Lesion segmentation and characterisation

Tuesday 30th January 2018

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Outline

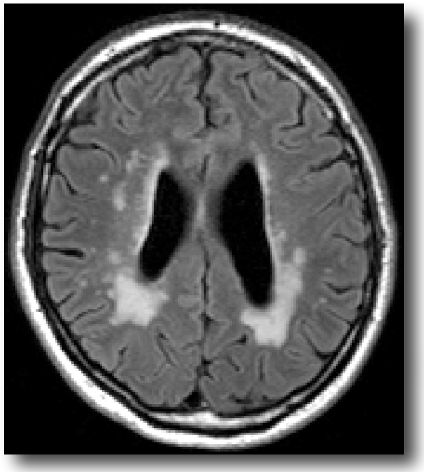
White matter hyperintensity (WMH) segmentation

Technical impact
Proposed solution
Extension to longitudinal studies

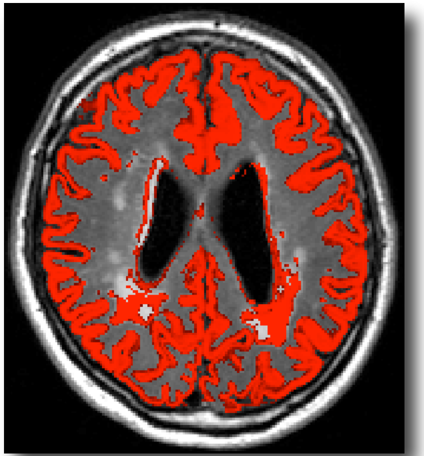
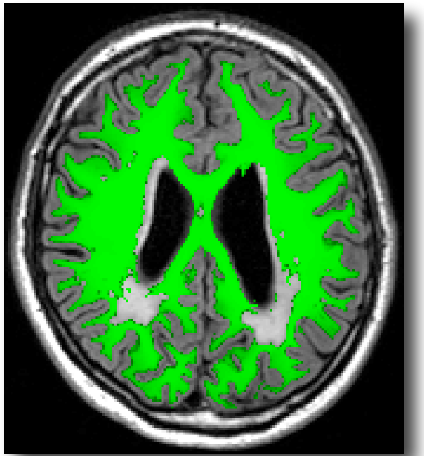
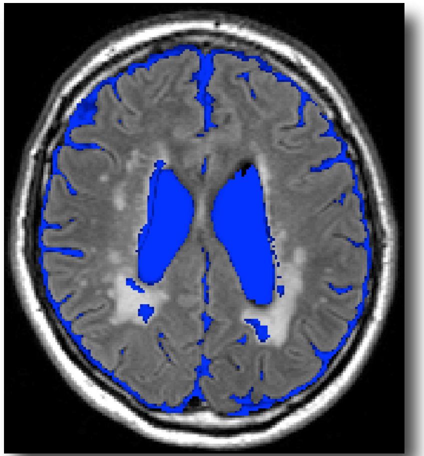
Location characterisation

Available scale range and uncertainties
Proposed solution
Population level applications
Patient level applications

WMH - Technical impact

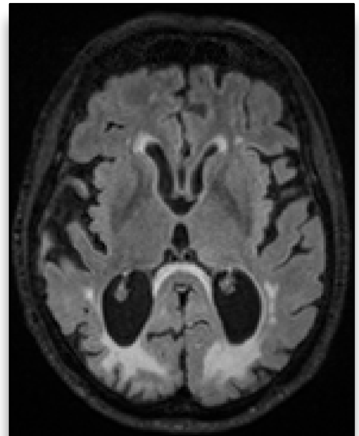



- Errors in tissue volumes
- Errors in tissue borders
- Errors in parameters estimation

