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METHODOLOGY AND APPLICATIONS OF EYETRACKING

dr inż. Arkadiusz Rajs
Institute of Telecommunications and Computer Science, University of Science andTechnology,
Al. Prof. S. Kaliskiego 7, 85-796 Bydgoszcz, arajs@utp.edu.pl
dr inż. Mariusz Aleksiewicz
Institute of Telecommunications and Computer Science, University of Science and Technology,
Al. Prof. S. Kaliskiego 7, 85-796 Bydgoszcz,, mariusz.aleksiewicz@utp.edu.pl
dr Agnieszka Banaszak-Piechowska
Institute of Physics, Faculty of Mathematics, Physics and Technique Science, Kazimierz Wielki University,
85-052 Bydgoszcz, Powstanców Wlkp. 2, agnb@ukw.edu.pl
dr inż. Jacek Gospodarczyk
Institute of Computer Science and Mechatronics, University of Economy,
Garbary 2,85-229 Bydgoszcz, jacek.gospodarczyk@byd.pl

Summary
Eyetracking gives great capability of computer's systems control and study of usability applications. In this paper we show construction of eyetracker and range of applications.

Key words: eyetracker, computer vision.

Introduction

At present a much attention is focused on the development of alternative methods of communication and computer control. One of the noninvasive and contact less method is the eye tracking method. The important feature of this method is no interference in natural human behavior and a broad range of application. The goal of this paper is the presentation of the eye tracker operation principles and possibilities of its applications.

EYETRACKER- construction, principles and operation; image processing

The construction of the eye tracking device is based on the processing of the image from camera situated on the front of the computer operator and few infrared light sources, which illuminate the observer eyes [2]. In the first stage of operation is the eyes localization, determination of the sight lines and the distance between the centers of eyeballs. The eyes must be localized on horizontal line and the observer face should be directed to the camera objective. These operations can be realized on many ways as for example the way using brightness gradient. Next, the image of both eyes recorded by camera operating with frequency of 16-60 Hz is processed in order to determine the coordinates of eye pupil. In this purpose is used a phenomenon of the Purkinje reflection. Usually is used so called first Purkinje reflection it means the reflection of the light wave from the front surface of the eye

cornea. This reflection is visible in the form of white point in the pupil vicinity (big black circle) and allows on detailed analysis of its movements. The image of the Purkinje reflection is shown in Fig.1. The characteristic feature of this reflection is its stability during the eyeballs movements [1].

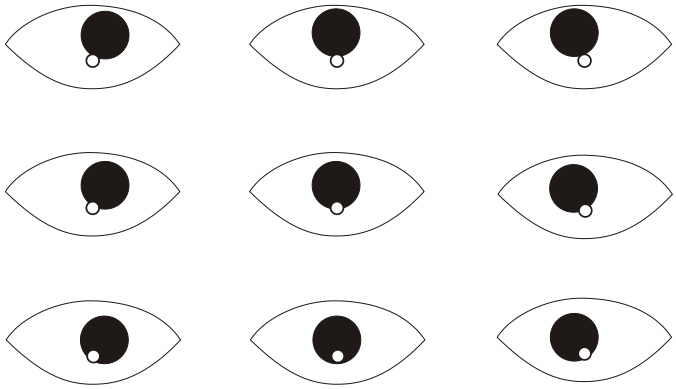

Fig. 1. Localization of pupil in relation to Purkinje reflection – camera view

On the basis of standing item-the Purkinje reflections should be determined, on the image from camera, the coordinates of crossection of the line from aye crossed the computer monitor. The coordinates should be determined separately for each eye assuming that the point of view for both eye is the same. It is shown in Fig.2

