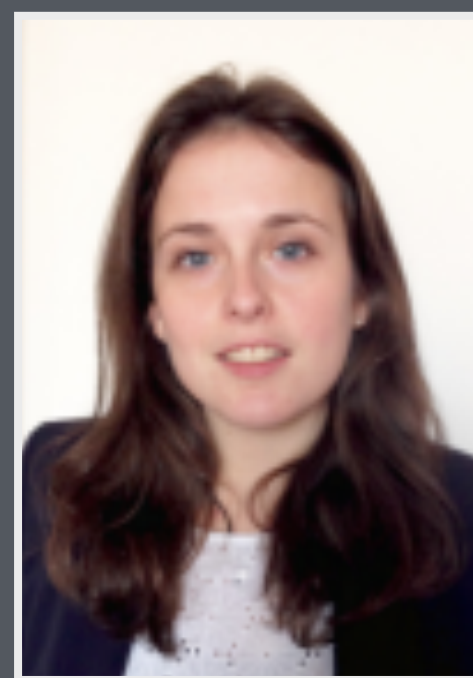




Partial volume effect correction for surface-based cortical mapping



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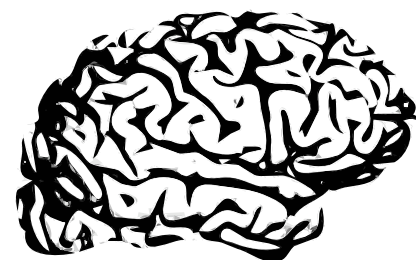
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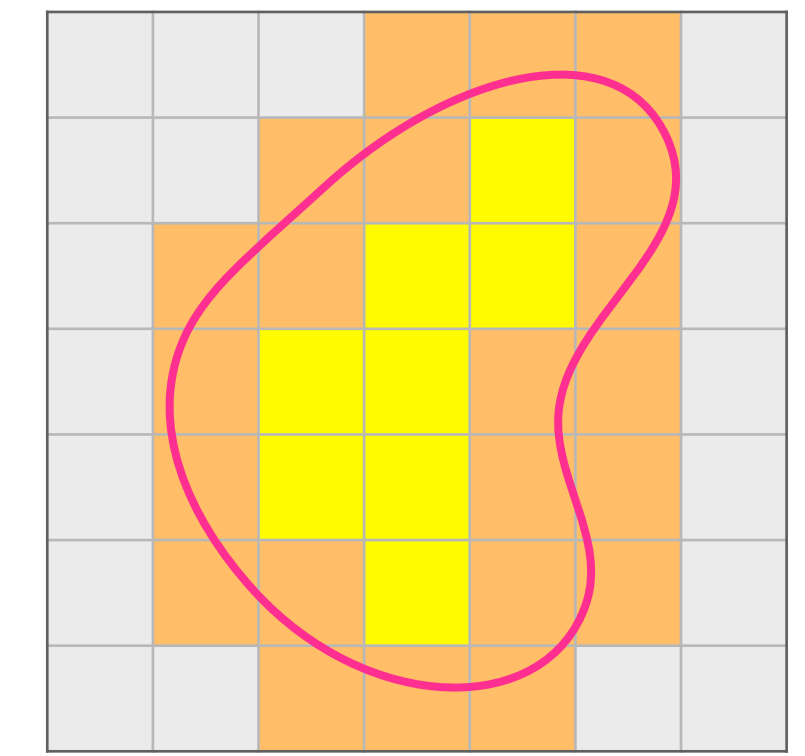
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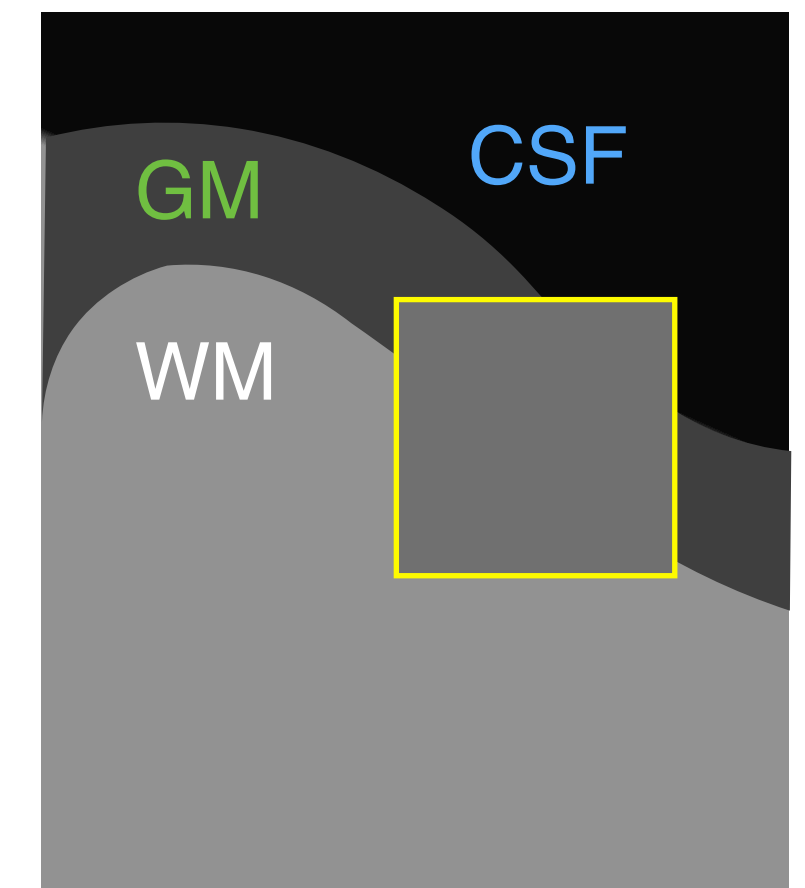