Automated WMH segmentation

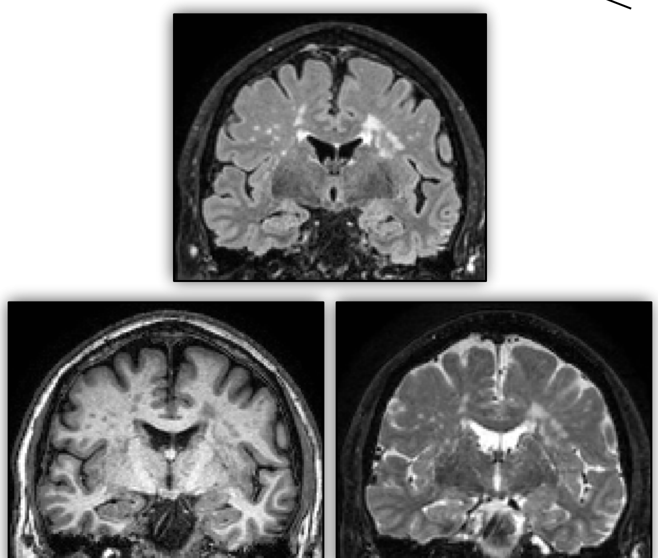
Pathology



Clinical association

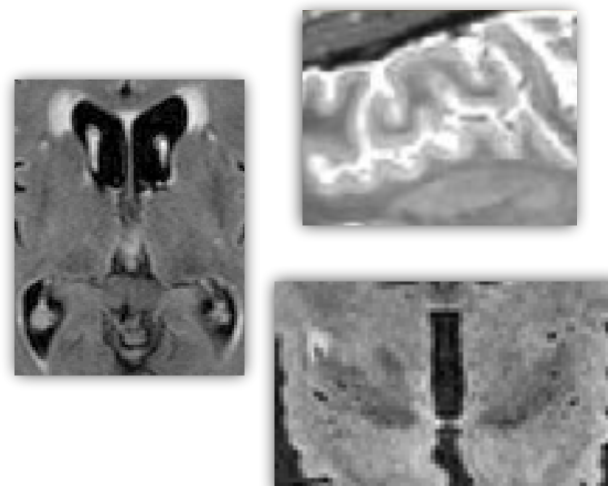
Technical impact

Multimodal



Automation needed

Outlier modelling

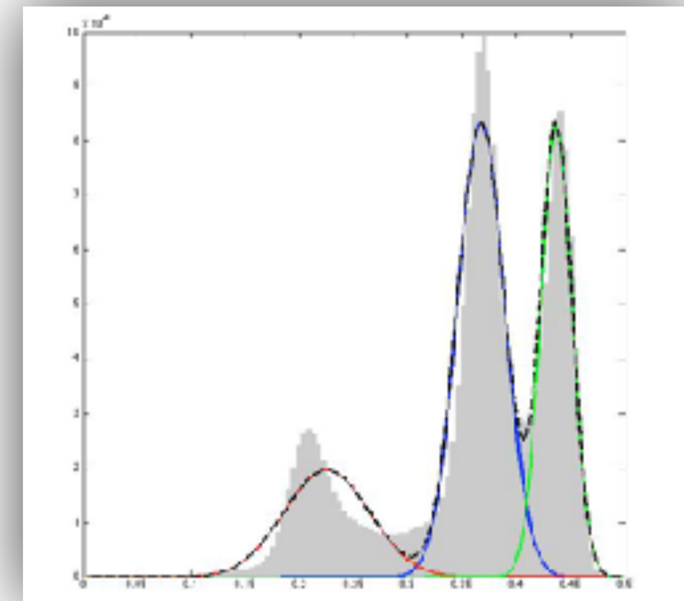


Generic

Multiple applications
Model flexibility

WMH - White matter hyper intensity

Gaussian mixtures



Number of components

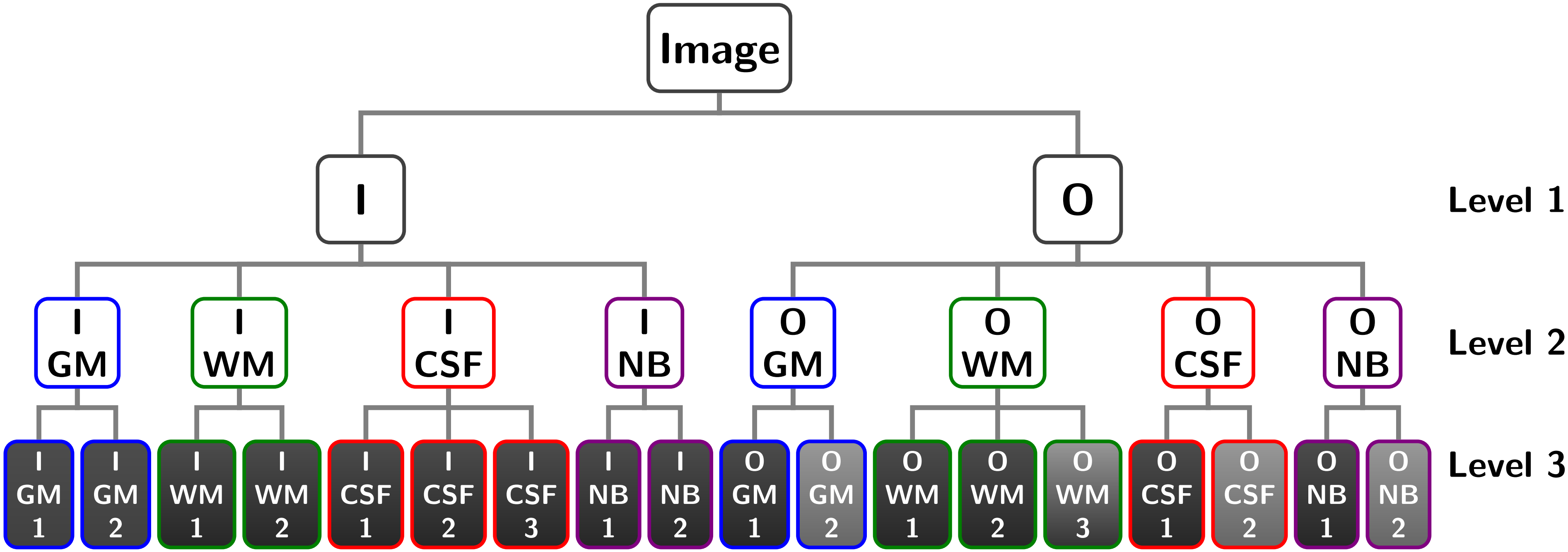
Vector of intensities at voxel n

Gaussian density distribution

$$p\left(\mathbf{y}_n | \mathbf{\Theta}_K\right) = \sum_{k=1}^{K} w_k \phi\left(\mathbf{y}_n | \theta_k\right)$$

- Data modelled as weighted sum of Gaussian distributions
- Noise in magnitude image considered as Gaussian
- Each tissue modelled with Gaussian distribution

Data modelling



HIERARCHICAL GAUSSIAN MIXTURE MODEL

Anatomical and contextual constraints

Statistical atlases

Markov Random Fields

Adaptive and dynamic model

Split and merge strategy

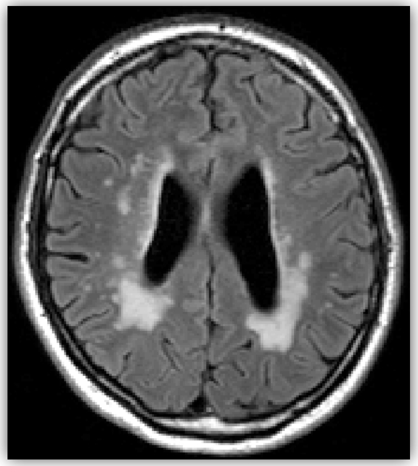
Automated model selection

C. H. Sudre, M. J. Cardoso, and S. Ourselin, “Bilayered anatomically constrained split-and-merge expectation maximisation algorithm (BiASM) for brain segmentation,” in SPIE Medical Imaging (S. Ourselin and M. A. Styner, eds.), vol. 9034, pp. 903411–903411–7, International Society for Optics and Photonics, International Society for Optics and Photonics, 2014.

