Segmenting the Invisible : Processing 4D Image Data

Avantika Vardhan, Sylvain Gouttard

Introduction

Applications of longitudinal MR image analysis and segmentation of these images into tissue classes (gray matter, white matter and cerebro-spinal fluid) include [1], [3]:
(1) Monitoring trajectories of growth patterns in the brain and its internal structures
(2) Studying myelinational and maturational processes after birth
(3) Understanding definitions of normal and abnormal growth
(4) Clinical significance of change in structure and intensity of tissues and tissue classes with respective to brain disorders and diseases (eg. Autism, and other neurodevelopmental disorders).

Longitudinal Data

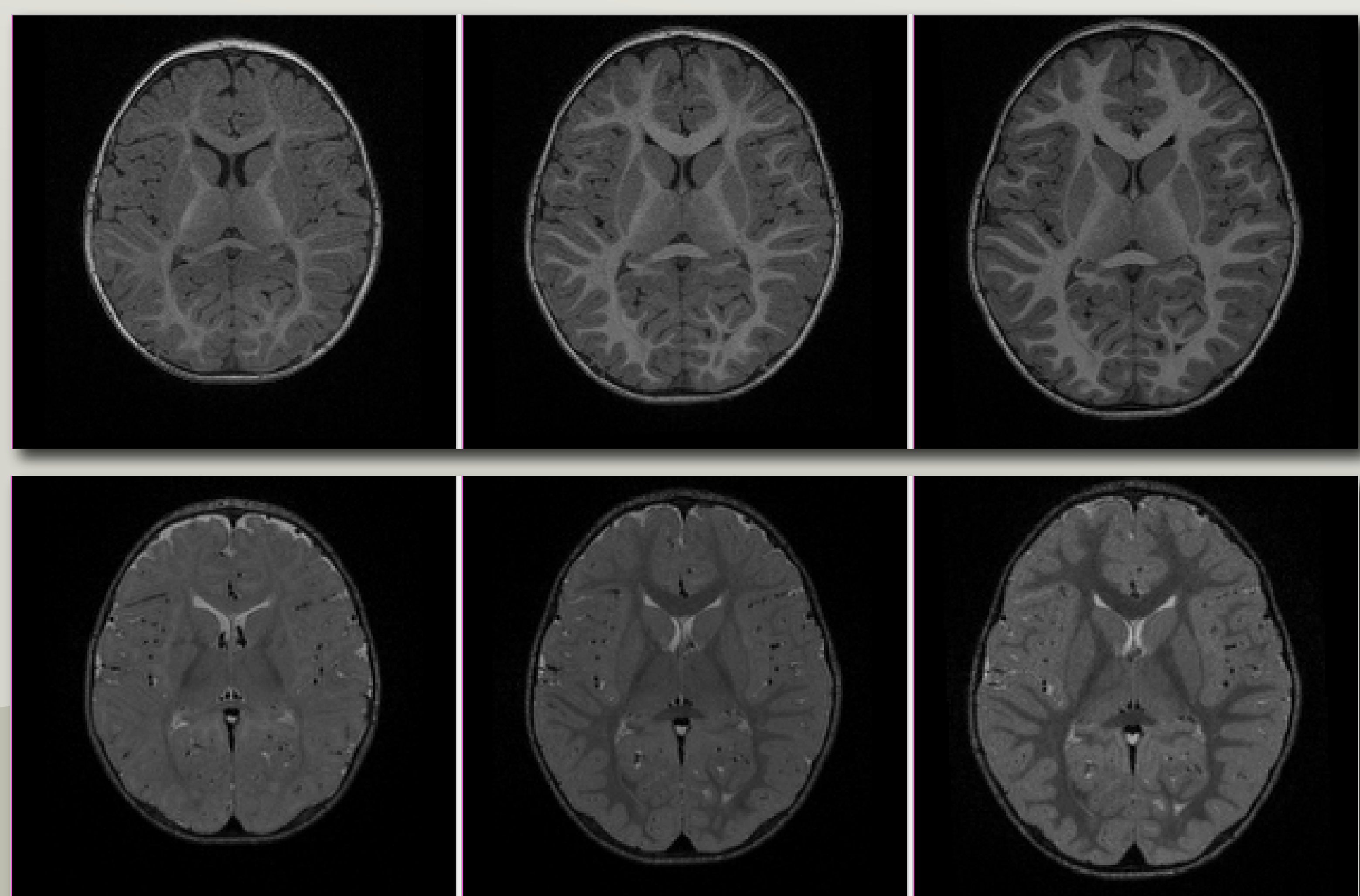

Fig.1 (Top) T1 weighted, (Bottom) T2 weighted scans (from left to right) 6 months, 1 year, 2 year.