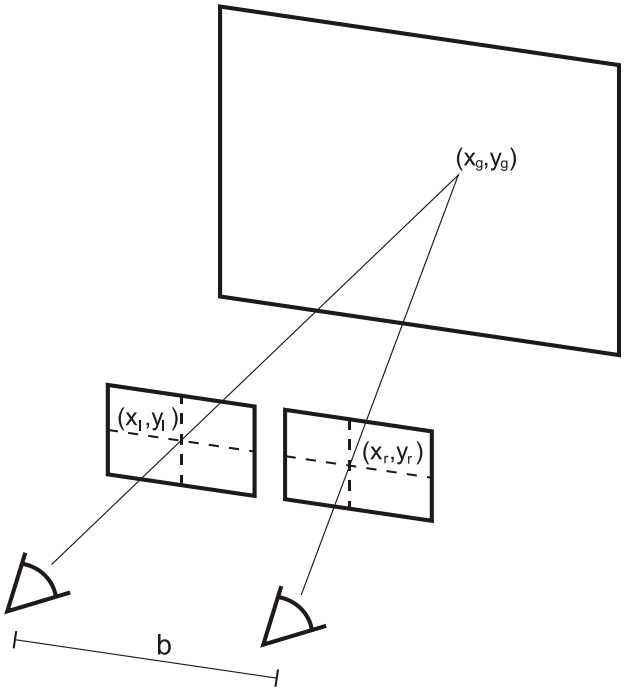

Fig.2. Basic principle of gaze lines define

On the basis of the determined coordinates of left eye (x,y), right eye (x,y) and the distance b between ayes it is possible to determine the coordinates (x,y) of the point on which the sight is directed according to following equations:

$$x_g = \left(1 - \frac{b}{x_l - x_r + b}\right) x_h + \left(\frac{b}{x_l - x_r + b}\right)\left(\frac{x_l + x_r}{2}\right)$$

$$y_g = \left(1 - \frac{b}{x_l - x_r + b}\right) y_h + \left(\frac{b}{x_l - x_r + b}\right)\left(\frac{y_l + y_r}{2}\right) \quad (1)$$

The main problem of the devices proper operation is the observer movements. The movements of the whole body or of the head have negative influence on the proper determination of the aye pupil positions. By using of the additional algorithms it is possible to minimize these unfavorable factors [1].

EYETRACKING – the range of applications

During the studies the eye tracker very precisely tracks the eye movement of the analyzed person. In the effect we can get two types of information's. The first information is the precise localization of the points (fixations) on which the sight of the analyzed person stopped for certain time (fixation time in general is the range of 0.15-1.5 s). Secondly we analyze the so called sakkad, it means the path on which the sight of the analyzed person is moved between fixations. The sakkad is performed in average 4 to 6 times per second with duration from 0.03 to 0.06 s. On that basis we are able to make (formulate) conclusions on type of the cognitive processes of the analyzed person.

The properly prepared software collects all information concerning the eyes positions at certain time and time duration of the sight stop on chosen position on the screen. The whole path on which the sight moves is also registered.

In the result the suitable processed data give the possibility of the generation of so called heatmaps and the focus maps i.e. the images on which, using suitable colors, are presented the average results of the sight localizations of the analyzed persons. The heatmaps essentially present the heat distribution of the focus points of chosen objects, which are easier observed than other negligible objects. In the case of leader of eyetracker producers- Tobii company- the software allows on the generation of two type of the heatmaps: gray-scale heatmaps (more intense focus point corresponds to certain level of transparency) and color heatmaps. Bright red color usually corresponds to point on which the sight is most frequently focused and lightgreen color corresponds to points at which the sight is rarely focused.

Fig. 3. Heatmap shows regions which attract especial attention of user

The next results of the studies by using eyetracker are, so called gazeplots. The gazeplots present the direction of eye scanning path during subsequent fixations. At is was shown in Fig.4 the single circles illustrate the subsequent fixations (the circle diameter is proportional to the duration of fixation). The lines which connect the circles correspond to direction of the eye scanning path. This process is called the eye sakkad movement.

