fig. 6 shows the basic block structure of the system I4Control® which comprises of:

- sensing device (Fig. 7),
- control unit and
- personal computer.

Sensing device

The eye position has no direct influence on the cursor position on the monitor but it determines the direction of its movement (as much as a joystick). This solution removes main disadvantage of other systems, namely the need to fix head – the user can move „freely“ without any limitations.

The core of the system is black&white camera (Fig. 7) with a CCD sensor and discrimination 208 x 156 pixels for recording the eye movements. The output of the camera is analog PAL signal that is digitized in the control unit.

Figure 7: Sensing device

Control unit

Principal function of control unit is:

- digitized PAL signal from the black&white camera,
- detection of pupil position from the digitized PAL signal and
- conversion of pupil position into the coordinates system.

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The digitizing block is constituted of an A/D converter with brightness feedback. Information about position of the pupil is stored in the memory and is evaluated by the CPU (processor) from the digitized PAL signal.

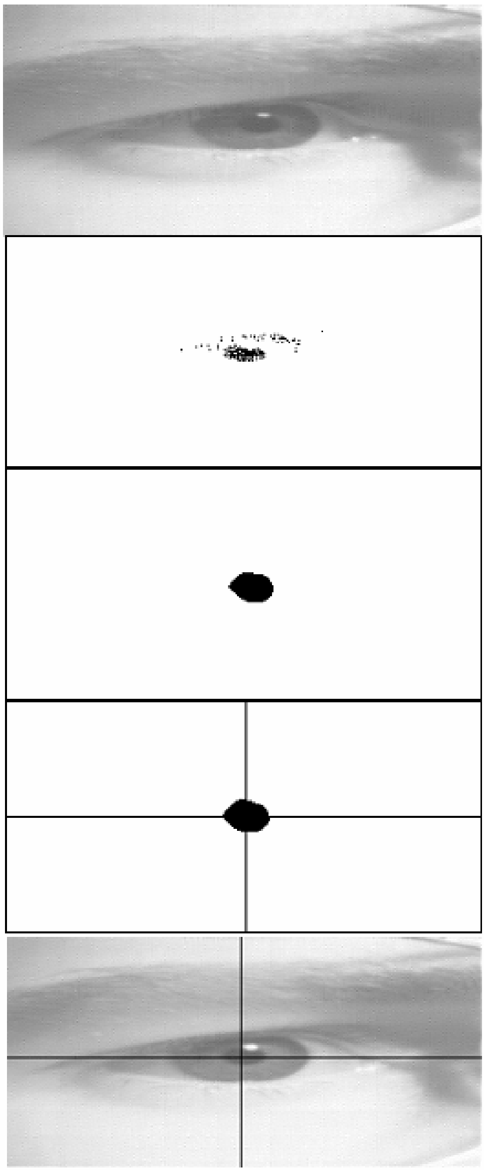


Figure 8: Detection of pupil position

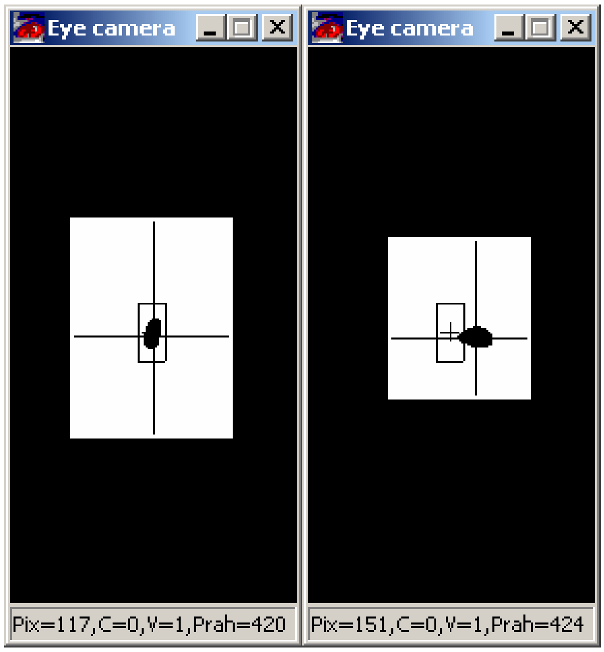
In the system I4Control® version 1.0 the SRAM 512 kB memory is used. The processor uses for the detection of pupil position the method of histogram thresholding and other types of filtration (e.g. cubic filter).

Another task of the processor is to control USB bus ensuring communication with a PC. The outputs of the system are the x- and y-coordinates of the mouse cursor.

Personal computer

The Fig. 9 shows control of cursor's movements. The direction of movement is appropriate deviation from the balanced position. In the first option (a), the cursor stands and in the second option (b) the cursor is moving to the right.

Mouse click or double-click is signalled by user's eye, too: when his/her eye is closed for relatively longer time (it removes influence of spontaneous eye blink).



(a) (b)

Figure 9: Controlling a PC cursor

Experiments

We performed a number of experiments with the system I4Control®. Writing a text with system I4Control® is very simple. User can use software keyboard which is included in common operating system and he/she can write the text documents, send the e-mails, brows the web pages, ect.

Figure 10: Text writing with system I4Control®

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Several students of Jedlicka´s Institute for handicapped young people volunteered to do the pilot tests of the I4Control® device. In the tested group there was for example a boy without hands (he lost both hands as a result of an accident) and a boy with myopathy (muscles dysfunction). I4Control® device was accepted very well. For example one of the users succeeded to paint a simple picture in a drawing software and another one used it to navigate through an education software with relatively complex menu.

Figure 11: Pilot tests in Jedlicka's Institute for handicapped young people

Training through edutainment

To master the control of cursor position through eye movements requires come experience. The user needs to learn how the system interprets his/her efforts. In this training phase, one does not need the computer itself. The I4Control® sensor and the control unit can be connected directly to the remote control of any appropriate toy and the training can start. We have used for that purpose a remotely operated crawler (caterpillar tractor) built from LEGO (Fig. 12). The task of the person undergoing the training is to transport the load (a ball) of the crawler into the wicket. Instead of a joystick, the user has to use for that purpose his/her eyes only. This solution proved very helpful for persons who have no prior experience with computers. Later the faculty gained when playing with toy crawler is reused for moving the picture of crawler on the screen. Now, the user understands the relation between the crawler (cursor) position and his/her eye movements, he/she learns to estimate the speed of cursor movement and the world of computer games is opened for him/her.

Figure 12: The crawler (caterpillar tractor) built from LEGO

Conclusion

I4Control® device offers simple means for control of the PC to people with serious physical handicap. Using it they can better integrate into the knowledge society despite their handicap and take advantage of ICT as well as access to the latest information on the Internet. The system is small, light and puts no restrictions on its user who can move freely – it disturbs the user at the minimum level. The hardware is based on easily available and financially not demanding off-the-shelf components. It is simple, efficient, fault tolerant. In combination with the software it is flexible and has good resolution. Advantage of this system is its simple installation (it is absolutely noninvasive) and the fact that a user of a new computer interface needs no special instruction. When working with the system I4Control® for control of the cursor, the user acquires certainty and

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precision after some time. The length of this period differs from user to user and depends on his/her abilities to control own eye movements and patience. At present it is possible to control the PC using the system I4Control® similarly to standard PC mouse or keyboard. This type of periphery enables to physically handicapped users to work or study on their own. The device can be used even in medical domain e.g. by patients with decreased ability to express themselves or by patients with cerebral palsy.

Acknowledgment

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