Method

We propose a joint segmentation method for 4D image data by applying a later time point image (2 year segmentation result in this case) as a probabilistic prior for the EM based segmentation of the earlier time point images. In the previous method the pediatric atlas was applied as prior for all images.

Challenges in Segmentation

Current Challenges in Segmentation [2], [4]
(1) Lack of contrast in early brain scans
(2) Variable tissue intensity within a single class (eg. white matter) due to varying rates of myelination
(3) Lack of spatio-temporal consistency when each image is individually segmented
The figure below illustrates how contrast improves with age in the developing brain.

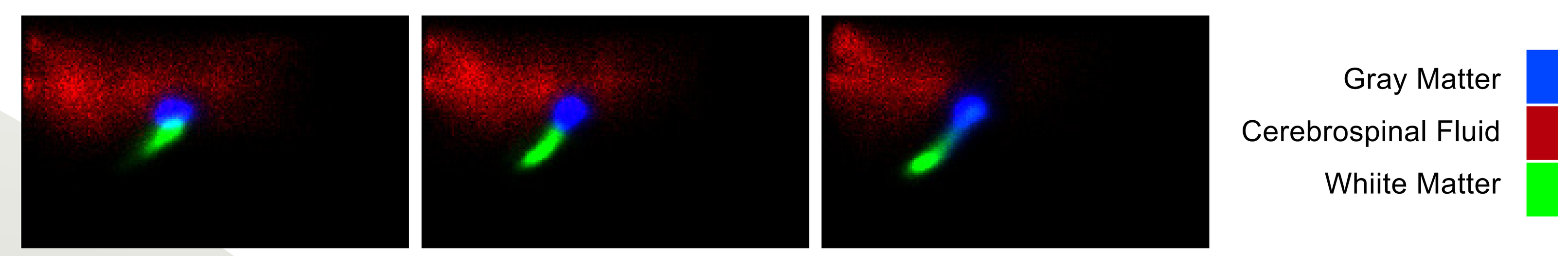

Fig.2 From left to right: 6 months, 1 year and 2 year 2-D histograms-T1 (vertical axis), T2 (horizontal axis).

Characteristics of Longitudinal single-subject data
(1) Structural/Shape changes-removed by Registration
(2) Signal Intensity and Contrast Changes
(3) Anatomy of a single subject remains the same with time – as shown in Fig 3 [2]. Hence we can use later time point image as segmentation prior.

Fig.3 From left to right: T1w 6 months, T2w 6 months, T1w 2 years, T2w 2 years, all nonlinearly registered.