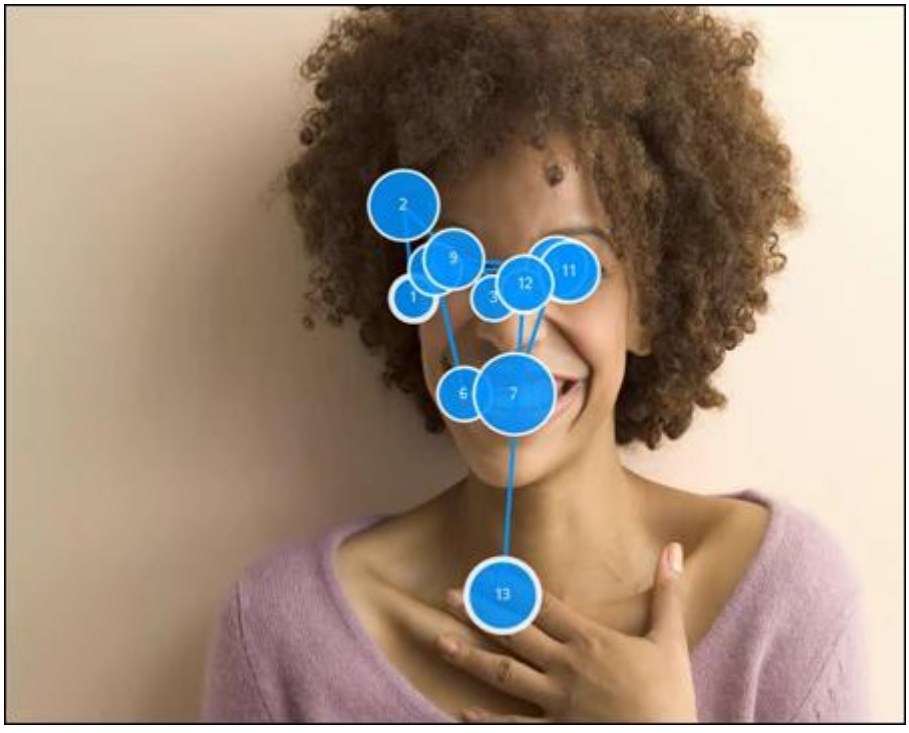

Fig. 4. Gazeplots show order and length of particular fixations

Additional forms of the eyetracking analysis are so called areas of interest (AOI). The investigator is able to determine the crucial, from his point of view, elements and to verify their popularity among respondents (how long and when the elements were observed). It is possible to perform the analysis of direction and duration of fixation in frame of given area. Moreover this method offers the possibility of comparison of the results between different areas what can lead to very interesting and valuable conclusions. Finally we can get the consistent information about number of peoples, which are especially interested in chosen AOI and how long continued the average fixation.

The data obtained from eyetracker experiment allow to determine the time the persons spend on observation of the interesting us elements on the screen (especially prepared presentation as for example videos or websites); what is the sequence of observation; what disturb the observers. Additionally we can also to determine which element immediately catches the eye and which are ignored.

Important fields of the eyetracking application is to support the analysis of general desktop programs and web pages (known as usability and webusability), or television advertisement. Usability is a science dealing with the ergonomics of interactive devices and overall applications. It determines the ease in the use and convenience of use. Usability and webusability it is strike a balance between the amount of features and ease of handling. End users will not be satisfied with a very ergonomic form WW, if you will not be able to perform the desired action. On the other hand they do not satisfy the application gives the theoretical possibility of making the desired task, but in a manner so complicated that it almost useless in practice. The results obtained allow the appropriate processes to remodel or even graphical structure of the product before you get on the market.

Usability, heat map and AOI

With a choice of appropriate tools (eyetracker Tobii and Tobii Studio software) decided to conduct usability testing, in which a randomly selected group of people presented a snapshot of her interviews with famous politicians. Based on the results we were able to determine the heat map and the areas of AOI (Area Of Interest). The purpose of the implementation of a more pictorial form of heat maps made known inversion, i.e., "_decrease the brightness" of elements of lower popularity of the respondents and to highlights section, which most attracted the public's attention. The effect of our measurements can be seen in Figure 5

Fig. 5. So-called „inversion" heat map obtained by testing shutter during the interview with well-known politician

Going a step further, we decided to appoint a so-called areas of greatest interest, i.e. the AOI. In Figure 6 we show the results of our measurements.

