

Tissue microstructure information from T_2 relaxometry and diffusion MRI can identify multiple sclerosis lesions undergoing blood-brain barrier breakdown

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Gd enhancing lesion detection

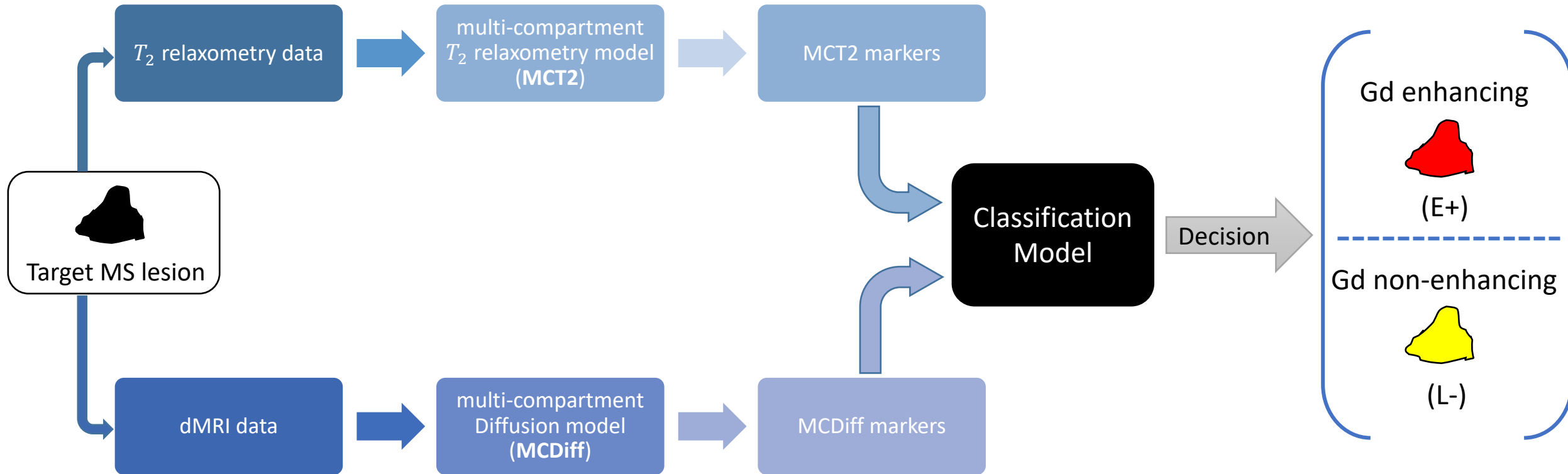
Motivation

- Gd retention observed in brain tissues after prolonged usage.
 - Leads to MRI signal change
- High risks when patients have renal complications.
- Highly valuable clinical information.
- Greater caution on repeated usage.