C. H. Sudre, M. J. Cardoso, W. Bouvy, G. J. Biessels, J. Barnes, and S. Ourselin,“Bayesian Model Selection for Pathological Data,” in MICCAI 2014 (P. G. Et al.,ed.), LNCS 8673, pp. 323–330, Springer International, 2014.

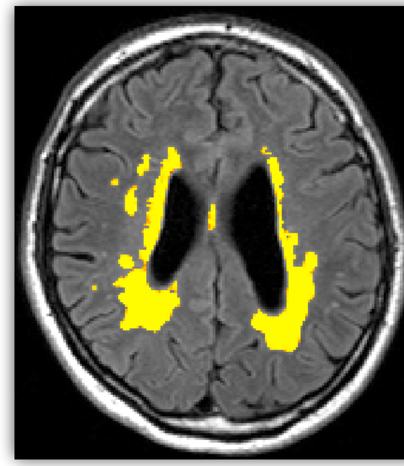
C. Sudre, M. J. Cardoso, W. Bouvy, G. Biessels, J. Barnes, and S. Ourselin, “Bayesian model selection for pathological neuroimaging data applied to white matter lesion segmentation.,” IEEE Transactions on Medical Imaging, vol. 34, pp. 2079–2102, apr 2015.

Model independent of application

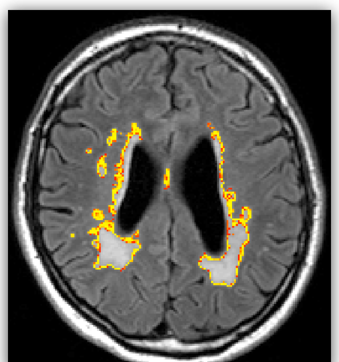


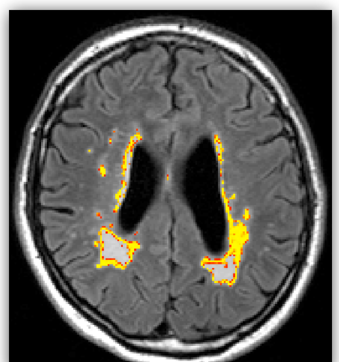
Postprocessing

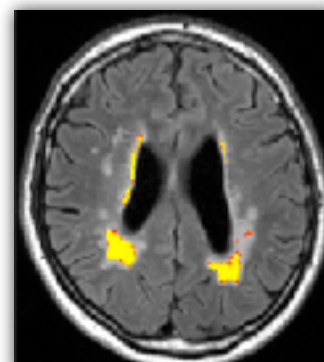
WMH segmentation



3 lesion-related components

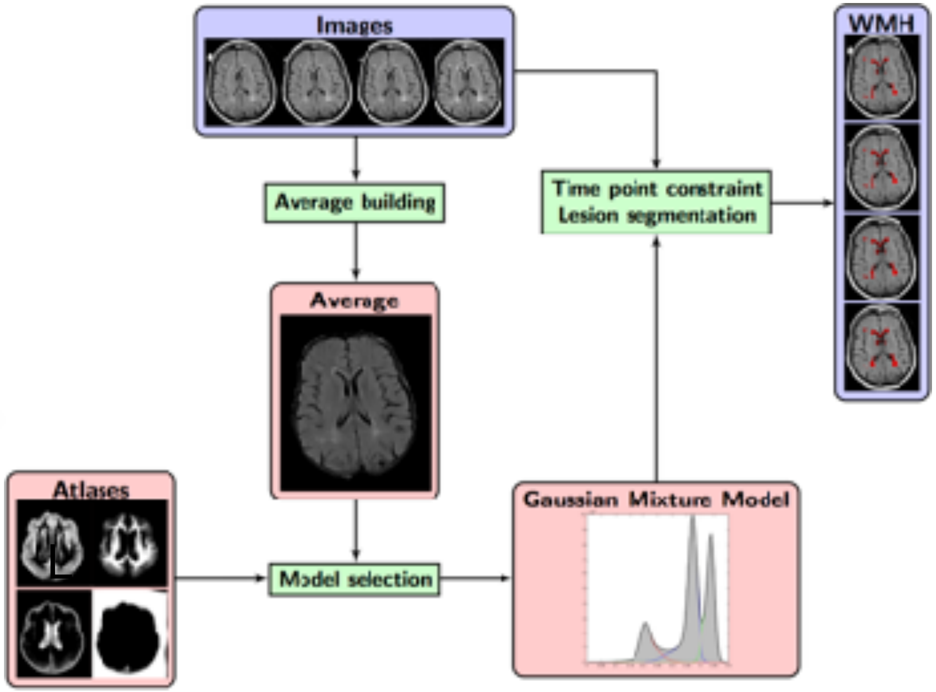




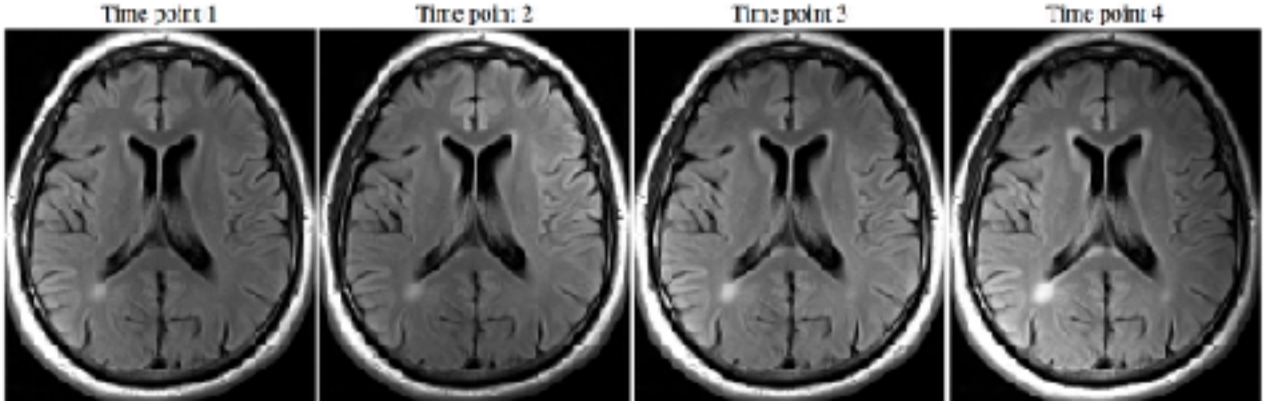


Longitudinal extension

Disease evolution in time
Intra-subject time consistency
Average model
Constraint over individual time points

