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Rotation invariant features for Alzheimer's disease identification using convolutional neural networks

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Rotation Invariant Features (RIFs) [1] extracted from dMRI scans represent a generalisation of the usually used 2nd order invariants such as Fractional Anisotropy (FA) and Mean Diffusivity (MD). This work studies the usefulness all of the 12 algebraically independent RIFs extracted from 4th order Spherical Harmonics in the context of Alzheimer Disease (AD) identification. To do so, we introduce a fair metric (*B-score*) that we use to evaluate the proposed deep Convolutional Neural Network (*Subject CNN*) which operates on subject slices to classify the whole subject while avoiding over-fitting. On the ADNI-SIEMENS¹ data set that contains 46 AD and 352 Normal Connectivity (NC) subjects respectively, we observe that the 12 algebraically independent 4th order RIFs are not equivalently useful to the classification task. A particular combination of a low degree RIF (R_{22}) with a high degree one (R_{22224}) achieves the best performance of 82.67% B-score and 84.88% accuracy on this data set. Also, the generated 3D Class Activation Maps (CAMs) [2] show that to classify a subject as AD or NC the model focuses on the value of the RIFs in the white matter around the ventricules.

Problem statement : How useful can the 4th order Rotation Invariant Features (RIFs) be in the context of Alzheimer's disease identification? And are all these RIFs useful to the task?

dMRI signal and Rotation Invariant Features

Representing the diffusion signal as a weighted sum of spherical harmonics.

 $\sum c_l^m Y_l^m(\theta,\phi)$ $f(\theta, \phi) =$ $l=0 \mid l\%2=0 m=-l$

Formula for extracting Rotation Invariant Features (RIFs) [1]

$$R_{l_1,\dots,l_d} = \sum_{m_1=-l_1}^{l_1} \dots \sum_{m_d=-l_d}^{l_d} c_{l_1m_1} \dots c_{l_dm_d} G(l_1, m_1 | \dots | l_d, m_d)$$

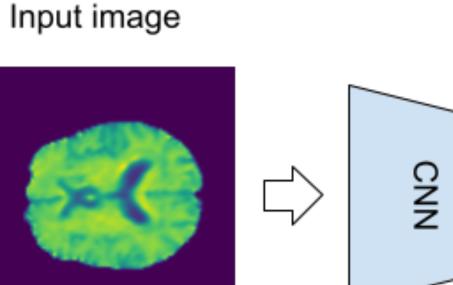
Metric

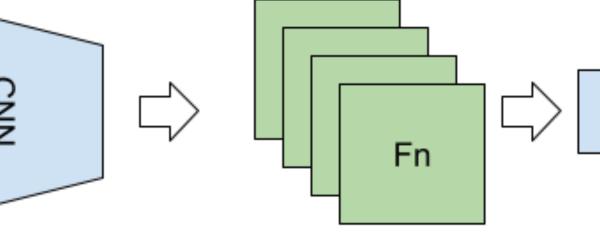
A fair metric that gives equal weight to both classes regardless of the number of data points is crucial in the used imbalanced data set.

$$B - score = 2 \times \frac{TPR \times TNR}{TPR + TNR}$$
$$TPR = \frac{\#True \ Positives}{\#Positives} \qquad NPV = \frac{\#True \ Negative}{\#Negatives}$$

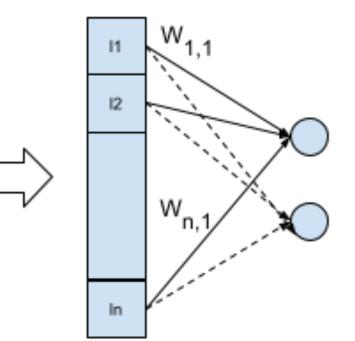
Class Activation Map

Class Activation Map can be extracted from our architecture and provides the location of salient voxels used for the classification of AD and CN subjects.



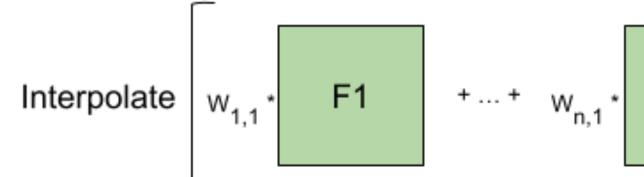


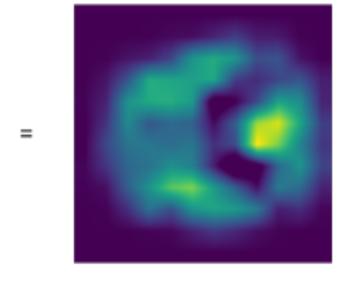
Feature maps



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Class Activation Map (CAM)