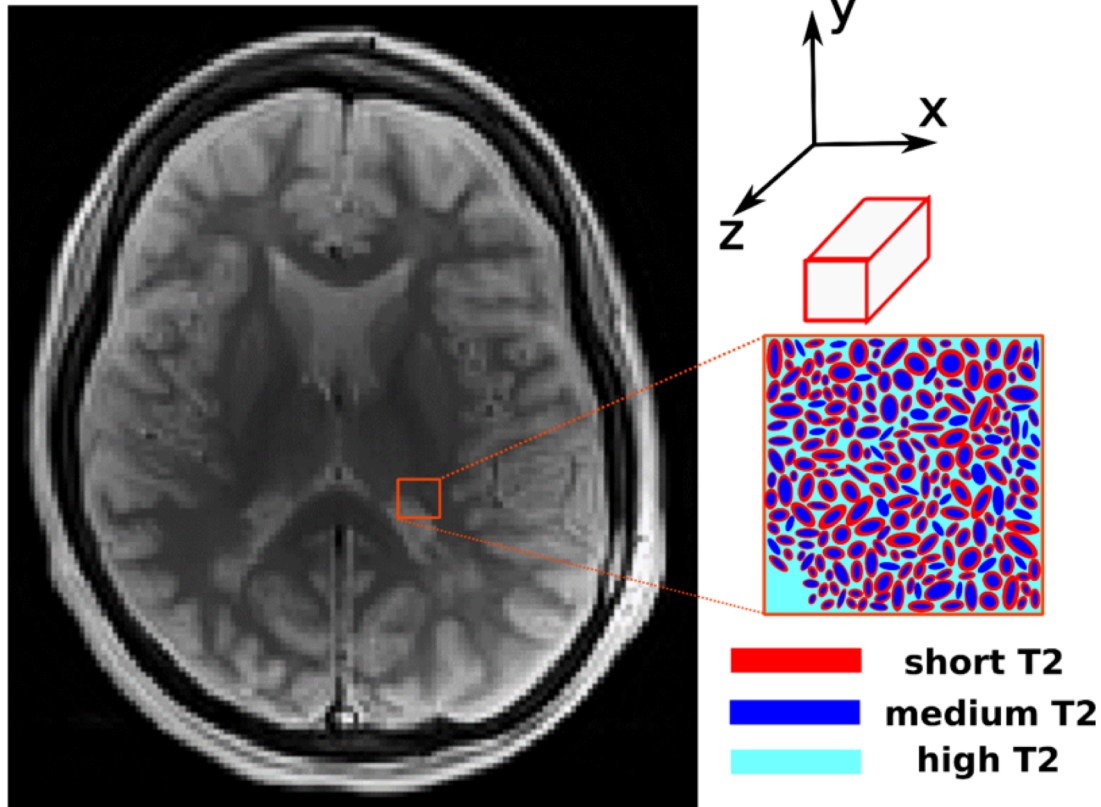
Objective

- Method to identify Gd enhancing lesions without Gd injection.
 - But from tissue microstructure information.
 - T_2 relaxometry and diffusion MRI (dMRI)
- Compare statistics of T_2 relaxometry and dMRI markers of Gd enhancing and non-enhancing lesions.
- A model to predict Gd enhancing lesions.
 - Test case evaluations

Approach



Multi-compartment T_2 relaxometry model (MCT2)



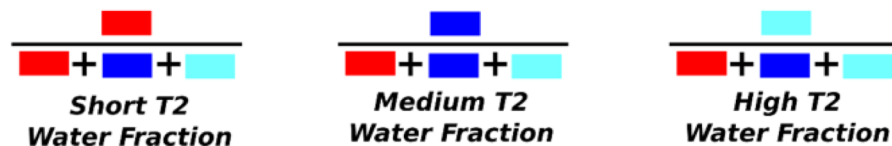
- Three compartments per voxel.
- **MCT2 markers:** Obtain fractional representation of each compartment in a voxel.
- Parametric model where each compartment is considered a gaussian PDF whose parameters are fixed.

- Refer: *Chatterjee, S., et al., MICCAI, 2018, (pp. 63-71). Springer, Cham.*

- Implementation available at:

<https://github.com/Inria-Visages/Anima-Public>

MCT2 Estimates per Voxel



Multi-compartment diffusion model (MCDiff)

- Ball and Zeppelin model [*Panagiotaki E., et al, 2012*]
 - Three fascicles. Fixed radial diffusivity.
 - An isotropic gaussian PDF for free water.

$$p(x) = f_w p_{FW}(x) + \sum_{i=1}^{N=3} a_i p_i(x) \quad \text{where } f_w + \sum_i a_i = 1$$

Multi-compartment features

MCT2

- Short T2 water fraction
- Medium T2 water fraction
- High T2 water fraction

MCDiff

- Free water fraction
- Fractional anisotropy*
- Apparent diffusion coefficient*
- Axial diffusivity*