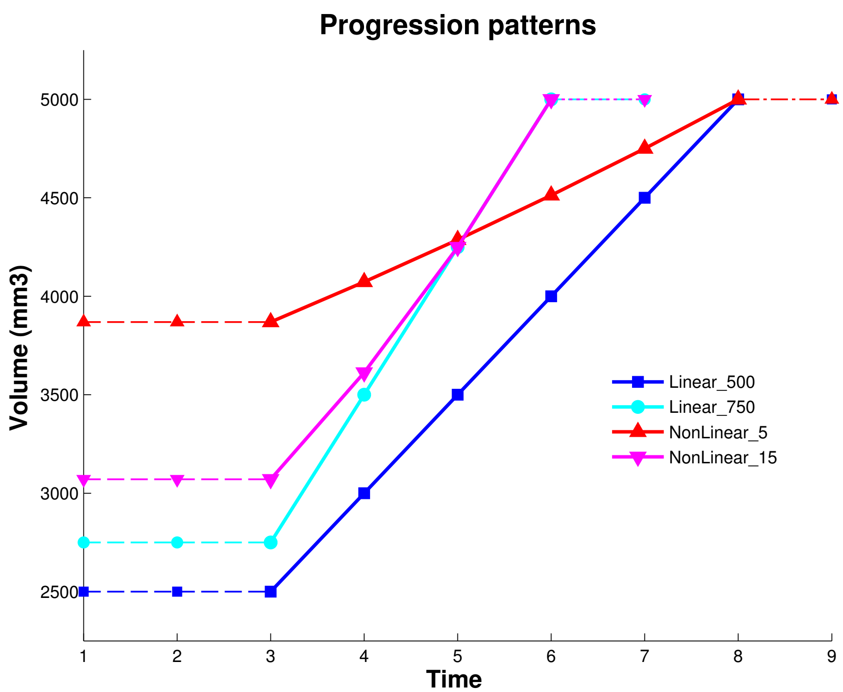


Association with APOE genetic status



Longitudinal simulator

Longitudinal simulation

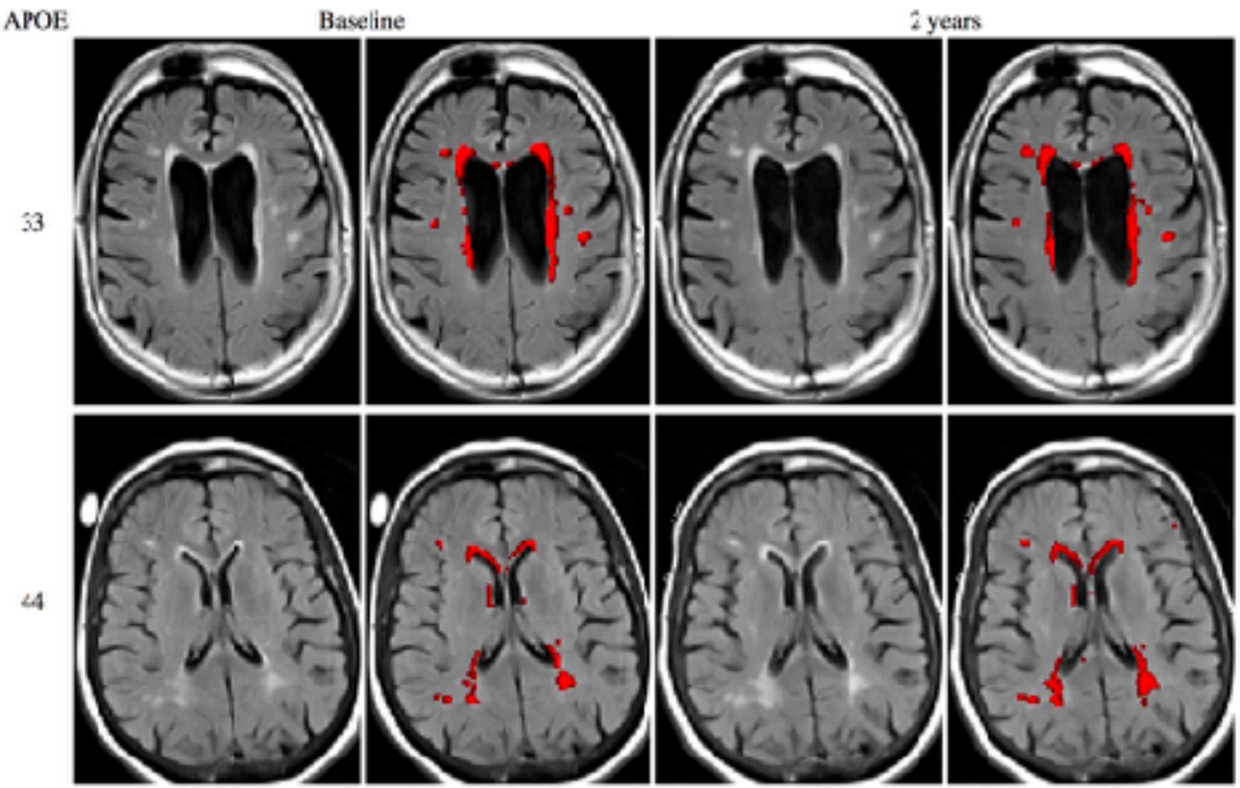


	Linear_500	Linear_750	NonLinear_5	NonLinear_15
DSC	0.66 [0.27 0.76]	0.66 [0.34 0.76]	0.68 [0.39 0.76]	0.64 [0.41 0.74]
TPR	0.85 [0.68 0.89]	0.80 [0.57 0.88]	0.81 [0.66 0.87]	0.79 [0.67 0.85]
AvDist	1.92] [1.14 11.98]	1.89 [1.06 9.69]	1.96 [1.09 5.25]	2.05 [1.11 6.62]
OE/TotF	0.81 [0.47 0.89]	0.77 [0.53 0.88]	0.81 [0.67 0.90]	0.8 [0.57 0.88]
OEFP/FP	0.73 [0.39 0.86]	0.71 [0.47 0.85]	0.71 [0.56 0.85]	0.69 [0.50 0.85]
OEFN/FN	0.96 [0.87 0.98]	0.93 [0.78 0.97]	0.96 [0.92 0.98]	0.94 [0.90 0.97]
FP/TotF	0.82 [0.60 0.88]	0.79 [0.59 0.86]	0.76 [0.59 0.85]	0.76 [0.59 0.82]

Acronyms expansion: DSC - Dice Similarity Coefficient; TPR - True Positive Rate; AvDist - Average Distance; FP/TotF - Proportion of false positives in the total of error; OE/TotF - Proportion of outline error in the total error; OEFP/FP - Proportion of false positive outline error in the false positives; OEFN/FN - Proportion of false negative outline error in the false negatives.

		Cross+	Long	Ref
Flat_High	**% change median**	2.28	0.21	0.09