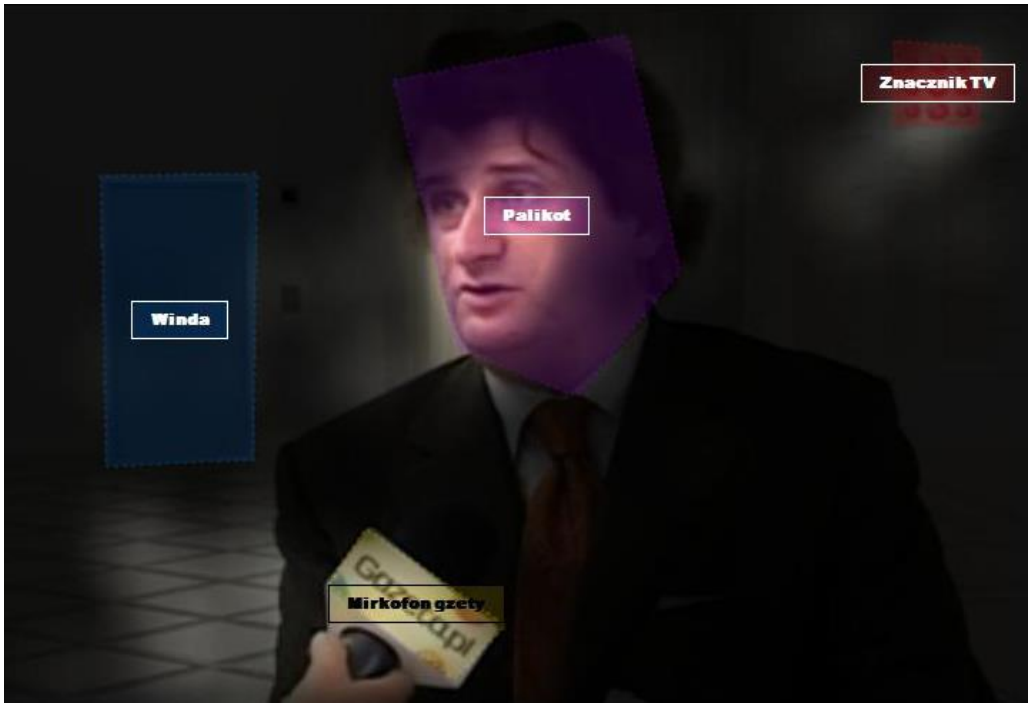

Fig. 6. Assignation of areas of interest (AOI)

As shown in the provided screen shots, properly calibrated equipment and customized software can produce interesting results. In the presented cases, we carefully managed to determine which areas of the image presented test-takers are of most interest. We believe that even more interesting results of the study, for example, miss out by making commercials. We

could thus indicate a "weak" points of the advertisement to define proposals for changes, etc. In addition, we consider the possibility in our studies to use the electroencephalogram, which coupled with the current infrastructure could give a chance to measure emotions during the eyetracking study.

Conclusions

Undoubtedly from point of view of practical use of collected information, the best feature of the studies with eyetracker use is a potential objective determination of the consumer activity and perception as function of chosen time unit. The properly constructed software is able to support the studies of usability of the created software market realized in Internet on WWW Websites and also to support the advertisement realized by TV Advertisement Agencies, billboards etc.

The eyetracking has also certain limitations. It may happen that due device construction (the necessity of eye illumination by infrared, camera position etc.), some analyzed persons during the procedure must dress off the glasses or to take of the contact lenses. Additionally, it necessary for respondent to have stable position during the studies procedure and sight must be in the range of camera operation. All these elements can have a negative influence on the activity of stimuli and in consequence the whole procedure can be unbelievable. In the context of eyetracker use as a transducer element between the disabled human sight and the fulfill of all condition can be problematic.

It is also important to mention that the necessity of averaging of the obtained data have an influence on proper interpretation and proper conclusions formulation. The stimuli (advertisement movie, static images) which are presented to the respondent influence them not uniformly. Each of them reacts on chosen presentation or Website in different way. In the consequence the data of honestly performed studies on the big group of peoples must be averaged and extreme opinion removed.

An interesting point of view on eyetracking seems to be the determination of the emotional activity for chosen moment of studies. In the order to achieve that goal the studies cam be enriched to record electroencelograph measurements. Because the unequivocal interpretation of such a record is very difficult and is characterized by big error therefore the problem is undertaken more and more frequently by specialist from the field of neuropsychology.

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