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Fetal diffusion MRI enhancement in early brain development

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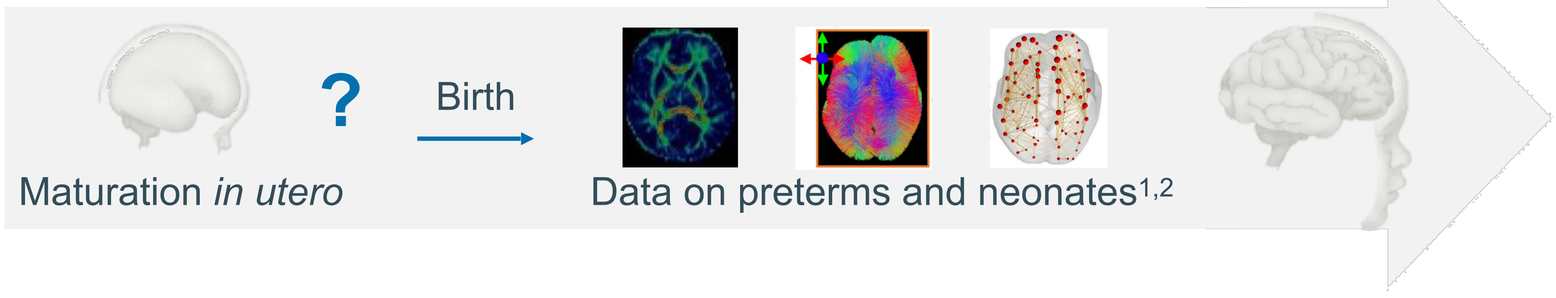
MOTIVATION



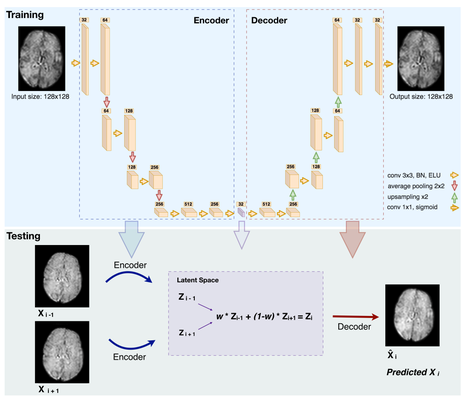
New tools for evaluating pregnancies
- Support for diagnosis/prognosis
- Link between prenatal and postnatal evaluation

Understanding of early brain maturation *in utero*
- White matter development
- Connectomics

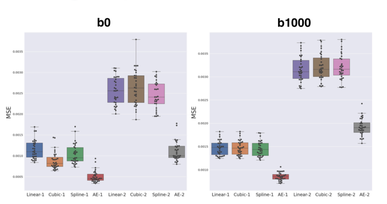
Autoencoders for super-resolution enhancement[3]

1. Pre-term baby brain[4] training and evaluation

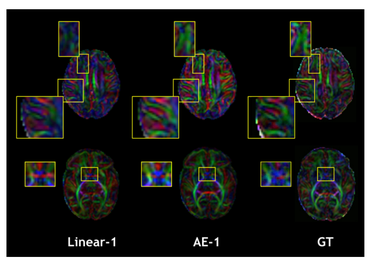
- Inspired by cardiac MRI[5], exploiting an autoencoder *latent space* to generate middle slice(s) using adjacent ones in order to artificially increase the through-plane resolution



Framework of autoencoder enhancement in training and testing phases



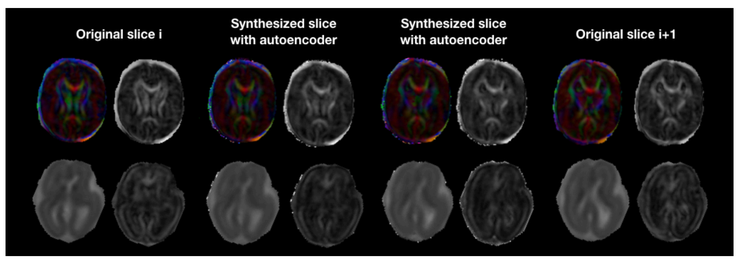
Mean squared error (MSE) between the three baseline methods (linear, cubic and B-spline 5th order) and autoencoder (AE) enhancement b1000 (right)