Context

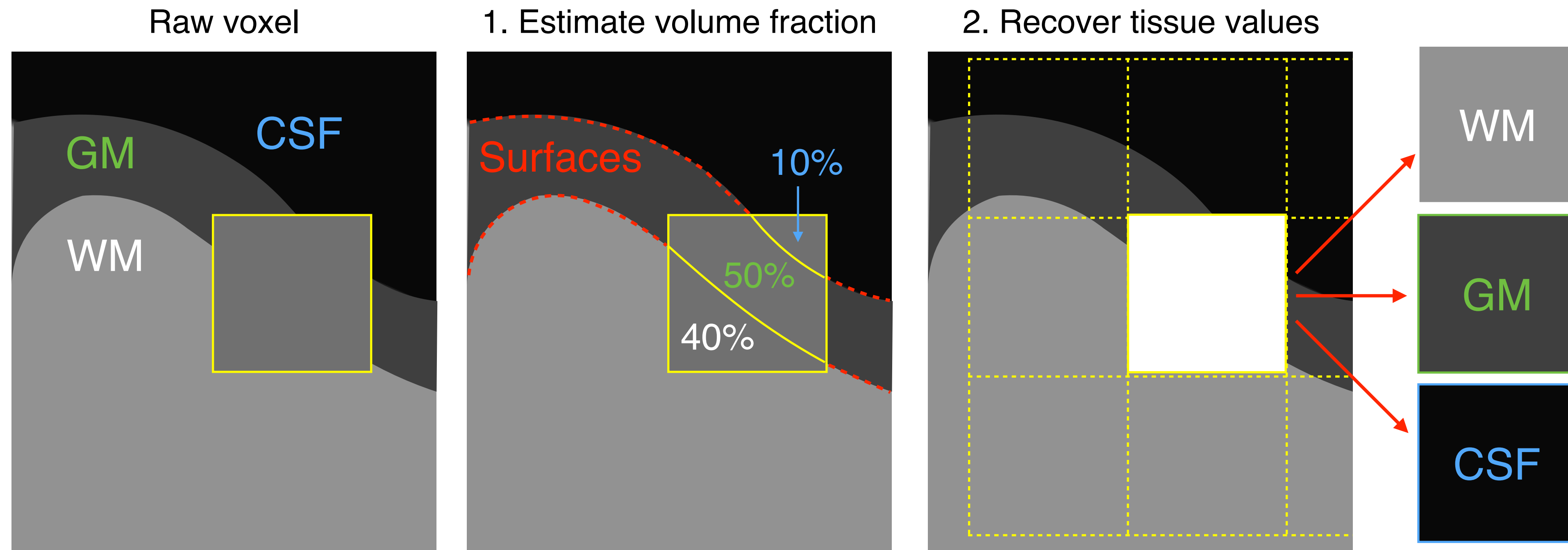
- Partial Volume Effect (PVE) affects the specificity of the tissue differentiation
- A voxel containing different tissues types will produce an averaged signal
- This may be a problem for small/thin ROI analysis, e.g. cortical studies are hampered by CSF and WM contamination
- The goal here is to overcome this problem by recovering the un-mixed tissue signal of the voxels affected by PVE



