Deep learning for analysis of diffusion-MRI based white matter tractometry

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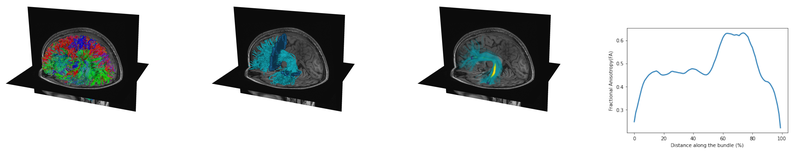
Introduction

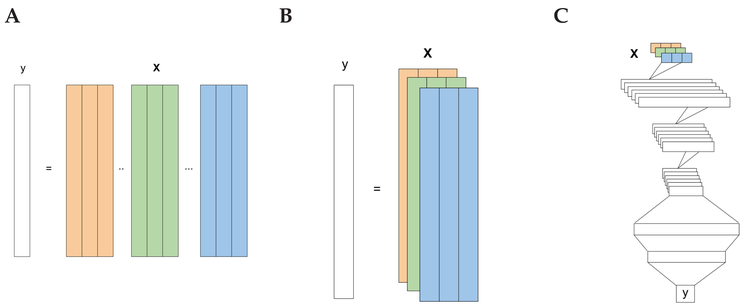
- Tractometry uses diffusion MRI (dMRI) to quantify brain tissue properties within white matter connections *in vivo* [1].
- The Healthy Brain Network Processed Open Derivatives (HBN POD2) is a large (n>2,000) pediatric dMRI dataset that has been processed and automatically QC'd[2, 3].
- The pyAFQ software was used to create tract profiles for statistical analysis [4].
- In previous work, we demonstrated that regularized regression provides accurate predictions of individual age in HBN from tractometry data (WM-based "brain age")[5].
- These models cannot capitalize on non-linear effects and sequence features, but deep learning models are well-suited to do that.



Whole brain tractography | Selecting a bundle with ROIs | Extracting values along the length of the tract | Tract profile

Question: Does deep learning provide improvements in inferences from tractometry?

