Cedalion: A Python-based framework for data driven analysis of multimodal fNIRS and DOT

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Abstract: We would like to announce the release of a new Python-based software framework, Cedalion, designed for data-driven fNIRS/DOT analysis, with the ultimate goal of merging well-established analysis methods for neuroimaging modalites (e.g. fNIRS, EEG) and physiological and behavioral measurements, with advanced multimodal machine learning techniques.

Introduction: fNIRS / DOT signals are inherently confounded by systemic physiological activity in the cerebral and extra-cerebral compartments. As a result, contrast, sensitivity, and specificity of the recovered hemodynamic responses are affected – a problem that is further amplified by natural behavior in experiments for neuroscience in the everyday world [1]. This motivates our research into new methods that make use of additional auxiliary measurements from physiological sensors and complementary neuroimaging modalities like EEG to explain variance in fNIRS signals and separate confounding components from those of interest. However, complex properties such as non-stationarities, non-instantaneous and non-linear coupling between the multimodal and multivariate time series make modelling the relationships between different signals a hard problem. A promising approach is learning these relationships from data with machine learning and AI. As we assume that these methods will play an increasing role in the upcoming years, we are developing Cedalion, a new Python-based framework, to aid the community in combining state of the art fNIRS/DOT methods with ML/AI. Towards improving contrast and statistical power in neuroimaging experiments, boosting performance in single trial analysis for BCI and Neuroergonomics and uncovering complex relationships between systemic physiology and the embodied brain [2].

Methods: Cedalion is a modular and open-source Python package that combines much of the key functionality of HOMER2/3 and AtlasViewer with the rich Python ecosystem of machine learning and data science tools for data-driven analysis using packages such as sklearn, PyTorch and Pandas. Our goal is 1) to facilitate the development of new data-driven methods, by simplifying the integration of machine learning workflows and conventional fNIRS data processing streams. 2) to provide user-extensible data structures and functionality that allow for easy data exchange with popular frameworks, and with established toolboxes through standardized file formats like SNIRF and BIDS. 3) to support the construction of workflows that chain existing functionality of versatile and well-tested analysis toolboxes that provide specific preprocessing methods for each neuroimaging modality. 4) to establish a community-centered development philosophy that focuses on easy contribution and distribution of new methods and clearly credits contributors and incorporated published work on its documentation page. Currently, Cedalion's functionality comprises photogrammetric optode coregistration, standard signal pre-processing (channel quality assessment, artifact rejection, filtering, mBLL conversion), General Linear Model analysis, integration of MCX for photon simulation, DOT image reconstruction, and first pipelines for ML-based single-trial analysis.

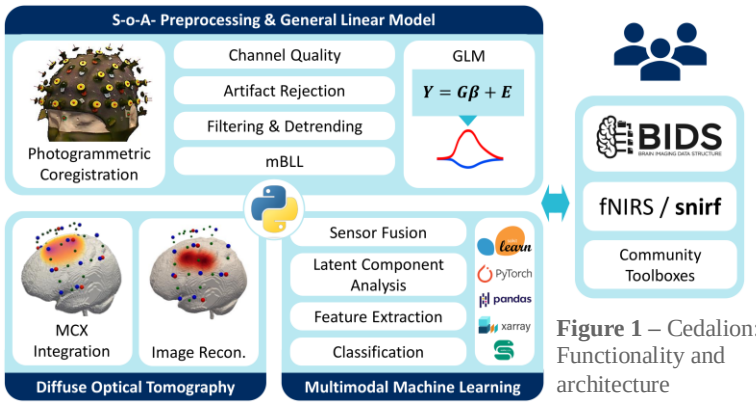

Figure 1 – Cedalion: Functionality and architecture

Results and Conclusion: Cedalion is an ongoing development project (see ibs-lab.com/cedalion) and openly available on github.com/ibs-lab/cedalion.

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