Abstract

Marta Anna Szmigiel

Measurement and numerical analysis of eye pupil kinetics and the possibilities of their use in ophthalmic diagnostics

PhD Thesis

Supervisor: prof. dr hab. inż. Henryk Kasprzak

This doctoral dissertation deals with the measurements of the variability of size and geometry of the eye pupil and on its basis with the eye movements. The dependence of the eye pupil with the blood pulsation is a less-known subject and may be a tool in the diagnosis and monitoring of some eye diseases..

As part of the doctoral thesis, a system for registering the image of the human eye pupil was designed and constructed. Its main element was a high speed camera, usually not used for this type of examination. The system also contained a pulsometer, to register the blood pulsation of the examined person simultaneously with the registration of the eye pupil. The measurements were carried out on a large number of subjects. Based on the registered sequences of the pupil images, basic parameters describing the shape and geometry of the pupil were proposed, such as the coordinates of the pupil center, its area, eccentricity, the orientation angle of the main axis. Information on the variability of these parameters over time provided the basis for determining further parameters, such as the length and angle of reposition, variability of parameters, as well as correlations and coherence between them.

Different parameters concerning the shape and geometry of the eye pupil were determined, some of which have not been analyzed so far. The conducted research is a unique observation of the pupil's eye dynamics measured synchronously with blood pulsation, and these tests were performed both on the reference patients group and on the group of patients with glaucoma symptoms. Although information on simultaneous heart and eye movements can be found in the literature, the analysis presented in this dissertation is a new approach to this issue. A method for modifying basic parameters was proposed, followed by their spectral analysis and analysis of interdependencies of the presented parameters. The level of coherence parameter $\mathbf{lev}\boldsymbol{C}_{z_1 z_2}$ was proposed as a parameter enabling the quantification of the interdependence of the tested signals and their comparison between the tested measurement sequences. Also fixation eye movements, although they appear to be accidental, show a high correlation with the blood pulsation, which is demonstrated in the coherence function between the analyzed signals.

The presented results of the eye pupil parameters examined in people with glaucoma symptoms show that the value of coherence level parameter of some pupil geometry parameters and blood pulsation have the potential to statistically differentiate patients with glaucoma symptoms from patients without such symptoms. This direction of research seems promising, as there is high interrelationships of some parameters with blood pulsation. Before introducing the proposed method for clinical use, however, it would be necessary to

repeat the test and results analysis on larger group of patients, in order to obtain appropriate values and ranges for differentiating parameters.

As a result of the conducted research and analysis it can be concluded that obtaining as much information as possible using non-invasive techniques for measuring individual structures of the human eye in vivo can be crucial in improving eye diagnostics. The new non-invasive method proposed in this dissertation, based on image registration of the eye pupil together with blood pulsation, has potential for clinical applications. Analyzing the earlier considerations, it can be concluded that the research hypothesis on the existence of "the possibility of quantifying changes in eye pupil geometry and size using different numerical methods and determination physiological factors affecting these relationships (eg heart rate variability)" has been confirmed.