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SCIENCE

A Differential Geometry-based Machine Learning Algorithm for the Brain Age Problem

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The Brain Age Problem (BAP) deals with understanding what age-related changes occur in the human brain. This problem, fundamental in neuroscience, is of rising importance given the overall aging global population and the associated increase in brain diseases. The unprecedented recent advances in artificial intelligence make this an ideal time to address the BAP using machine learning. In 2009, the National Institutes of Health (NIH) launched the Human Connectome Project (HCP), aimed at understanding questions related to brain connectivity, including the BAP.

In our work, we created a mathematically founded and interpretable model for predicting age from brain biometrics. We analyzed an HCP dataset of 1,113 young adults ages 22–36+ using the thickness and area data of 68 different brain regions. The relative stability of brain biometrics in this age range makes the age prediction problem difficult. We attacked the BAP by combining ideas from supervised learning and differential geometry. In particular, we derived a novel surrogate of the isoperimetric ratio, named normalized stretching ratio (NSR) and given by T^2/S, where T is the membrane thickness and S is the surface area. We fed the NSRs into a multinomial logistic regression model, which we compared to a similar model trained on the raw data. The NSR model maintained the resampling average of the raw data model (40% classification accuracy vs. 33% baseline) on the validation set while reducing the number of variables by 50% (136 to 68). These are strong positive results, since fewer variables correspond to higher interpretability, and this is reached without loss in accuracy.

Research advisor Alessandro Maria Selvitella writes: "Can we predict the age from brain biometrics? My research group is working on this important neuroscience question combining differential geometry and AI. Our algorithm joins the modern principles of interpretability and prediction accuracy. Justin Asher, Khoa Tan Dang, and Maxwell Masters, together with my other students Peter Klopfenstein and Jucoen Yeater, obtained encouraging results, and are trying to extend our current findings using neuroimaging techniques."

Asher, J., Dang, K. T., & Masters, M. (2020). A differential geometry-based machine learning algorithm for the Brain Age Problem. *Journal of Purdue Undergraduate Research, 10,* 104–105.

http://dx.doi.org/10.7771/2158-4052.1445

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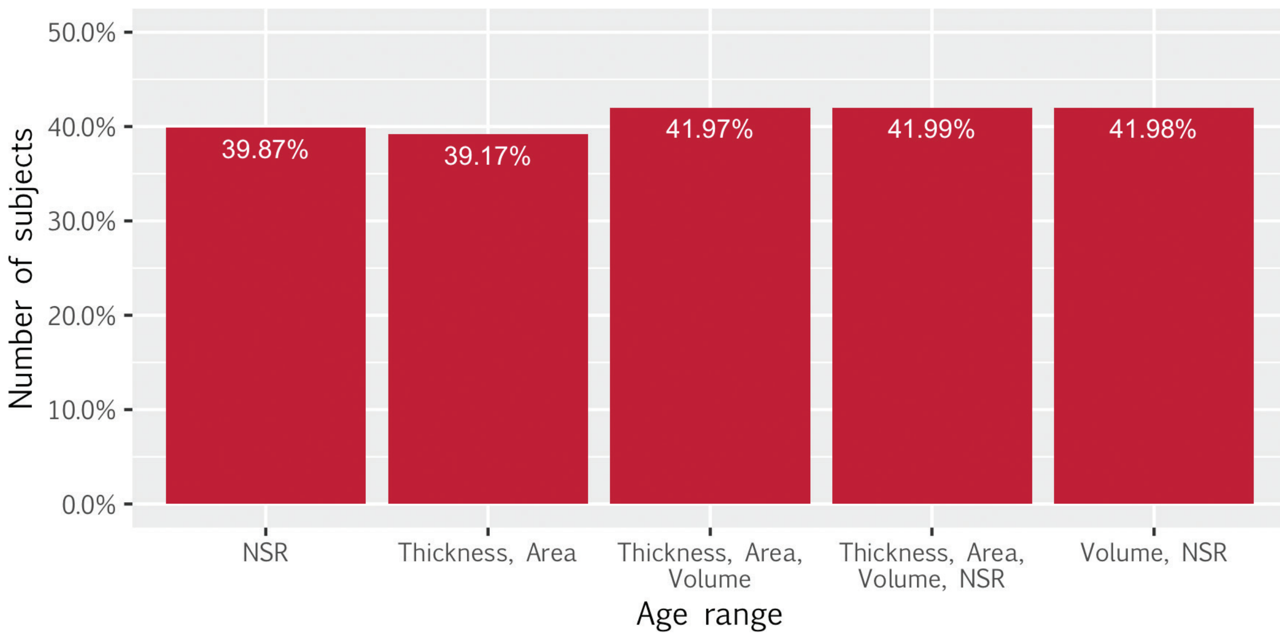

Bar chart comparing the model accuracies for different data subsets.

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