— Tissue boundary
■ voxels affected by PVE



Method – Overview

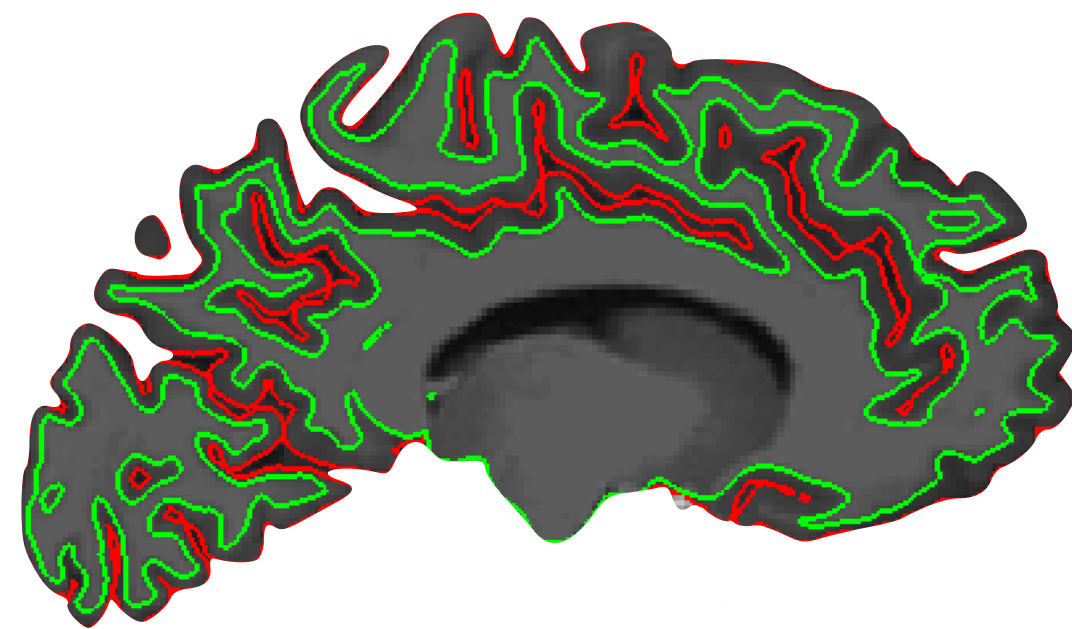


The method consists in two main steps:

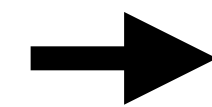
- 1) Estimate the proportion of each tissue in every voxel affected by PVE.*
- 2) Recover the true signal intensities of each tissue.*