	% change IQR	[-17.77 25.11]	[-8.19 9.29]	[-1.99 1.89]
	p-value	0.06	0.54	0.83
	Lin concordance	0.95	0.98	0.999
Flat_Low	**% change median**	6.53	1.53	0
	% change IQR	[-17.1 7.78]	[12.0 17.6]	[-1.96 1.46]
	p-value	0.0002	0.05	0.42
	Lin concordance	0.87	0.95	0.999

Application to ADNI data



	APOE		
	33	**43**	**44**
Number (Aβ)	164 (161)	108 (102)	24 (23)
% change	5.68	8.68	15.53
CI	[3.56 7.84]	[5.95 11.48]	[9.09 22.34]
Overall p		0.009	
Pairwise		33 vs 44 **	

Effect size

	33 vs 43	43 vs 44	33 vs 44
Cross+	0.05	0.21	0.28
Long	0.21	0.32	0.47

Sudre, C. H., Cardoso, M. J., & Ourselin, S. (2017). Longitudinal segmentation of age-related white matter hyperintensities. *Medical image analysis*, *38*, 50-64.

WMH Location characterisation

Voxelwise | **Regional** | **Global**

Lesion maps
Probabilities
Noise
Low signal

What regions?
How to separate them?
Concept definitions

Raw description
Limited information

Periventricular?

Continuity with ventricular lining

Within absolute extent

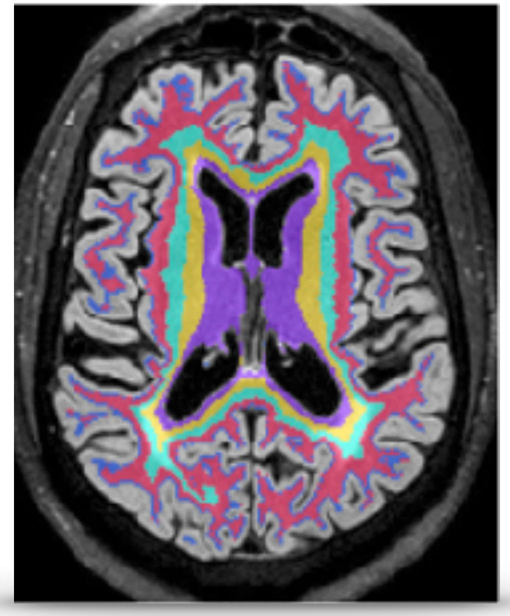
Continuity with absolute (mm) extent

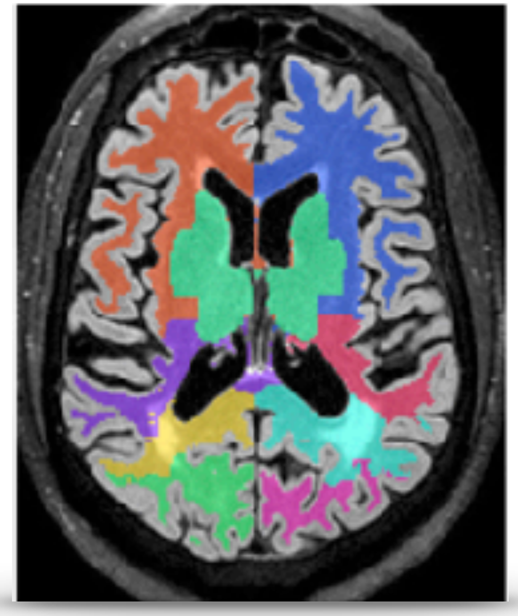
Confluent lesions
Concomitant atrophy
Lobar separation