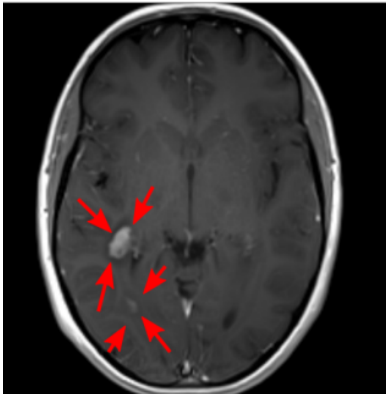
**compartmental weighted average*

Dataset

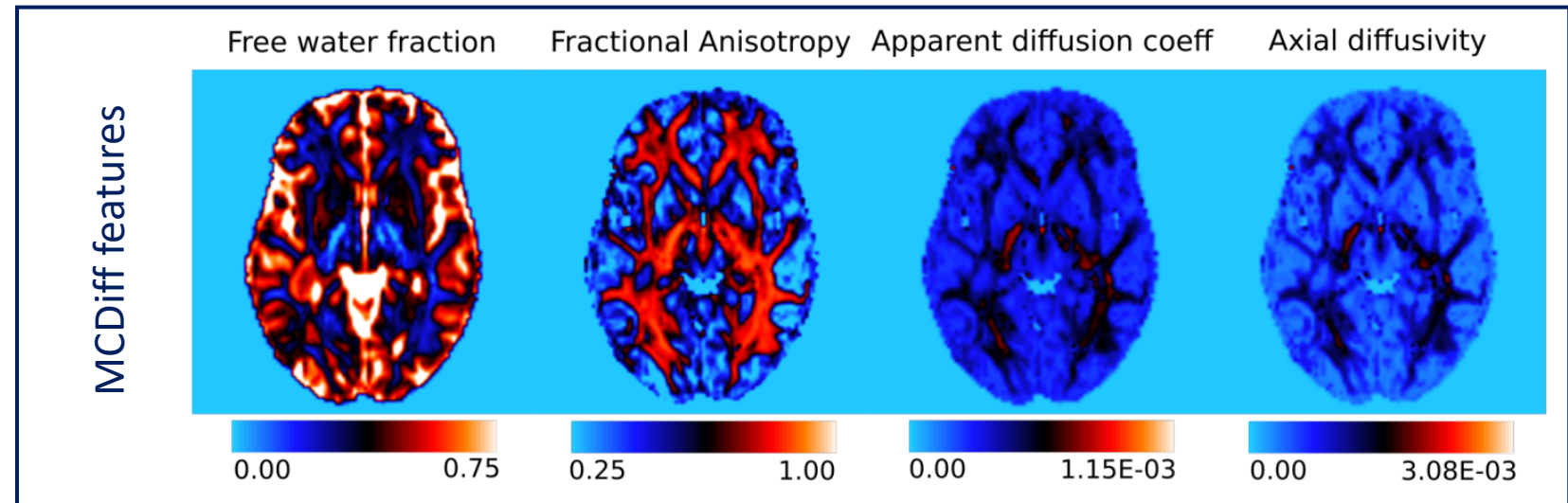
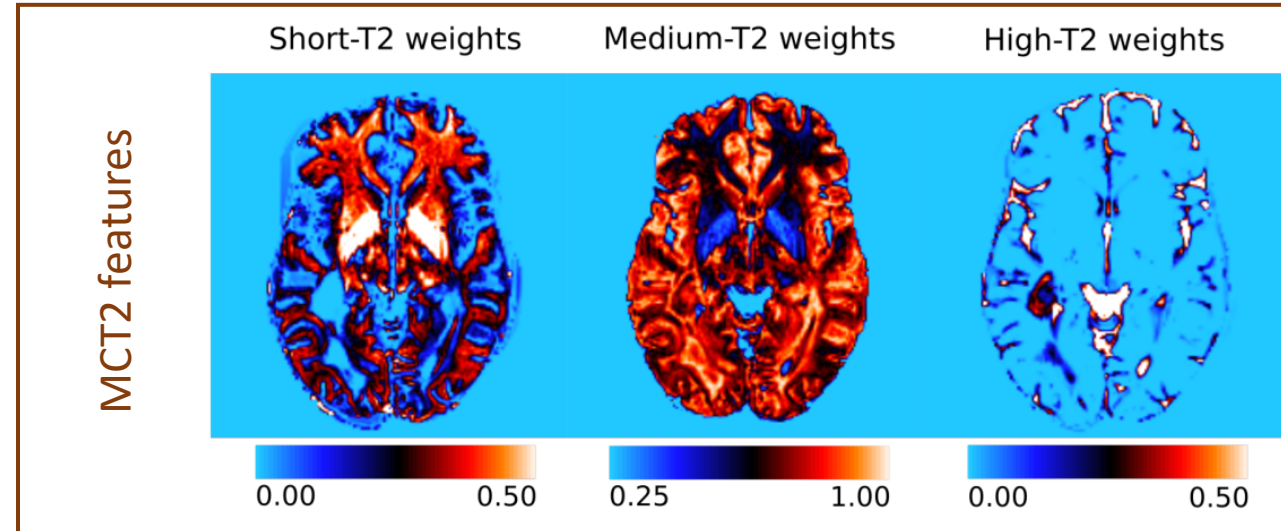
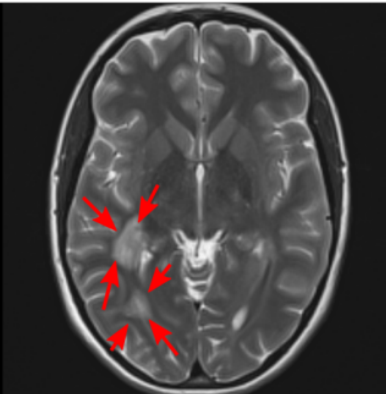
- T_2 relaxometry data:
 - Echo time = 13.8ms
 - No. of echoes = 7
 - TR = 4530ms
 - Voxel resolution = $1.3 \times 1.3 \times 3.0 \text{mm}^3$
- Diffusion MRI data:
 - Echo time = 94ms
 - 30 directions on a single shell
b-value = 1000s/mm^2
 - TR = 9.3 sec
 - Voxel resolution = $2 \times 2 \times 2 \text{mm}^3$
- Total acquisition time < 14 mins