Partial Volume Estimation

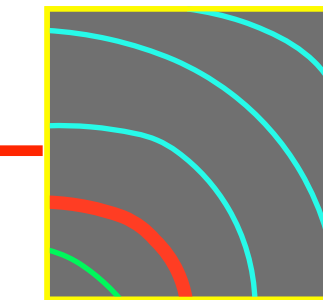
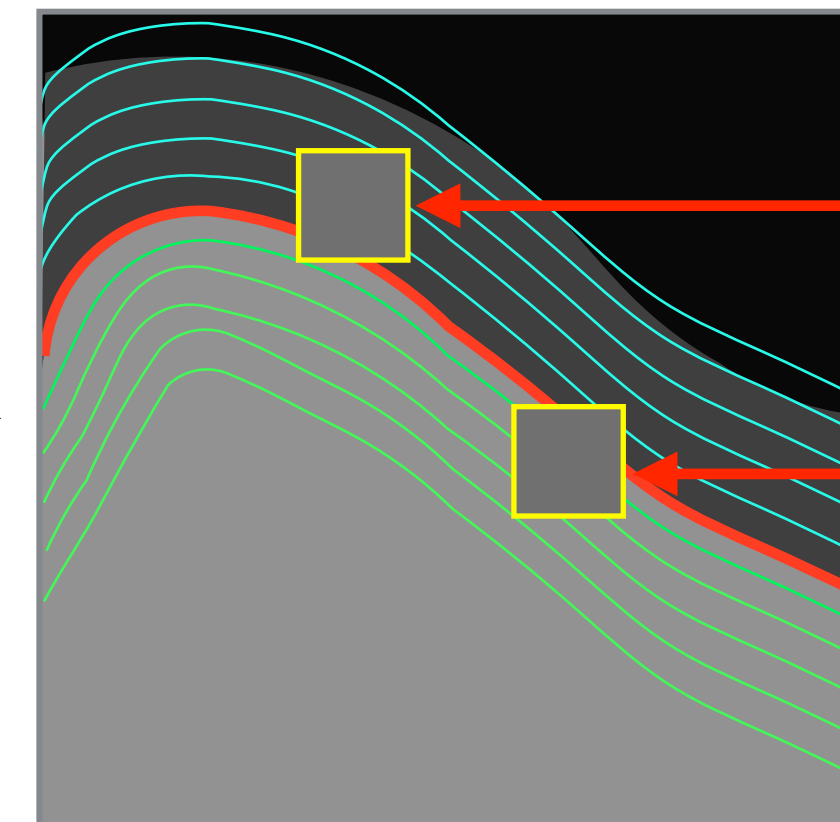
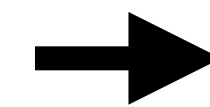
Step 1.1: Proportion of surface classes within voxel



Inputs : Volume + surfaces

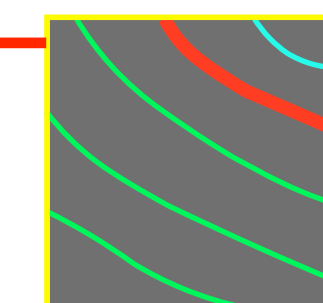


5 expanded surfaces are created on both sides of the original surface.



$\frac{3 \text{ exterior surfaces}}{5 \text{ total surfaces}}$

$$h = 3/5$$



$\frac{1 \text{ exterior surface}}{5 \text{ total surfaces}}$

$$h = 1/5$$

number of surfaces crossed in one compartment

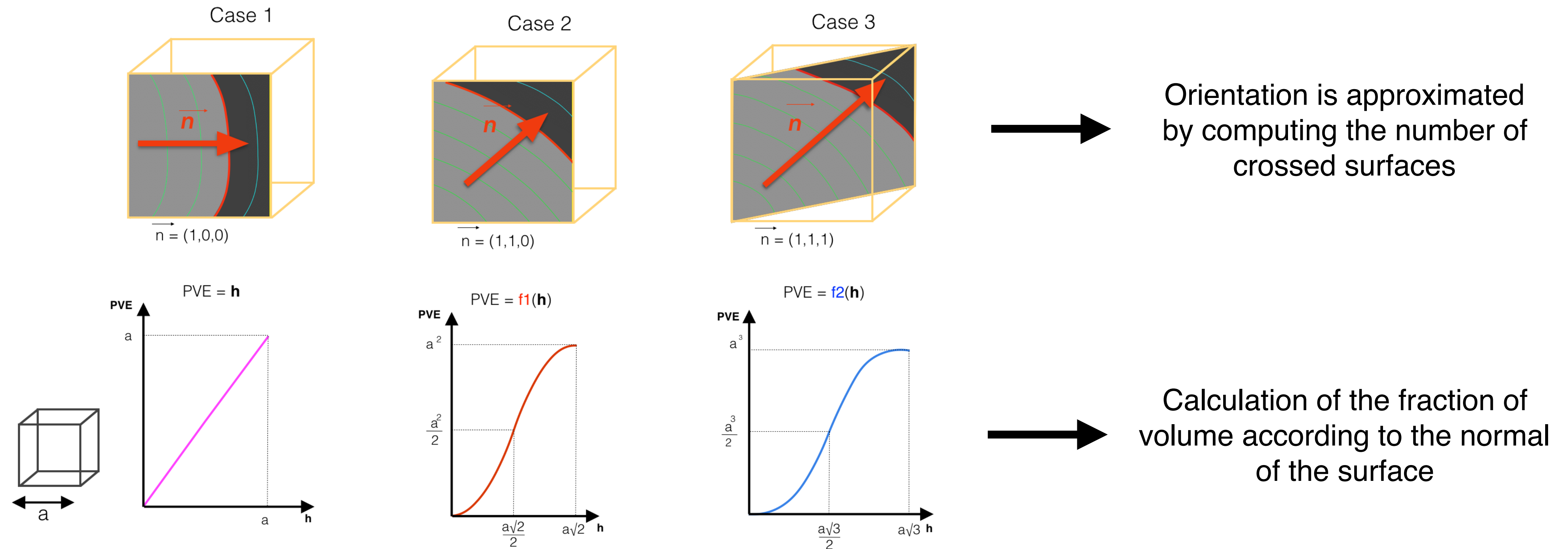
$$h = \frac{\text{number of surfaces crossed in one compartment}}{\text{total number of surfaces crossed}}$$