Lobes and layers

Layers
Laplace equation between ventricular and cortical surface
Normalised distance
Independent of atrophy
Discretised = 4 layers

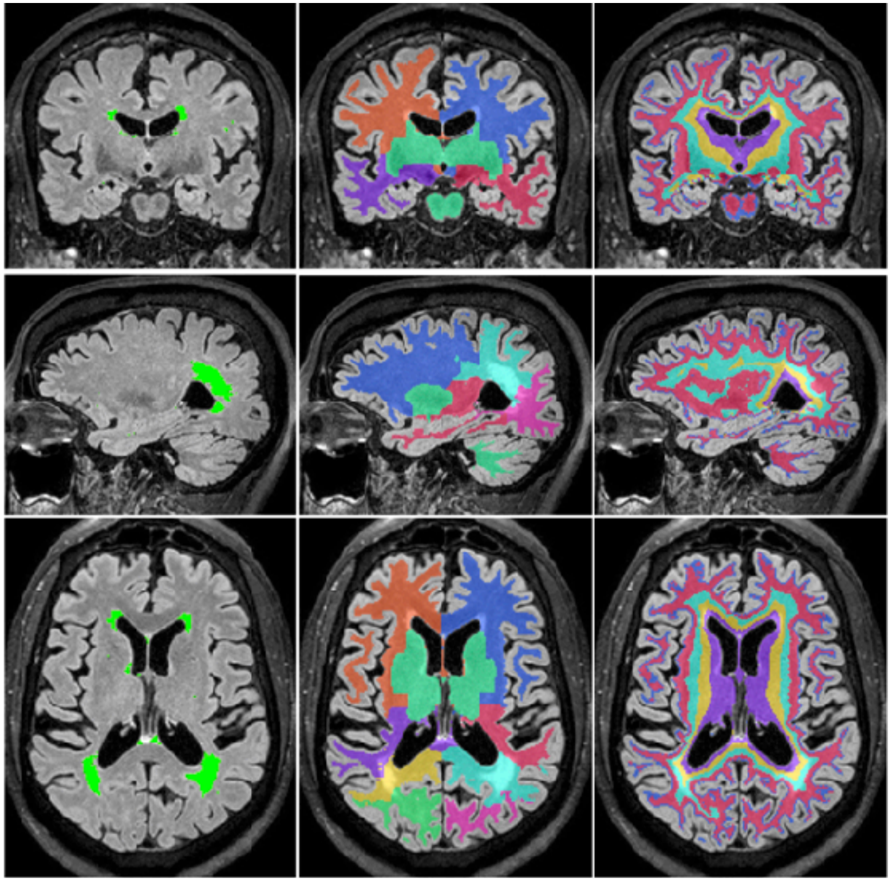
Lobes
Cortical parcellation
Aggregation of regions
Minimum Euclidean distance

