Mapping longitudinal changes in the brain affected by Alzheimer's disease

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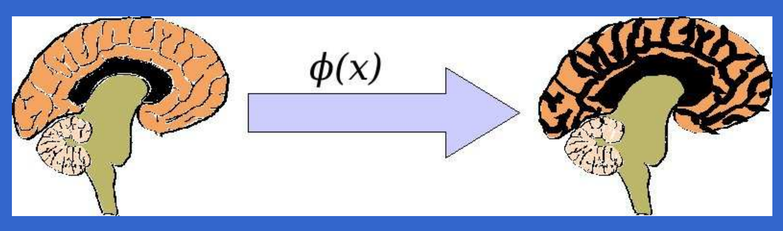
Background. The brain of patients with Alzheimer's disease undergoes changes starting from many years before the development of the first clinical symptoms.

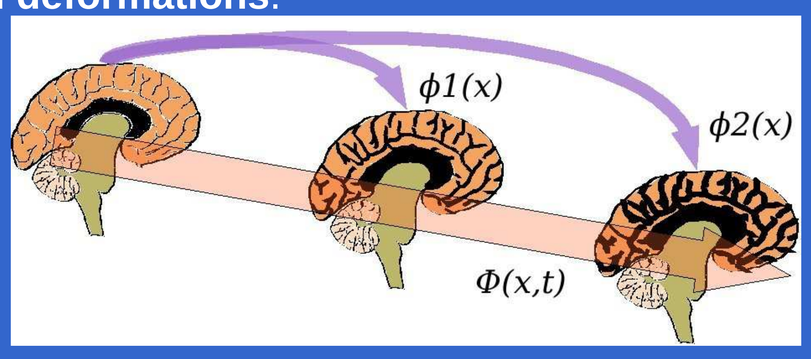
- Large prospective neuroimaging datasets provide data to study the structural changes over time in health and disease.
- The **evaluation of the longitudinal changes in the brain** poses several challenges concerning the consistency of the measurements at both **spatial and temporal level** and the development of a reliable general model to adapt to the subject-specific temporal evolution.

Objectives.

1) To use deformation based morphometry to develop a unique framework to consistently quantify the changes in the brain, at both local (voxel) and regional level.



2) To describe the longitudinal changes in the brain affected by Alzheimer's under a multilevel approach, where the subject-specific structural changes at each time point are integrated to describe a subject-specific trajectory for the changes in time composed by **coherent serial deformations**.

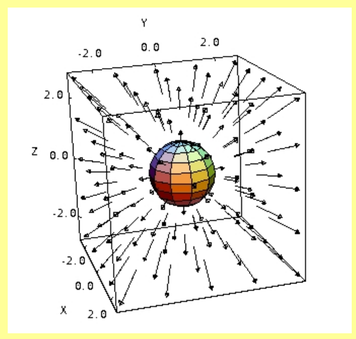


Methods. We employed the longitudinal scans for a group of 8 Alzheimer's patients from the ADNI dataset. For each subject we measured the deformations to match the follow-up scans to the baseline using the **Symmetric Log-Domain Demons Algorithm**[1]

- Spatial consistency –

The degree of expansion/contraction in the whole brain can be assessed at two different levels within the same framework

- **Global change at regional level (Shift of the boundaries)**: computing the flux of the deformation across the brain's surface.



- **Local change at voxel level (Infinitesimal volume change)**: point evaluation of the deformation's Jacobian determinant.

- Temporal consistency –

For each subject, the sequence of deformations at each time point was used to define a **subject-specific prior longitudinal deformation** and the prior was used to re-estimate the deformations as a weighted average between spatial and temporal information.

$$\mathbf{v} = G_\sigma * \left(\frac{\sigma_t^2 \mathbf{v_x} + \sigma_x^2 \bar{\mathbf{v}}_t}{\sigma_t^2 + \sigma_x^2} \right)$$

Updated deformation — Spatial information — Temporal Prior

Results.

The correlation between manual derived brain volume changes and the measure of whole brain changes derived from the deformation field was of **0.899**. The temporal regularization procedure generally led to more linear trends for the subject-specific changes in time and increased the correlation with manual derived measures reaching the maxima of **0.922** when the weight of the temporal information was half of the spatial.

