A NEW FRAMEWORK FOR ANALYZING WHITE MATTER MATURATION IN EARLY BRAIN DEVELOPMENT

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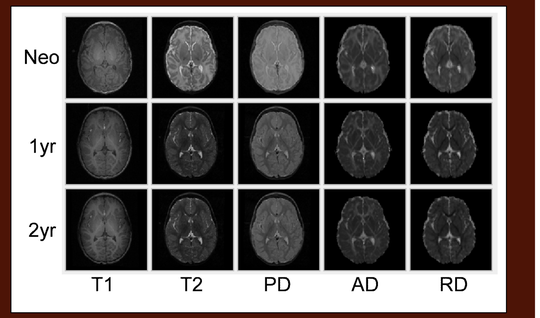
INTRODUCTION

The understanding of human brain development is of significant scientific and clinical importance as relatively little is known about the quantitative trajectory and pattern of early growth.

Assumption:
- Longitudinal tissue property changes of MRI/DTI reflects brain maturation

Procedure:
- Coregistration of longitudinal multimodal data
- Voxelwise modeling, and analysis of longitudinal changes of intensities



3D Images coregistered across time and modality.

Method

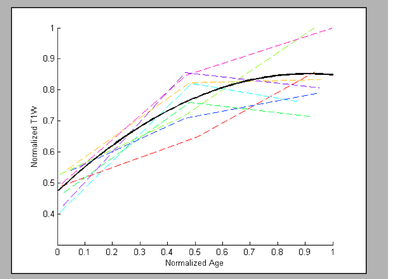
Population Model of Mutlimodal Intensity Changes

We perform a least square fit within each modality to a modified Legendre polynomial basis to create a model for the average growth in the observed multimodal data. The following three basis functions are used for the three time points:

$$L_1(t) = 1$$
$$L_2(t) = \sqrt{3}(2t-1)$$
$$L_3(t) = \sqrt{5}(6t^2-6t+1)$$

We estimate the polynomial coefficients $\beta = (\beta_1, \beta_2, \beta_3)$ that minimizes the squared error measure:

$$\sum_{j=1}^{m}(y_j - \sum_{k=1}^{3}\beta_k L_k(t_j))^2$$

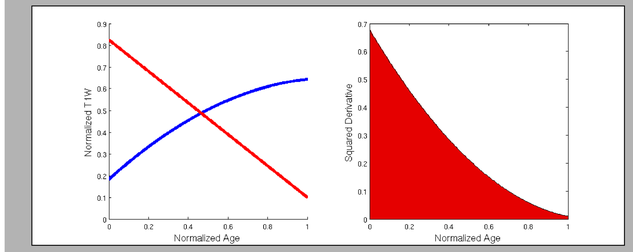


Absolute Measure of Maturation: Growth Rate GR

We measure the absolute growth as the total changes in time at each location. We measure the total growth rate for a set of multimodal observations as follows:

$$GR = \sum_{c\in C} || \frac{d}{dt} f^{(c)}(t) ||^2 = \sum_{c\in C} \int_0^1 \frac{d}{dt} f^{(c)}(t))^2 \, dt$$

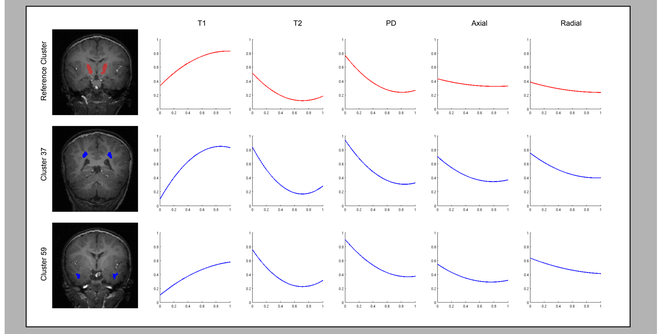
where C represents a subset of the modalities in our datasets.



Data Driven Spatial Clustering

We are interested in isolating spatial regions with distinct patterns of growth as observed in different modalities at different times. We use the Dirichlet Process Mixture Models for estimating the mixture parameters along with the number of mixtures present in the data.

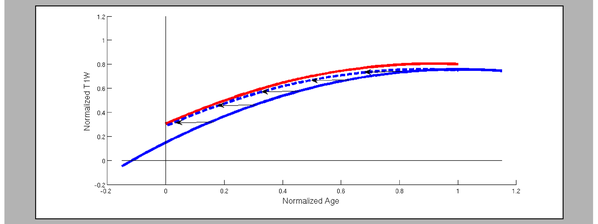
The following image shows the mean curves of three different clusters (left column) for all modalities (T1,T2,PD, axial diffusion, and radial diffusion).



Relative Measure of Maturation: Time Shift TS

The white matter regions appear to undergo similar growth patterns, but different locations may be at different stages of growth. We introduce a new measurement called relative measure of maturation, which is the amount of shift (in time) required to transform a curve to a reference curve. The reference curve is assumed to be a representation of a region that has already matured.

$$TS = \arg\min_s \sum_{c\in C} || f^{(c)}(t+s) - g^{(c)}(t) ||^2$$



Conclusion and Future Work

- Analysis of growth using multimodal curves, complements morphometric analysis
- Population model of normative spatiotemporal trajectories
- Maturation maps: absolute and relative measures of maturation
- Potential for comparison of populations with normal growth vs at risk

References

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Results

Axial and coronal views of growth rates (GR), where darker regions mark low GR and bright regions high GR.

Time shift (TS), where darker regions mark areas with small amount of time shift and white areas indicate a large amount of time shift.