Tytuł projektu

Optyczne metody obrazowania struktury i funkcji oka ludzkiego w celu diagnostyki chorób neurodegeneracyjnych

Project title

Optical methods for imaging of morphology and functions of the human eye for diagnostics of neurodegenerative diseases

Dyscyplina /Area of science

Nauki fizyczne

PROJECT DESCRIPTION

Project goals

- To optimize the existing multimodal optical setup consisting of the Scanning Laser Ophthalmoscope (SLO), the Optical Coherence Tomography (OCT) imager and the retinal tracker for comprehensive examinations of human subjects in clinical environment.
- To design experimental protocols for human subject examination using the optimized device.
- To conduct experiments with human subjects in clinical environment
- To create data analysis tools for finding potential biomarkers of various neurodegenerative diseases from data acquired from human subjects using the optimized device.

Outline

The first research objective of the doctoral project will be to develop methods for assessment of structure and dynamics of the living human eye. The second objective will be to attempt to apply the developed methods for diagnostic use of neurodegenerative disorders, such as multiple sclerosis (MS), Alzheimer disease (AD), Parkinson disease (PD) or Huntington disease (HD). The methods to be developed will be based on the multimodal optical device comprised of the ultrafast retinal eye tracking module (FET – FreezEye Tracker), the optical coherence tomography (OCT) imager, and the scanning laser ophthalmoscope (SLO). The project will be carried out alongside a larger multidisciplinary team consisted of physicists, engineers, mathematicians and software developers that is currently developing the retinal tracker (FET) for image stabilization purposes.

The retina and the optic nerve are considered to be the outermost part of the central nervous system (CNS). They are also the only part of CNS that is accessible with optical methods, in completely non-invasive manner due to the fact that the layer of retinal nerve fibers (RNFL) is composed of the unmyelinated axons of ganglion cells (which allows for better penetration of light to deeper structures of the retina down to the retinal pigment epithelium), the relatively low density of the glia cells and the transparency of the vitreous humor. In the literature there are reports that confirm the manifestation of neurodegenerative diseases in the condition and behavior of the eye. The initial set of the candidates for biomarkers are:

1. The thickness of the retinal layers, especially retinal nerve fiber layer (RNFL). It will be

accessed with structural OCT imaging which provides 3D images of the retina [1]. The decreased number of the retinal ganglion cells and their axons in the nerve fiber layer (RNFL) was observed in AD subjects via postmortem histopathology [2]. There are numerous examples of application of OCT imaging to quantitatively show that the RNFL and thickness is reduced in AD populations [3] and PD populations [4].

2. Dynamics of the flow in retinal vessels. It can be measured with functional OCT imaging using techniques of OCT angiography as well as assessed with SLO device. In AD patients it was observed an overall reduction of vessel response, which mostly affected the vasodilatation of the arteries [5].
3. Tracking of eye movements. Eye movements deficits and abnormalities play a key role in many neurodegenerative diseases as they affect brain circuits responsible for eye movement control. Saccadic dysfunction, fixation instability, and abnormal smooth pursuit are among the most common abnormalities. Eye movement abnormalities are known to be part of diseases such as PD, AD, HD and MS [6]-[7], therefore can be important and promising biomarker of the disease on its early stages as well as biomarker for cognitive decline in patients. The parameters of the eye dynamics will be accessed with the use of ultrafast retinal tracker based on MEMS scanning device.

Work plan

1. systematic organization of the state-of-the-art knowledge in the field of diagnosis of the neurodegenerative diseases of interest with the use of optical methods,
2. design of measurement protocols for each of the optical modules,
3. adjustment of the measurement software for realization in cooperation with the opticians in optional hardware setup adaptation,
4. development of the data analysis tools providing access to the parameters having the potential to be used as biomarkers,
5. test measurements on healthy subjects for estimation of the feasibility of the, evaluation of the measurement protocols,
6. systematic measurements on the cohorts of patients suffering particular disorders,
7. development of the tools for efficient and safe handling of big data,
8. synthesis of the results providing correlation between the stadium of the disease and the range of values of the chosen parameters.

Literature

1. Daniel Ruminski, Bartosz L Sikorski, Danuta Bukowska, Maciej Szkulmowski, Krzysztof Krawiec, Grazyna Malukiewicz, Lech Bieganowski, Maciej Wojtkowski, OCT angiography by absolute intensity difference applied to normal and diseased human retinas, Biomedical optics express 6 (8), 2738-2754 (2015)
2. Hinton, D. R., Sadun, A. A., Blanks, J. C. & Miller, C. A. Optic-Nerve Degeneration in Alzheimer's Disease. N. Engl. J. Med. 315, 485–487 (1986).
3. Marziani, E. et al. Evaluation of retinal nerve fiber layer and ganglion cell layer thickness in Alzheimer's disease using spectral- domain optical coherence tomography. Invest. Ophthalmol. Vis. Sci. 54, 5953–8 (2013).
4. Tsironi EE, Dastiridou A, Katsanos A, Dardiotis E, Veliki S, Patramani G, et al. Perimetric and retinal nerve fiber layer findings in patients with Parkinson's disease. BMC Ophthalmol 2012; 12: 54.
5. Kotliar, K. et al. Altered neurovascular coupling as measured by optical imaging: A biomarker for Alzheimer's disease. In Scientific Reports 7 (2017).
6. MacAskill MR, Anderson TJ. "Eye movements in neurodegenerative diseases" Curr Opin Neurol. 2016 Feb;29(1):61-8.
7. Roberto Rodriguez-Labrada, Luis Velazquez Perez, Eye Movement Abnormalities in Neurodegenerative Diseases, Eye Motility, 2019

Required initial knowledge and skills of the PhD candidate

➔ basics in optics ➔ basics in computer programming (preferably Python, Labview, Matlab, C/C++/C#) ➔ eager to learn	
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