The partial volume is estimated by:

- 1) *Creating 10 expanded surfaces (5 each side, adjustable gap, 0.3mm here).*
- 2) *Computing the ratio h , which is a first approximation of the partial volume of a voxel.*

Partial Volume Estimation

Step 1.2: Calculation of PV fraction according to surface orientation



A finer estimation of the partial volume is computed by taking into account the voxel orientation:

- 1) The voxel orientation is estimated using the number of surfaces crossed.*
- 2) Depending on the orientation, different functions are used to estimate the partial volume.*

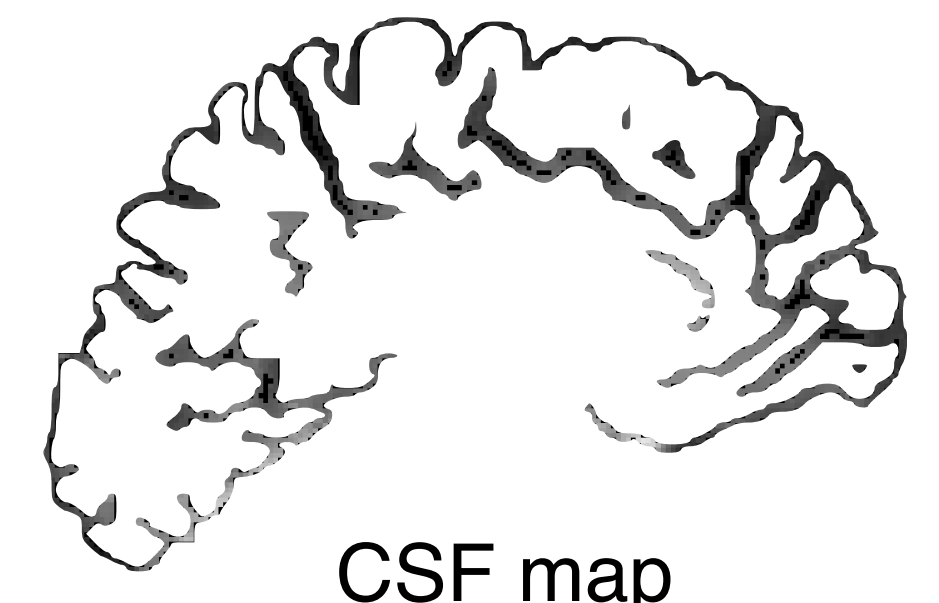
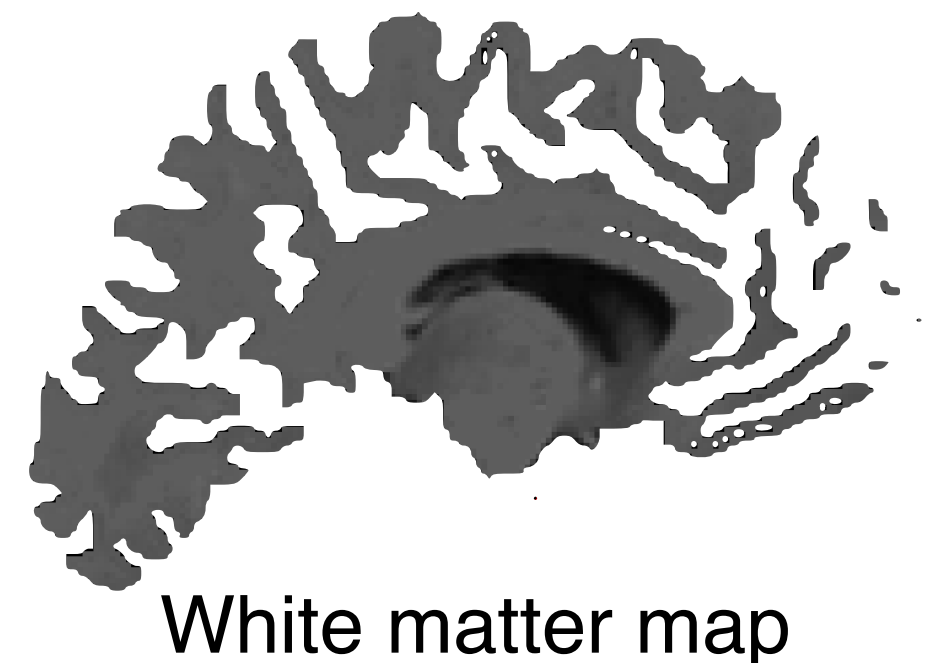
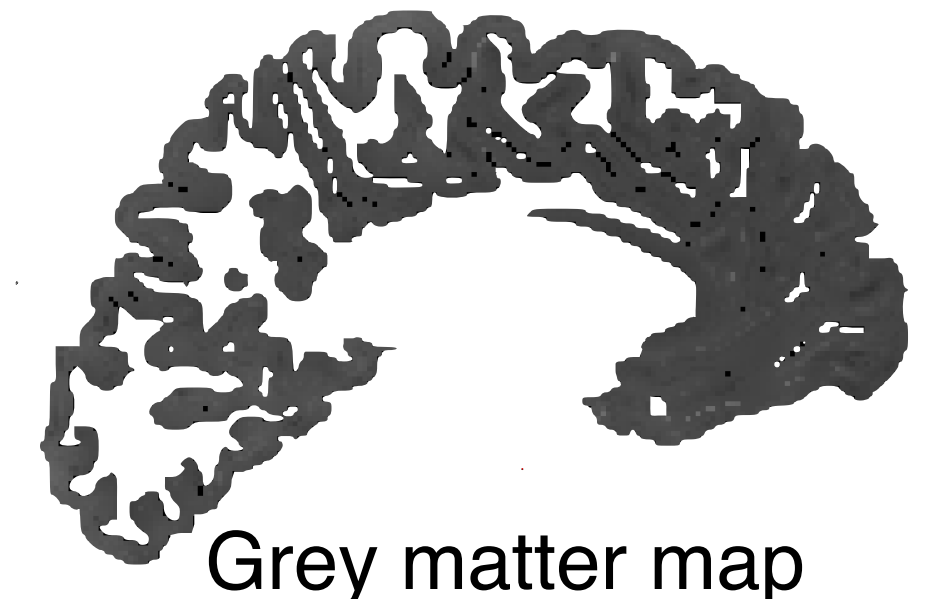
Signal un-mixing

Step 2: Calculation of PV fraction according to surface orientation

$$\text{Voxel Value} = X_1 * \text{WM} + X_2 * \text{GM} + X_3 * \text{CSF}$$

(β)

Least square estimation : $\beta = (X^T X)^{-1} X^T y$ with $y = \begin{bmatrix} \text{WM} \\ \text{GM} \\ \text{CSF} \end{bmatrix}$