Example

Post Gd T1 MRI

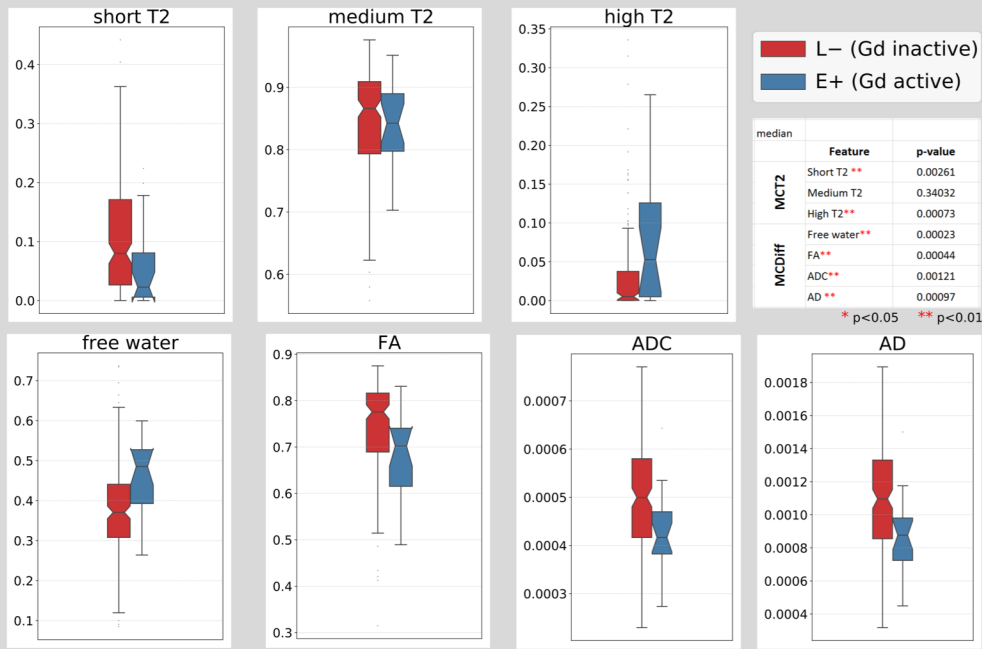


T2-w MRI



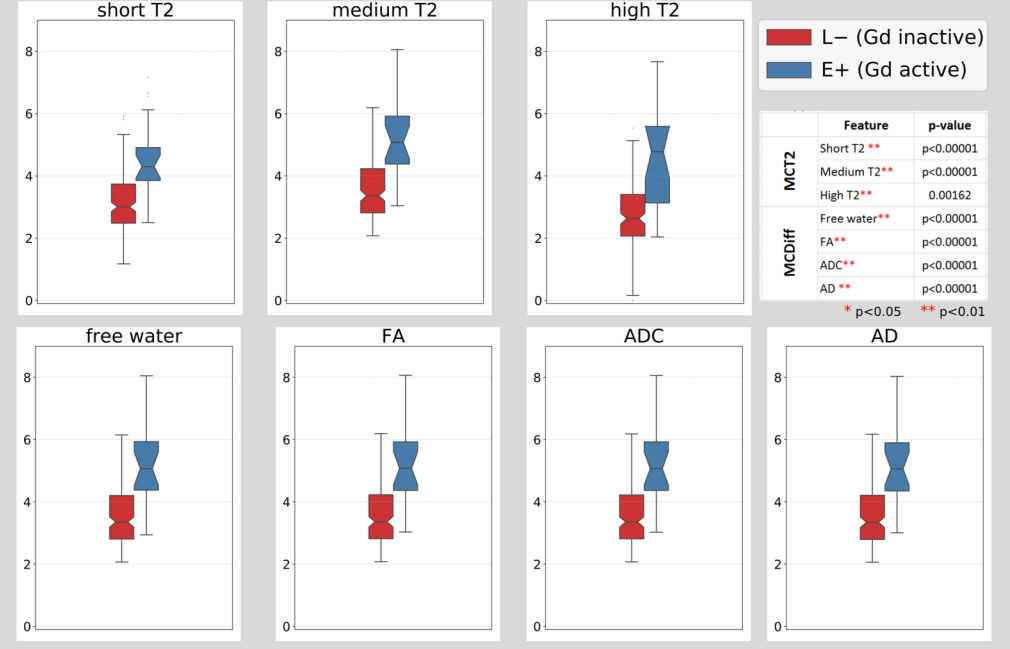
Comparison of markers between groups