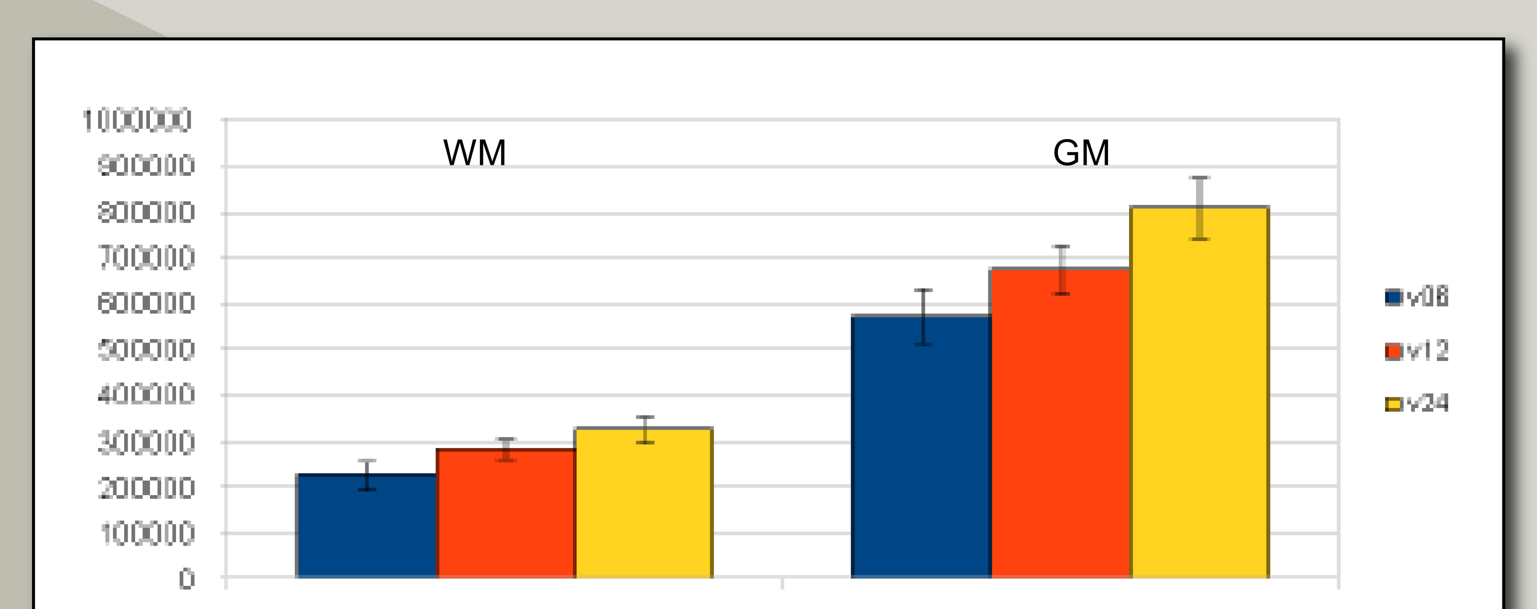

Fig.4 The figure above indicates the volumetric changes (smooth increase in volume) of each tissue class with age