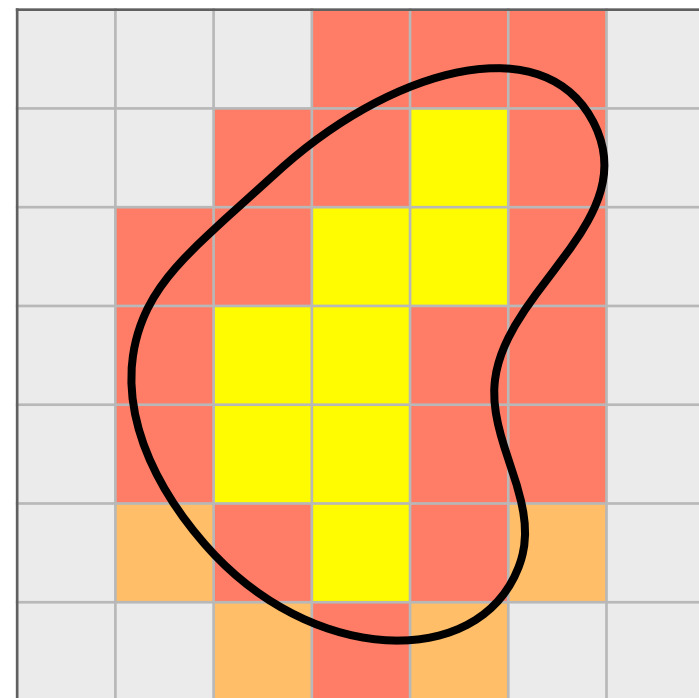
Outputs

The recorded signal being a linear combination of the true tissue signals weighted by the partial volumes:

- 1) A least square estimation is used to recover the true tissue values.*
- 2) For each voxel, the estimation was done using the information of the 3x3x3 closest neighbours*

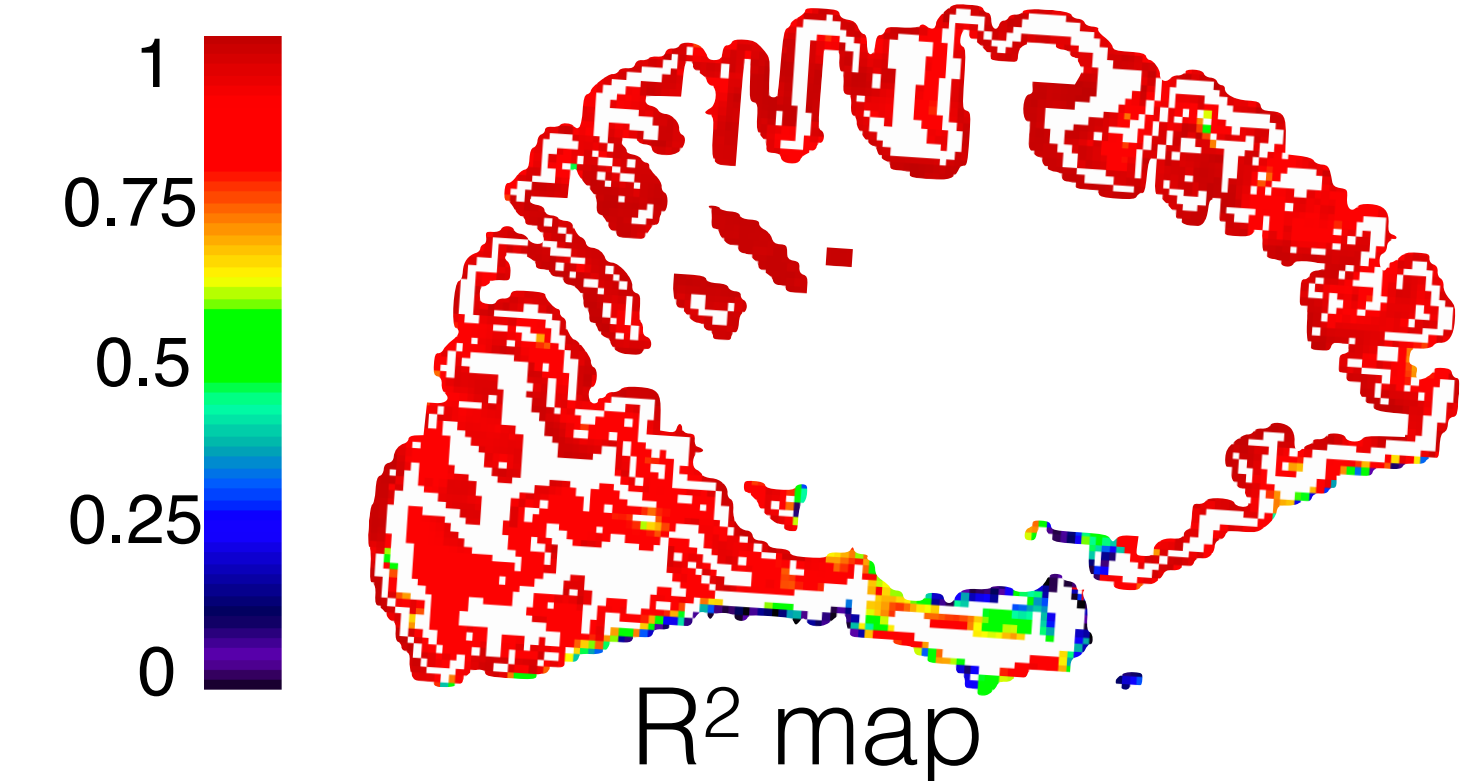
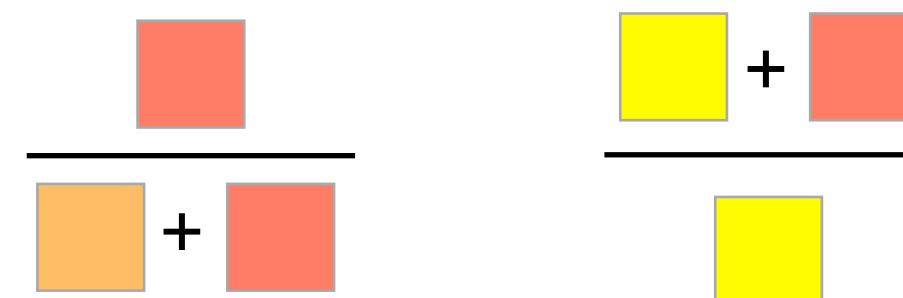
Results/validation