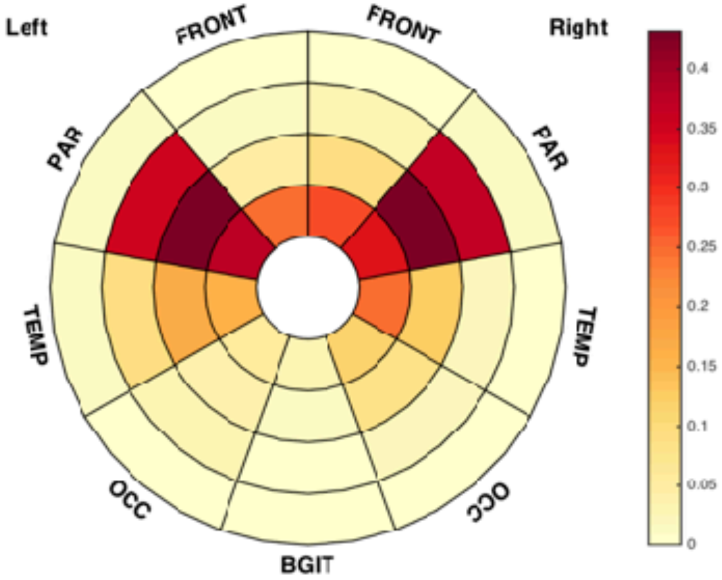




Infographic representation

4 layers and 9 lobar regions





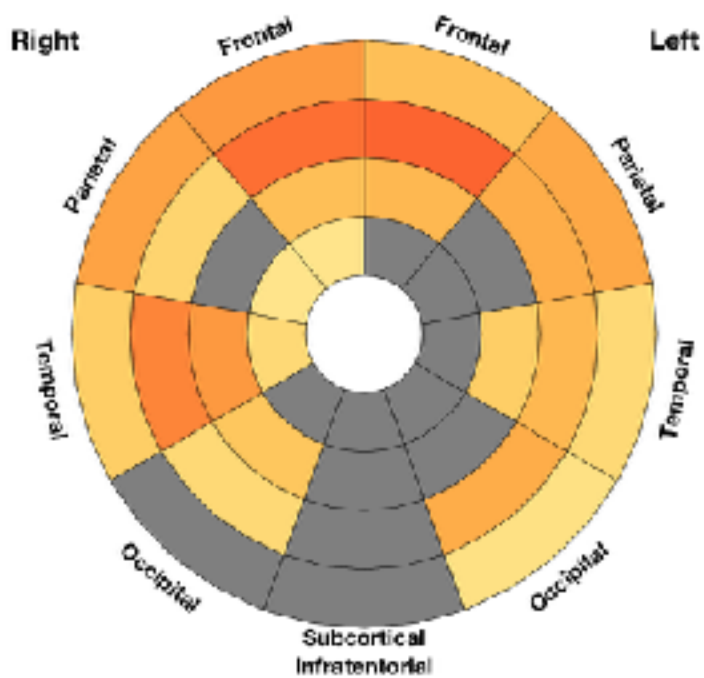
Sudre, C. H., Anson, B. G., Davagnanam, I., Schmitt, A., Mendelson, A. F., Prados, F., ... & Cardoso, M. J. (2017). Bullseye's representation of cerebral white matter hyperintensities. *Journal of Neuroradiology*.

Lesion frequency: Proportion of a region occupied by WMH

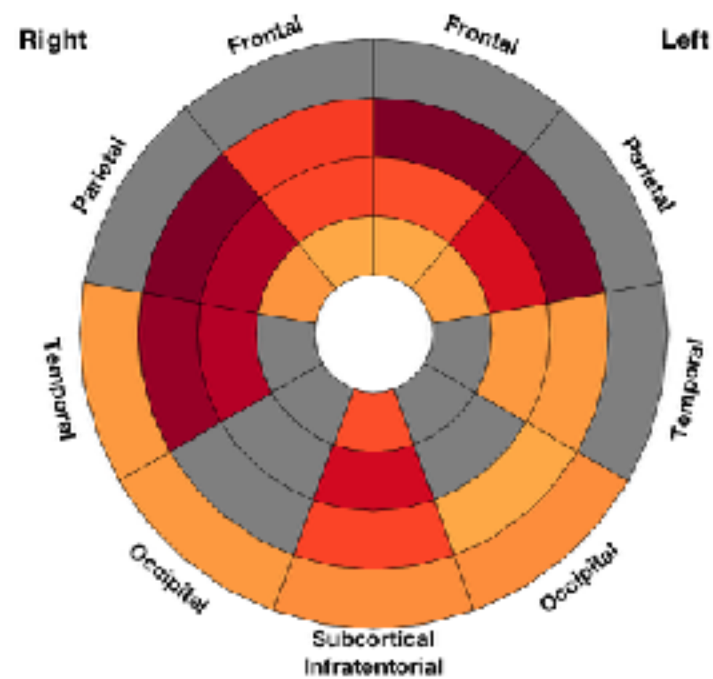
Lesion distribution: Proportion of the WMH volume localised in a region