Results

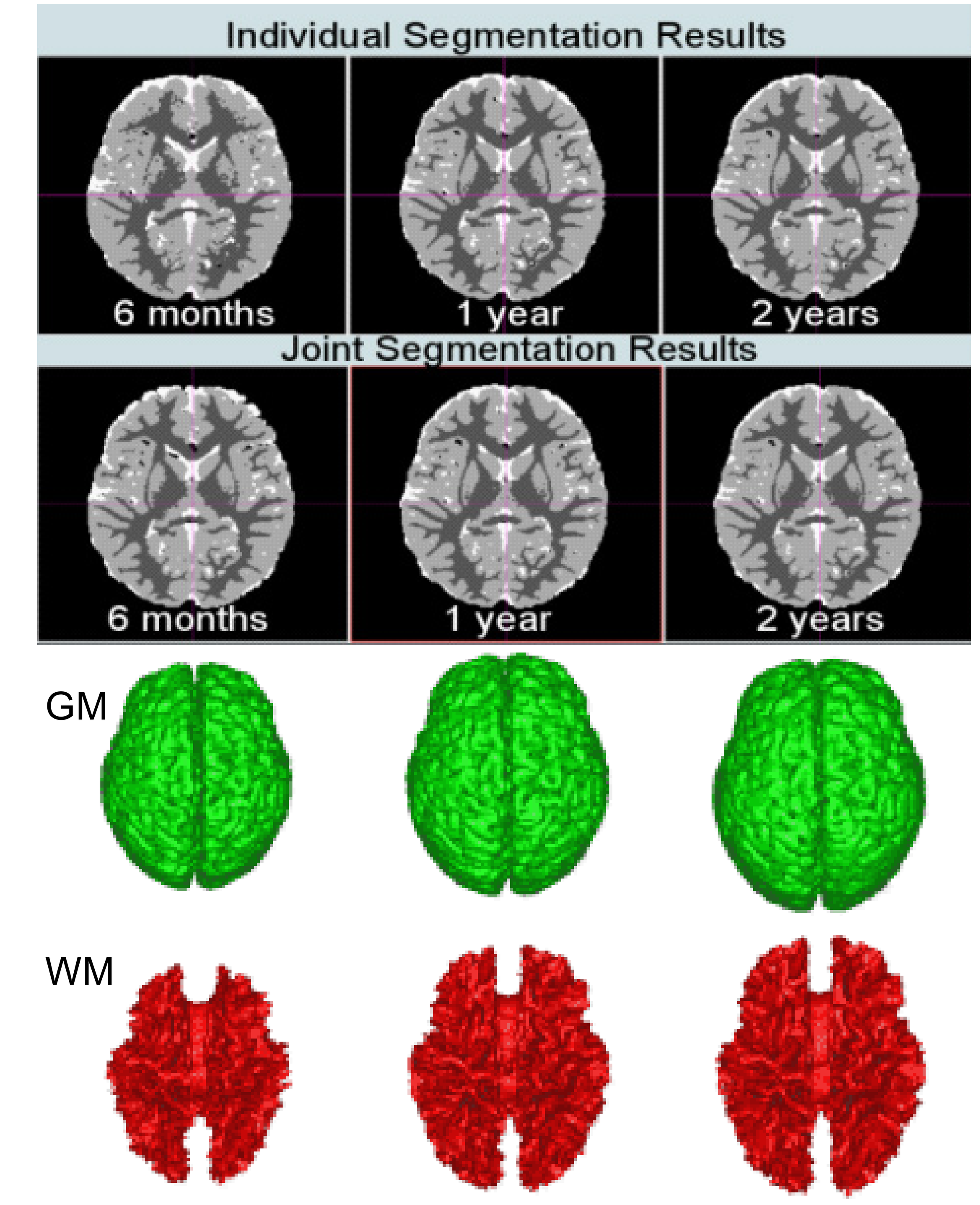

Fig. 5 : Rows 1 and 2 show the results of segmentation for 6 months (left most), 1 year (center) and 2 years (right most) scans. Rows 3 and 4 show the 3D brain surfaces of gray matter (row 3) and white matter (row 4) for the same 3 time points, ordered as mentioned above.

The Fig below illustrates the improvements seen when joint segmentation is used despite very low contrast, especially in areas of late maturation such as the temporal lobe and prefrontal lobe.

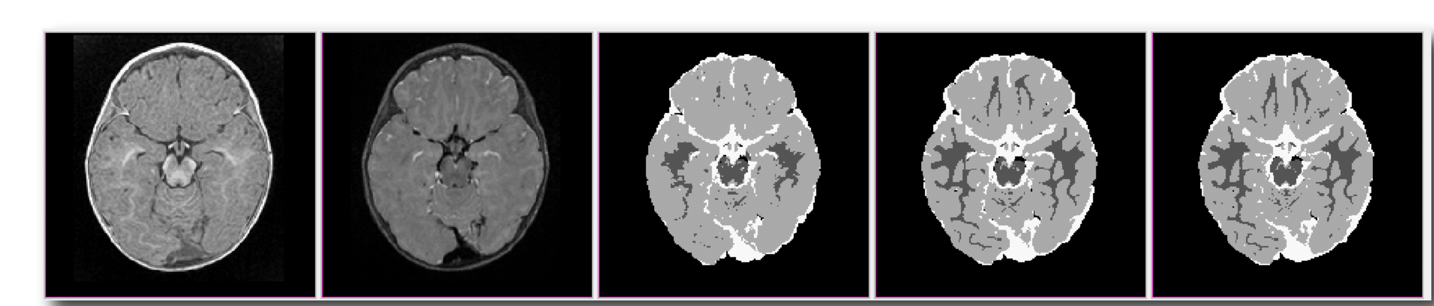

Fig.6 (From left to right): 6 months T1w, 6 months T2w, 6 months individual segmentation, 6 months joint segmentation ,segmentation of 2 year old which is used as the prior probabilistic atlas for joint segmentation.

References

1) Rutherford, 2001 M. Rutherford, MRI of the Neonatal Brain, Saunders Ltd (2001).
2) Feng Shi, Yong Fan, Songyuan Tang, John H. Gilmore, Weili Lin, Dinggang Shen, Neonatal brain image segmentation in longitudinal MRI studies, NeuroImage, Jan 2010.
3) Prastawa, M., Sadeghi, N., Gilmore, J.H., Weili Lin, Gerig, G., "A new framework for analyzing white matter maturation in early brain development," ISBI 2010
4) Sun Hyung Kim, Fonov, V., Piven, J., Gilmore, J., Vachet, C., Gerig, G., Collins, D.L., Styner, M., "Spatial intensity prior correction for tissue segmentation in the developing human brain," ISBI 2011