Doctoral School of Information and Biomedical Technologies Polish Academy of Sciences (TIB PAN)

SUBJECT:

Application of machine learning- and artificial intelligence-based methods for accurate functional regions in the cerebral cortex identification with the implementation of brain data

SUPERVISOR:

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DESCRIPTION:

Thesis statement: Machine learning methods enable accurate identification of functional regions of the cerebral cortex based on the analysed brain data.

Recent advances in machine learning (ML) and artificial intelligence (AI) have fundamentally transformed research into human brain organization, particularly the identification of functional regions of the cerebral cortex using large-scale brain data [1-5]. The cerebral cortex, with its characteristic convolutions and intricate structure, underpins many higher-order cognitive functions [4, 6-9]. Historically, mapping its functional regions relied on classical neuroimaging and manual expertise, but such approaches struggle with individual variability and the complex nature of brain activity [7-10].
Cutting-edge ML algorithms—including deep learning frameworks such as convolutional neural networks (CNNs) and graph-based neural networks—have been successfully applied to neuroimaging data such as functional MRI (fMRI), electroencephalography (EEG), functional near infrared spectroscopy (fNIRS), enabling more accurate, automated delineation of functional territories [11, 12]. For instance, recent studies have demonstrated the utility of interpretable machine learning pipelines in mapping neuron-level phenotypes to cortical layers, distilling high-dimensional imaging information into meaningful functional parcellations [5, 11, 12]. These novel approaches allow both broad (image-level) and granular (neuron-level) analyses, providing deeper insight into the organization and diversity of the cortex [13, 14].
AI-driven brain mapping is not limited to segmentation: it encompasses biomarker identification, functional network discovery, and robust classification of regions based on spatiotemporal dynamics within multimodal datasets [11, 13-15]. Machine learning excels in revealing hidden patterns, compensating for measurement noise, and integrating data across individuals—facilitating cross-species comparisons and personalized neuroscience [16, 17]. These methods have accelerated neuroimaging analysis, network discovery, and

disease diagnosis, finding applications in the characterization of neurological disorders and the development of individualized treatment approaches [8, 11-13].

The proposed research addresses the task of developing machine learning and AI methods capable of reliably identifying functional regions in the cerebral cortex from diverse brain datasets [11, 18]. This involves advanced data preprocessing, model design, validation against expertly annotated data, and interpretability analysis. Special attention will be paid to the challenges of data heterogeneity, individual differences, and model explainability. The integration of AI not only enhances mapping accuracy but also opens new perspectives for hypothesis generation, cross-modal analyses, and clinical translation.

REQUIREMENTS:

- M.Sc./M.A. degree in computer science, mathematics or a related field
- High programming skills in Python
- Experience with knowledge engineering
- Knowledge about current research on agent-oriented workflows for Generative AI
- Advanced Level in English (speaking and writing)

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