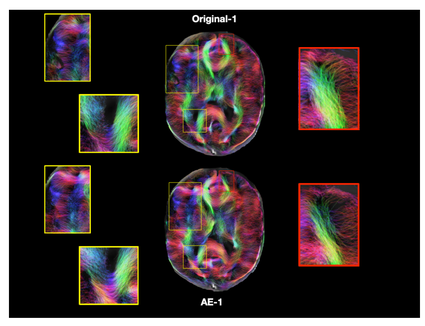
Color FA of a pre-term subject in interpolation Linear-1 (left), autoencoder enhancement AE-1 (middle) and ground truth GT (right)

2. Evaluation on fetal brains

- Trained network on pre-terms could generalise to fetuses
- Smooth transition in FA, color FA and MD for generated slices
- Tractography on a fetal subject shows improved density in some regions and coherent white matter structures



Top row: color FA (fractional anisotropy) and FA of autoencoder enhancement between two original adjacent fetal slices in a still subject (35 GW). Bottom row: MD (mean diffusivity) and FA for a moving subject (23 GW).



Tractography on a fetal subject of 35 gestational weeks

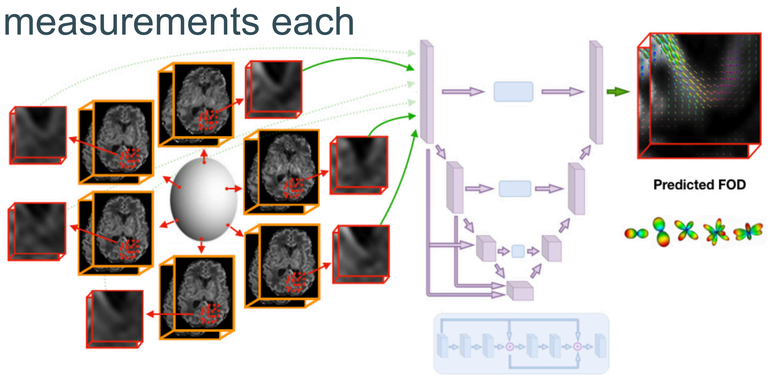
- Autoencoders can be used for dMRI super-resolution and outperform conventional interpolations in pre-terms, particularly for large slice gaps and can successfully generalize to fetal brains

Deep learning estimation of fiber orientation distribution functions (FODs) with few diffusion MRI measurements[6]

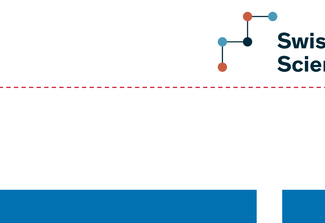
1. Generating FODs with 6 diffusion measurements

- Patch-based network trained on predicting FODs constructed using multi-shell multi-tissue CSD (MSMT-CSD)[7] with 300 measurements using 6 input samples

- Comparison with state-of-the-art methods and with the agreement of two independent sets constructed with MSMT-CSD of 150 measurements each



2. Evaluation on newborns and a fetal subject



AFD error for the different methods and for the agreement between the two independent sets

Qualitative evaluation of a newborn subject (left) and a fetal subject (right) on predicting anatomically valid FODs

- Significantly lower Apparent Fiber Density (AFD)[8] error
- Low error in number of estimated peaks per voxel and low angular error
- Low agreement between two independent high quality sets (ex: only ~30% for 2- peaks voxels)

- Deep learning can successfully predict FODs using a small number of measurements by leveraging neighbouring information and high quality datasets. This has the potential of contributing to scanning time reduction with more than an order of magnitude and can highly benefit non-cooperative cohorts such as neonates or fetuses

REFERENCES [1] Dubois et al., Neuroscience 2014; **[2]** Song et al., Frontiers in Neuroscience 2017; **[3]** Kebiri et al., Frontiers in Neuroimaging 2022; **[4]** Hutter et al., Magnetic Resonance in Medicine 2018; **[5]** Sander et al., SPIE 2021; **[6]** Kebiri et al., (submitted to) ISBI 2023; **[7]** Jeurissen et al., Neuroimage 2014; **[8]** Raffelt et al., Neuroimage 2012.

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