- Goodness of least square fit was assessed with the R-squared value
- Validation was done on 17 healthy controls subjects, 3T MEMPRAGE, 1x1x1mm



— Tissue boundary
 ■ voxels affected by PVE
 ■ voxels not affected by PVE
 ■ voxels affected by PVE for which $R^2 > 0.9$

R-squared value	Percentage of voxels	usable ROI increase
0.9	63.4%	x2.5
0.8	87.7%	x3

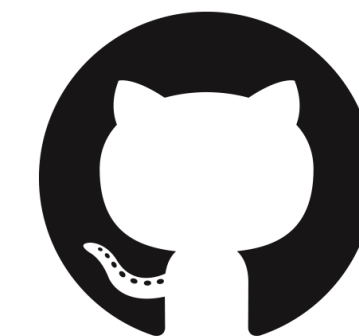


For each voxel, the goodness of the least square estimation was assessed using the R^2 value.

- 1) Only voxels with an excellent R^2 value are then considered for further analysis.
- 2) The gain in number of usable voxel can then be computed. We computed it for a cortical study of 17 healthy brains.

Conclusion

- We presented a fast, robust and reliable method to extract the un-mixed tissues values hampered by PVE.
- This method allows for more accurate extraction of MRI metrics using surface-based ROIs.
- Particular interest for quantitative cortical analyses.
- https://github.com/neuropoly/partial_volume_correction



Acknowledgements

Introduction
Methods
Results
Conclusion



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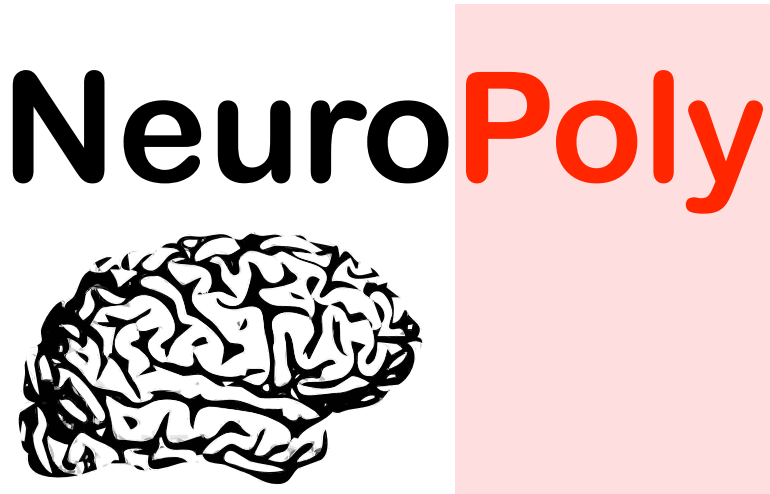
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