Feature: Median



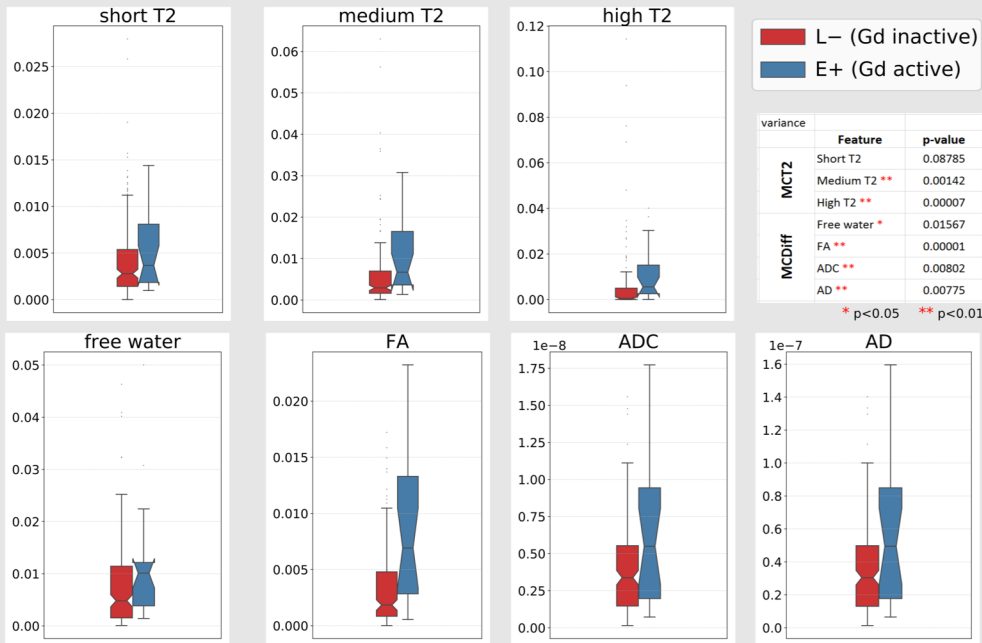
FA: Fractional anisotropy; ADC: Apparent diffusion coefficient; AD: Axial diffusivity