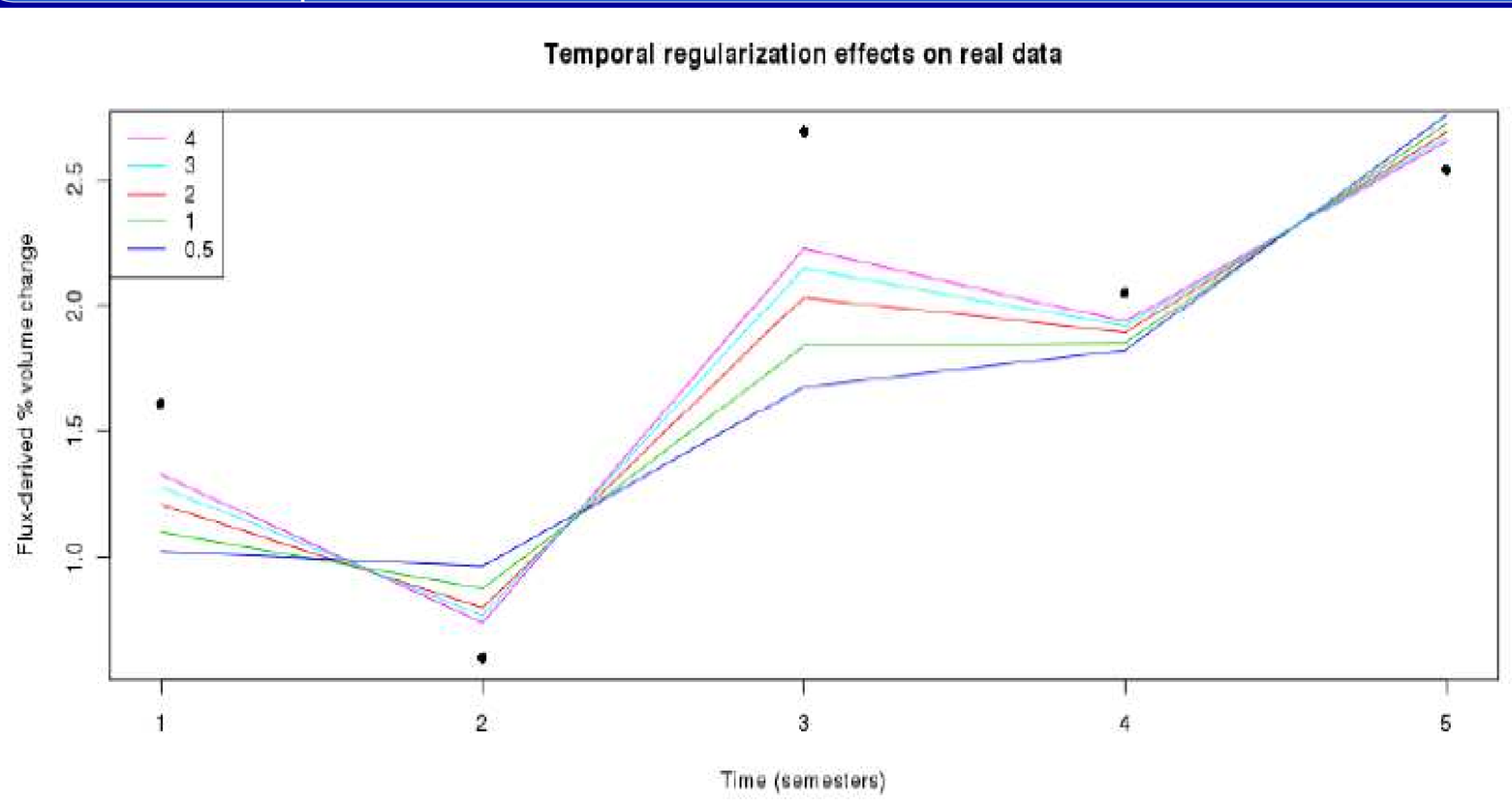


Figure. Flux-derived brain volume change in time for a specifc subject without temporal regularisation (black dots) and with different trade-off for the temporal constrain (coloured lines). The amount of the weight on the temporal constrain led to a more linear (regular in time) estimation of the progression

Conclusions. Deformation based morphometry provides a framework to evaluate the changes in the brain along the time consistently along the spatial dimension, from the voxel to the regional level, and consistently along the temporal dimension, regularising the longitudinal estimation of the deformations.

1-Tom Vercauteren, Xavier Pennec, Aymeric Perchant, and Nicholas Ayache. "**Symmetric Log-Domain Diffeomorphic Registration: A Demons-based Approach**." *MICCAI 2008*, New York, NY