A Thesis for the Degree of Ph.D. in Engineering

Correlating Functional Near-Infrared Spectroscopy with Underlying Brain Regions for Adult and Infant Populations by Theoretical Light Propagation Analysis

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Thesis Abstract

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Thesis Title

Correlating Functional Near-Infrared Spectroscopy with Underlying Brain Regions for Adult and Infant Populations by Theoretical Light Propagation Analysis

Functional near-infrared spectroscopy (fNIRS) is a noninvasive neuroimaging modality that assesses neural activity by measuring changes in oxygenated and deoxygenated hemoglobin after positioning single/multiple source-detector (SD) pairs over the human scalp. In the past few decades, fNIRS has widely been used to investigate the function of the adult brain and developing brain in the field of cognitive neuroscience. The fast growth of fNIRS studies is due to the several advantages that fNIRS is highly portable and has a relatively robust tolerance for body movements, which is suitable for different experimental settings and various populations including neonates, children, and adults. However, it remains a challenge for fNIRS to target specific brain regions of interest by the positioning of SD pairs on the scalp. Since fNIRS data does not provide any anatomical information on the cerebral cortex, it is extremely important to establish a scalp-cortex correlation (SCC) between the scalp location of the SD pair and brain regions for measuring brain functions. Given that the near-infrared light is strongly scattered in head tissues, the objective of this thesis is to establish the precise optics-based SCC using the light propagation analysis based on the diffusion equation for the adult and infant populations.

Chapter 1 describes the purpose and background of this thesis.

Chapter 2 validates that the diffusion approximation is a highly efficient and robust light propagation analysis methodology, which can be used to obtain the precise optics-based SCC, by comparing optics-based SCC results obtained by the finite element method and Monte Carlo method that is viewed as the gold standard method.

Chapter 3 proposes a sensitivity-based matching (SBM) method to establish the optics-based SCC for 45 subject-specific adult head models. Furthermore, when the SCC was computed, the performance of the SBM method was compared with that of three conventional geometrical matching methods ignoring the effect of light scattering. The results demonstrate that the light scattering and individual anatomical differences in the head affect the SCC, which further indicates that the SBM method is compulsory to obtain the precise SCC.

Chapter 4 aims to establish optics-based SCC for 0-, 1-, 2-year-old infants using the SBM method, and to determine the optimal SD distance for this age period, during which the most dynamic growth in head structures and remarkable cognitive changes occur.

Chapter 5 summarizes the main findings of this thesis and presents conclusions with future works.