Feature: Entropy



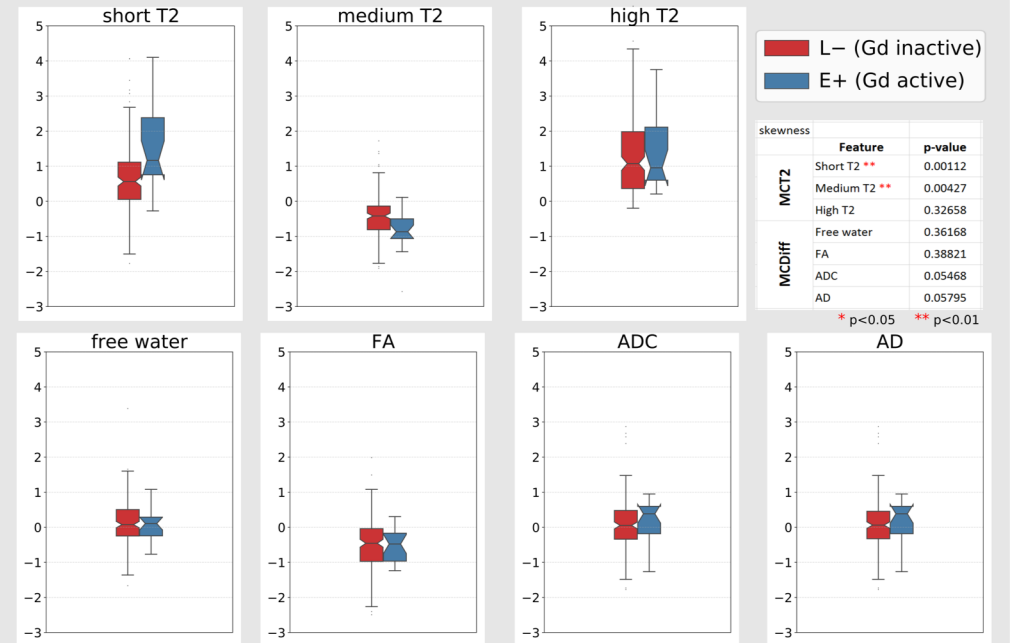
FA: Fractional anisotropy; ADC: Apparent diffusion coefficient; AD: Axial diffusivity

Feature: Variance



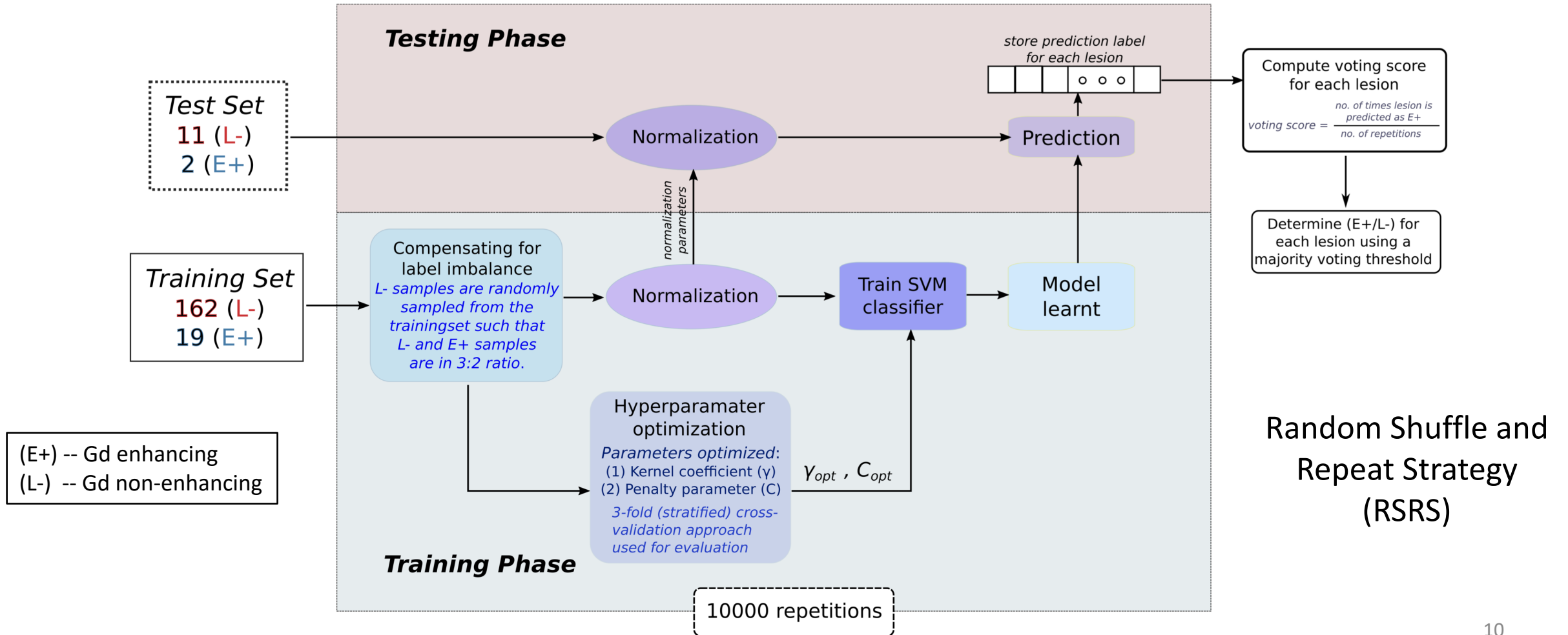
FA: Fractional anisotropy; ADC: Apparent diffusion coefficient; AD: Axial diffusivity