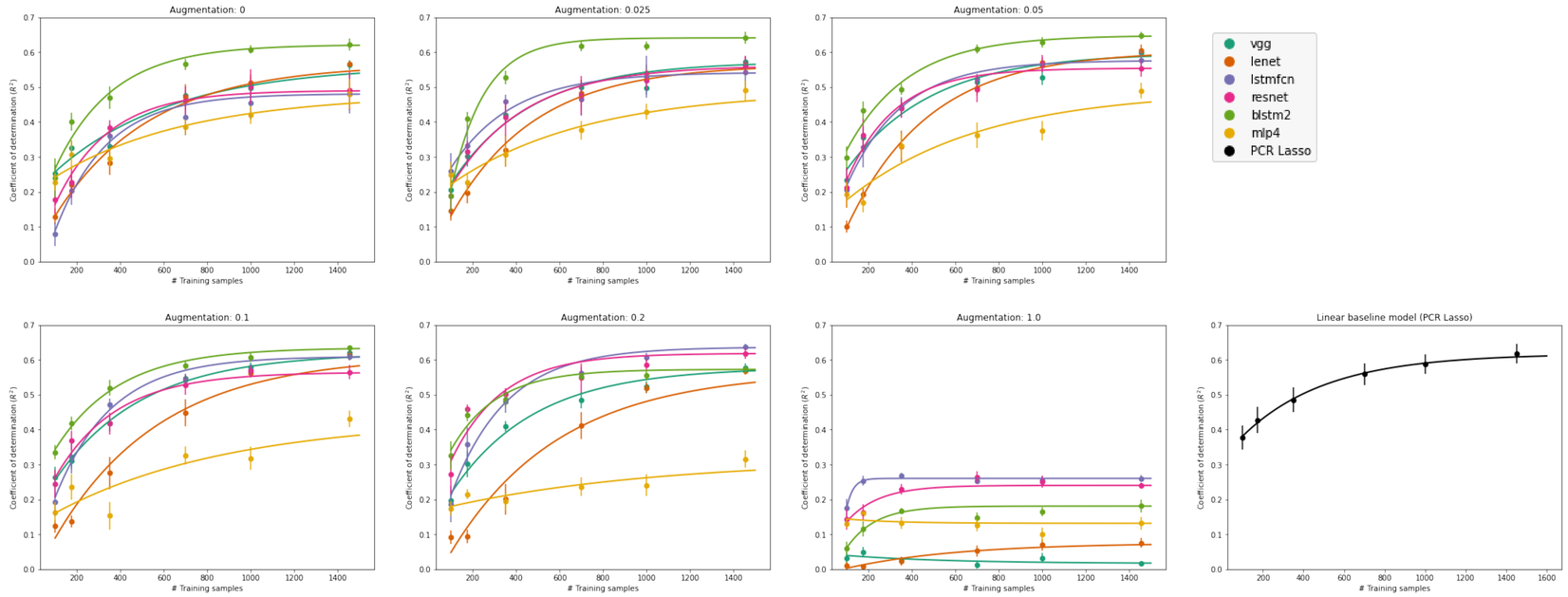
Methods



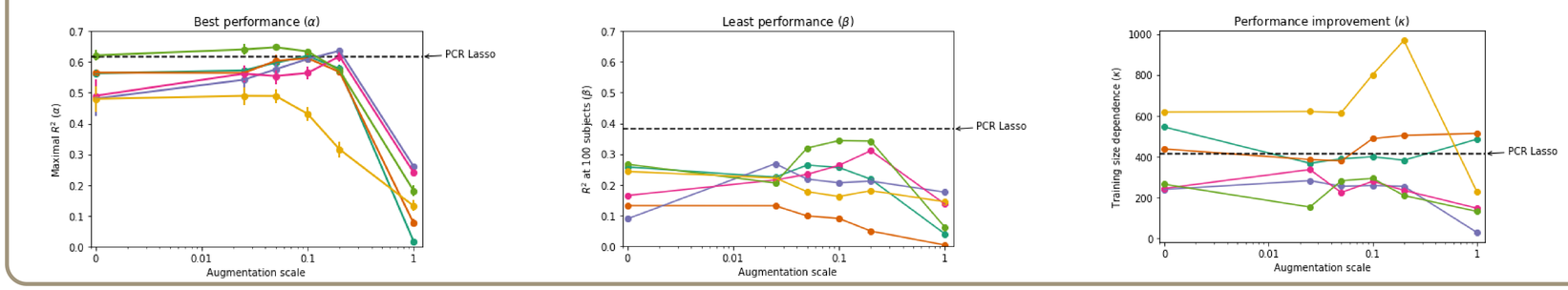
- (**A**) In a linear tractometry model, $\mathbf{y} = \beta X$. (**B**) To move towards a convolutional neural networks, we stack the data from different tracts and metrics (FA, MD, MK) as different measurement "channels" . (**C**) Training samples are then passed to a network (here as schematic)
- We used the 1817 subjects from HBN POD2 that had passing QC scores and age information.
- A variety of convolutional neural networks were implemented in `AFQ-Insight` (`https://richiehalford.org/AFQ-Insight`)
- We trained the models in "brain age" prediction. To evaluate the models, we set aside a test set of 20% of the subjects (363 subjects)
- To compare model dependence on training set size, we trained with variable train set sizes (100, 175, 350, 700, 1000, 1453 subjects) and different augmentation levels
- We compared to a state-of-the-art linear model: PCR Lasso [5]
- Model performance was quantified as the coefficient of determination, R^2, in predicting the age of the test set subjects.
- R^2 was modeled as: $\alpha - (\alpha - \beta)e^{-\frac{x - x_{min}}{\kappa}}$, where x is the number of training samples, α is R^2 at the maximal number of training samples, β is R^2 at the smallest number of training samples (x_{min}) and κ is a free parameter that denotes that number of training samples required to achieve R^2 that is 67% of the difference between β and α.

Results

At each augmentation level, performance improves with training set size:



The models' performance at each augmentation level is summarized through three parameters that quantify the maximal and minimal performance levels, and the convergence of performance with training set size:



Conclusion and future work

- Neural network models (NNs) improve accuracy of tractometry analysis
- NNs are very data hungry
- Tuning and training these models is complicated and time-consuming
- Differences can be much more important in some cases (see poster # XXX)

References

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[4] John Kruper et al. Evaluating the reliability of human brain white matter tractometry. *Aperture*, 1:10.52294/e6198273–b8e3–4b63–babb–6e6b0da10669, 2021.

[5] Adam Richie-Halford, Jason D. Yeatman, Noah Simon, and Ariel bf Rokem. Multidimensional analysis and detection of informative features in human brain white matter. *PLoS Computational Biology*, in press(6):1–24, 06 2021. PMC5838108[pmc.

Acknowledgments

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