Population level - Risk factors in WMH

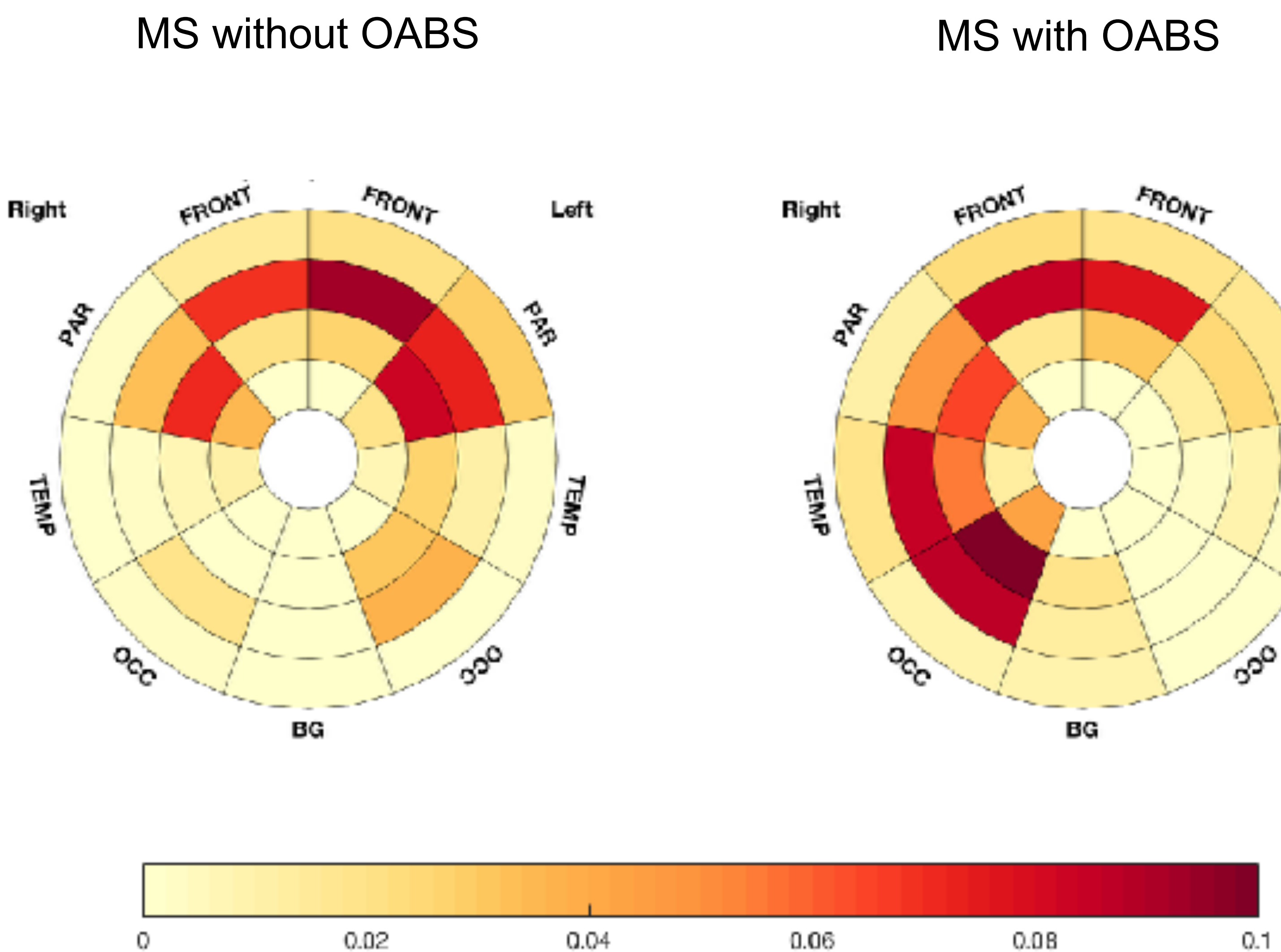
Diabetes disease duration



Diastolic blood pressure



Population level - Comparison

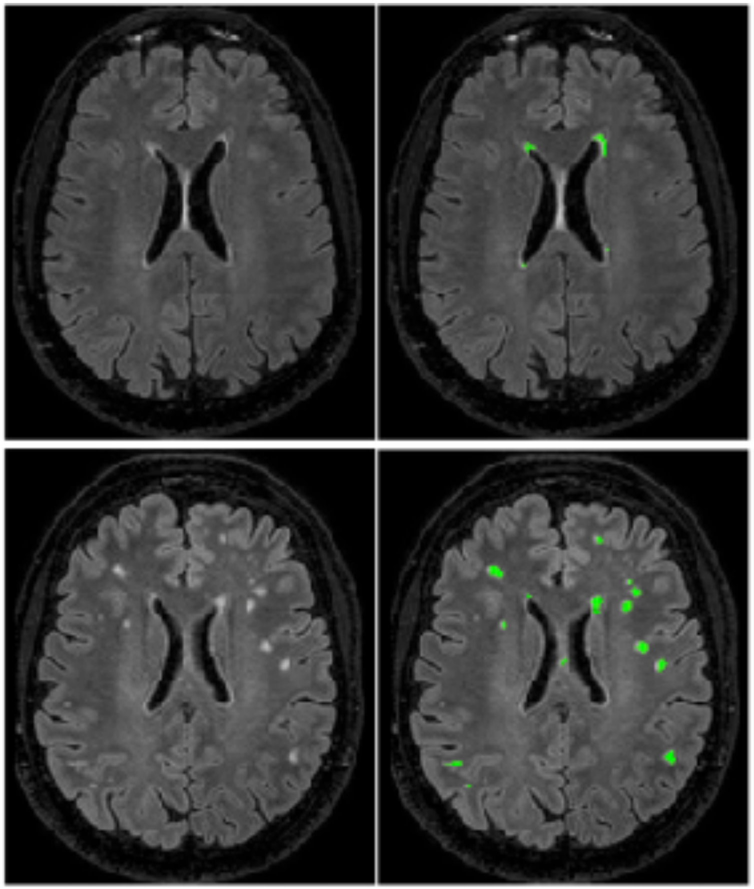


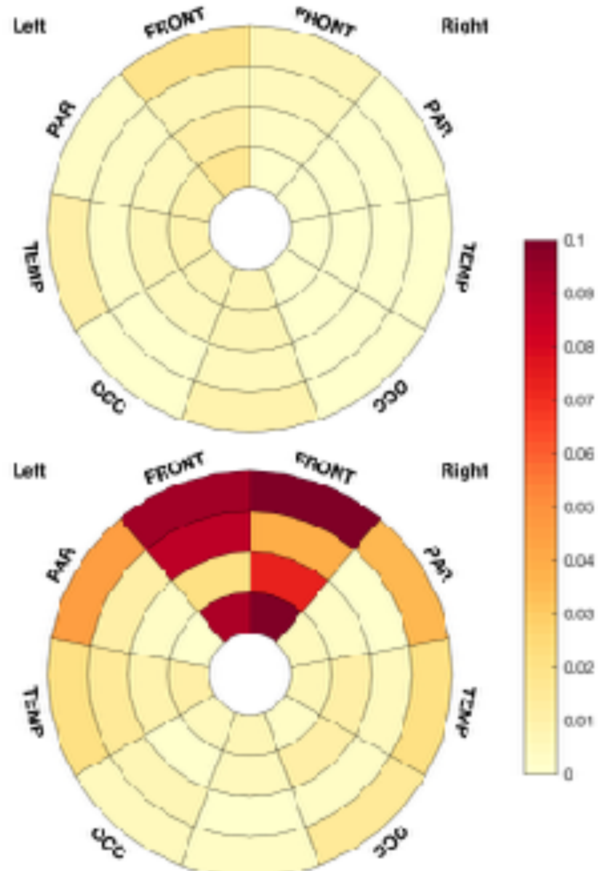
MS - Multiple sclerosis
OABS - Overactive Bladder syndrome

Patient level - Diagnostic tool

UCL

CUSHING Disease





Blinded diagnosis

3hrs with images
5 min with Bullseyes

Conclusion - Ongoing work

WMH segmentation

Automated generic outlier data modelling
Adaptable post-processing
Longitudinal extension

Location characterisation

Systematic patient-specific coordinate frame
Infographic tool summarising 3D distribution
Application to patient or population level
Other applications quality control, protocol comparison

And beyond…

Longitudinal location patterns
Distinction between subtypes of lesion
Beyond the brain onto spinal cord
Analysis of lesion texture and shape…

Thank you for your attention !

Questions ?

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