Feature: Skewness

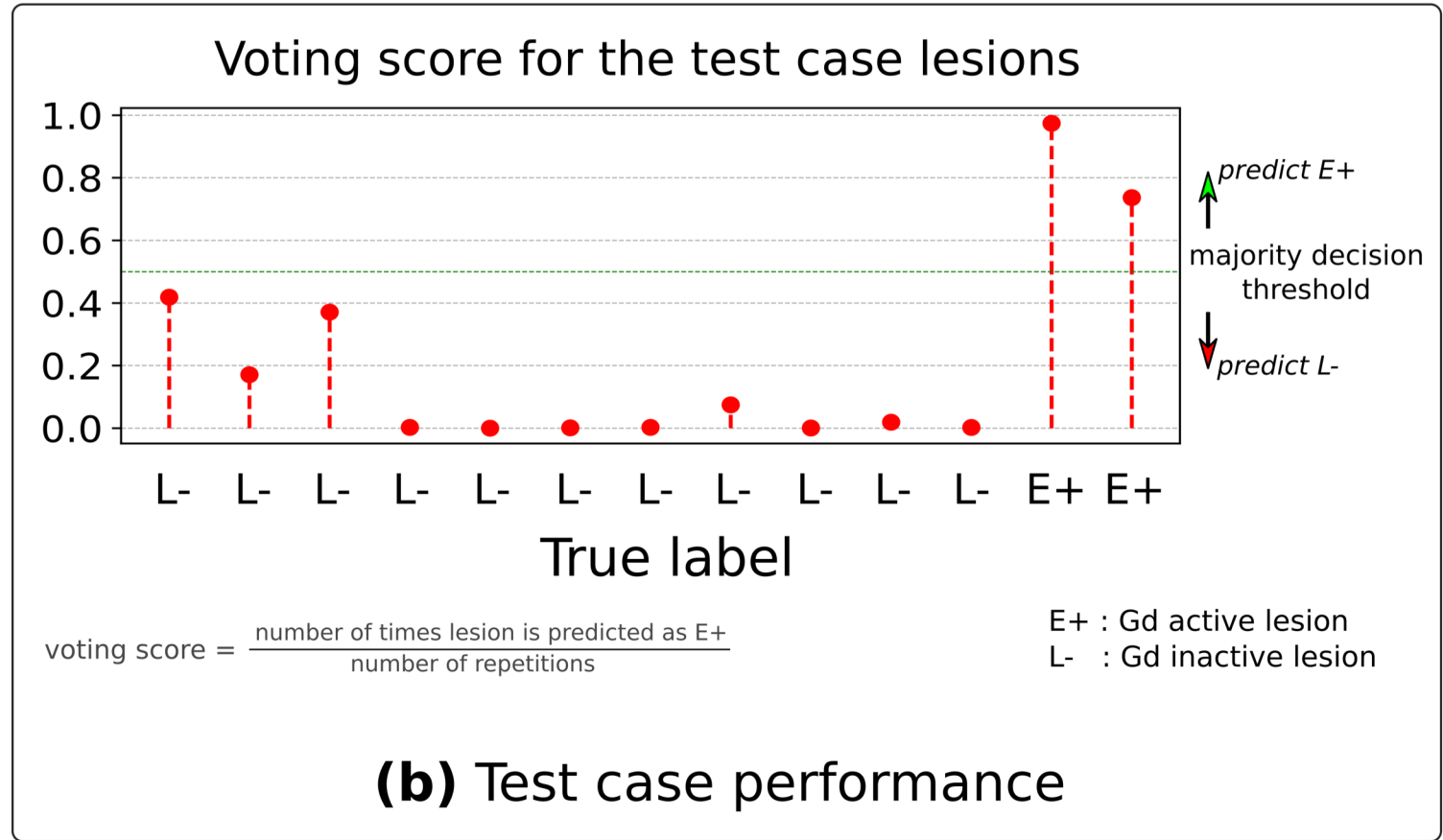
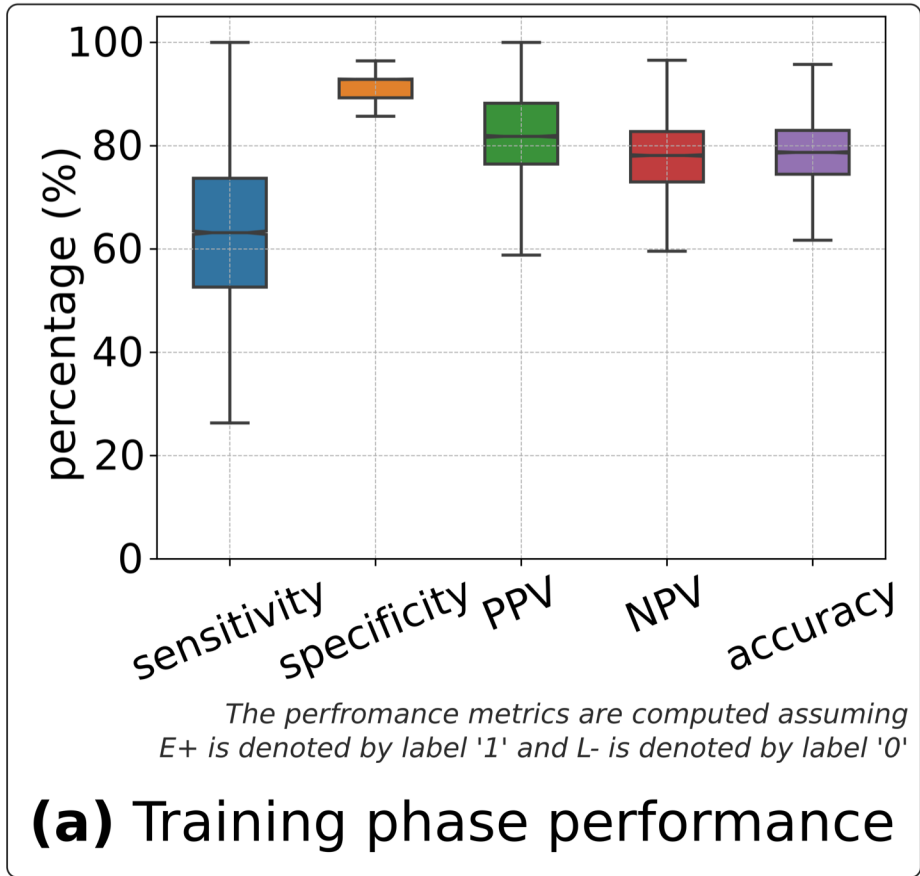


FA: Fractional anisotropy; ADC: Apparent diffusion coefficient; AD: Axial diffusivity

Classification module



Classification performance



Discussion

- The MCT2 and MCDiff features are able to identify MS lesions undergoing BBB from the others as these features provide information on demyelination, edema formation and axonal damage in the lesion affected brain tissues.
- We proposed a prediction framework to identify these lesions using statistics of MCT2 and MCDiff biomarkers values in a lesion and demonstrated its potential on a test case.

Multi-compartment model implementation available at: <https://github.com/Inria-Visages/Anima-Public>

Thank you

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