NeuroImaging Brain Chart: Individualized Imaging Biomarkers of Disease and Aging

*Guray Erus1, Christos Davatzikos1*

*1Artificial Intelligence in Biomedical Imaging Laboratory (AIBIL), Center for Biomedical Image Computing and Analytics, Perelman School of Medicine, University of Pennsylvania, Philadelphia, USA*

Purpose

To implement and validate a machine learning based image processing and analysis suite for calculating a panel of individualized imaging biomarkers of disease and aging.

Material and Methods

The NiChart software suite consist of stand-alone image processing pipelines for MRI images, as well as pattern analysis and machine learning (PAML) models for precision diagnostics and personalized prognostication that have been built on top of an extensive multi-study dataset of MRI images. A cloud-based infrastructure and a web-interface with associated seamless “drag and drop” procedures enables any user to easily upload their brain MRIs and obtain measures of brain age, Alzheimer’s Disease score, predictions of accelerated path to cognitive decline or of resilient brain aging, measures of vascular lesions, and many other measures of disease and aging. Image processing pipelines have been specifically designed to handle large-scale multi-study datasets and are integrated within a unified framework using a collection of independent software containers, ensuring high portability, reliable reproducibility, and increased modularity for future extensions. The data analysis and machine learning components of the suite include statistical harmonization [1], supervised pattern regression and classification for deriving disease biomarkers [2], and semi-supervised clustering for disease subtyping and heterogeneity analysis [3]. PAML methods are trained on harmonized multi-modal MRI image features from the diverse iSTAGING dataset [1].

Results

NiCHART reference dataset includes imaging data pooled from 22 studies (n = 65,693 individuals). Brain structure is quantified using deep learning based anatomical parcellation and data-driven structural covariance components [4]. Region of interest (ROI) segmentation [5] using atlas-based and data-based models allowed multi-scale characterization on brain antomy. Automated segmentation of white matter hyperintensities was performed for characterizing white matter disease in the reference population. Data harmonization provided unified and normalized measures of imaging variables. Supervised machine learning models included SPARE-AD [2] for quantification of AD like patterns of brain atrophy, and SPARE-BA for brain aging patterns. Semi-supervised pattern clustering methods investigated disease heterogeneity, identifiying data-driven neuroanatomical signatures of neurodegeneration in AD and aging.

Conclusion

We present NiChart, a software suite with a web-based interface that provides a user-friendly tool for automated analysis of multimodal neuroimaging datasets using state-of-the-art image processing, machine learning and deep learning methods. NiChart enables users to calculate an individualized panel of imaging scores associated with healthy and diseased brain states, using machine learning models that are extensively trained on harmonized imaging data from a large multi-study reference dataset.

Clinical Relevance

Adoption of specialized AI software and processing pipelines at a very broad scale and by non-expert users can be quite challenging. NiChart aims to fill in this gap allowing clinicians and researchers to calculate a panel of clinically interpretable scores that reflect brain patterns associatd with disease and aging

***References***

*[1] Pomponio, R., et al., Harmonization of large MRI datasets for the analysis of brain imaging patterns throughout the lifespan. Neuroimage, 2020. 208: p. 116450.*

*[2] Davatzikos, C., Xu, F., An, Y., Fan, Y. & Resnick, S. M. Longitudinal progression of Alzheimer's-like patterns of atrophy in normal older adults: the SPARE-AD index. Brain : a journal of neurology* ***132,*** *2026–2035; 10.1093/brain/awp091 (2009).*

*[3] Rozycki, M., et al., Multisite Machine Learning Analysis Provides a Robust Structural Imaging Signature of Schizophrenia Detectable Across Diverse Patient Populations and Within Individuals. Schizophr Bull, 2018. 44(5): p. 1035-1044*

*[4] Wen, J. et al. Characterizing Heterogeneity in Neuroimaging, Cognition, Clinical Symptoms, and Genetics Among Patients With Late-Life Depression. JAMA Psychiatry* ***79,*** *464–474; 10.1001/jamapsychiatry.2022.0020 (2022).*

*[5] Doshi, J., et al., MUSE: MUlti-atlas region Segmentation utilizing Ensembles of registration algorithms and parameters, and locally optimal atlas selection. Neuroimage, 2016. 127: p. 186-195.*