0

30

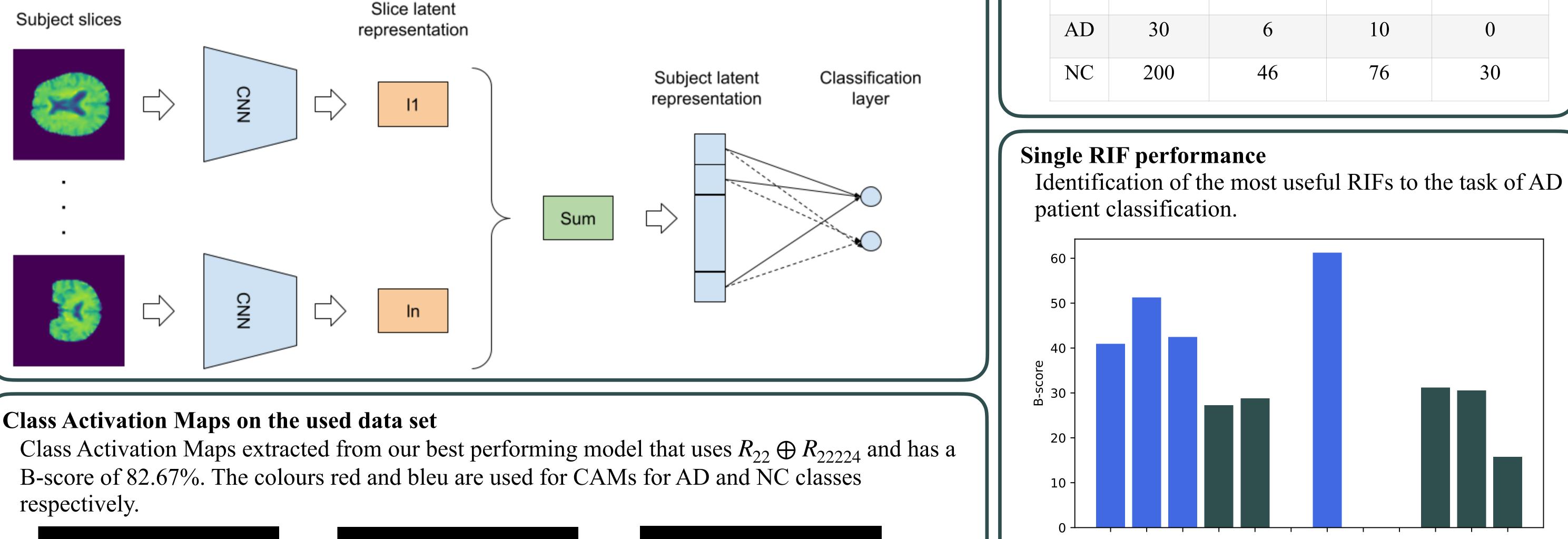
Subject CNN model

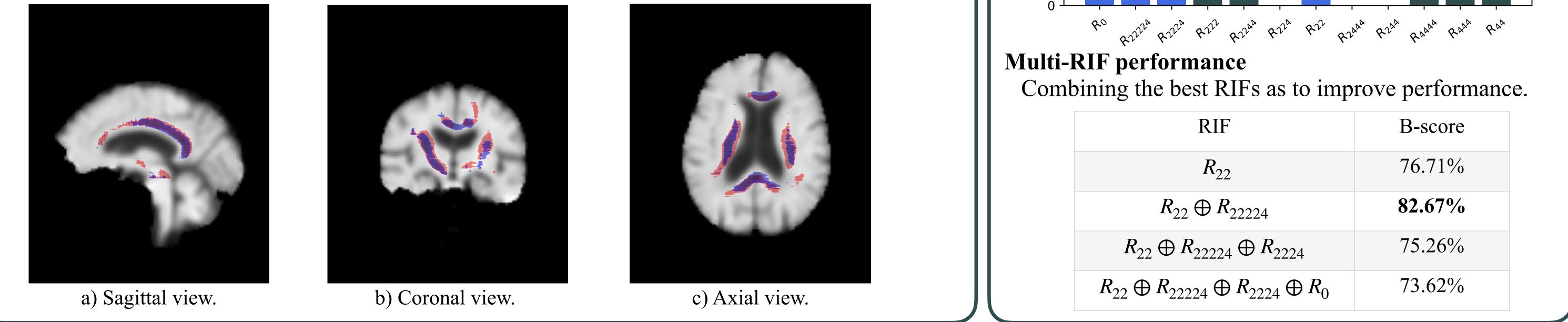
The proposed Subject CNN model that uses the encoding of each subject's slice to take the classification decision.

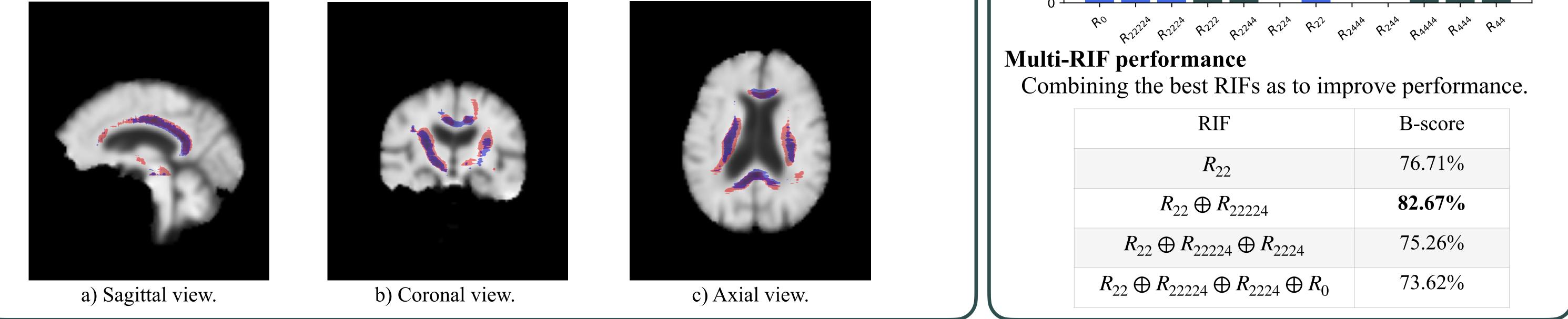
Data set	-				
The da	ata set spli	t over the AD	NI-SIEM	ENS ¹ data set	t.
	Train	Validation	Test	Not used	

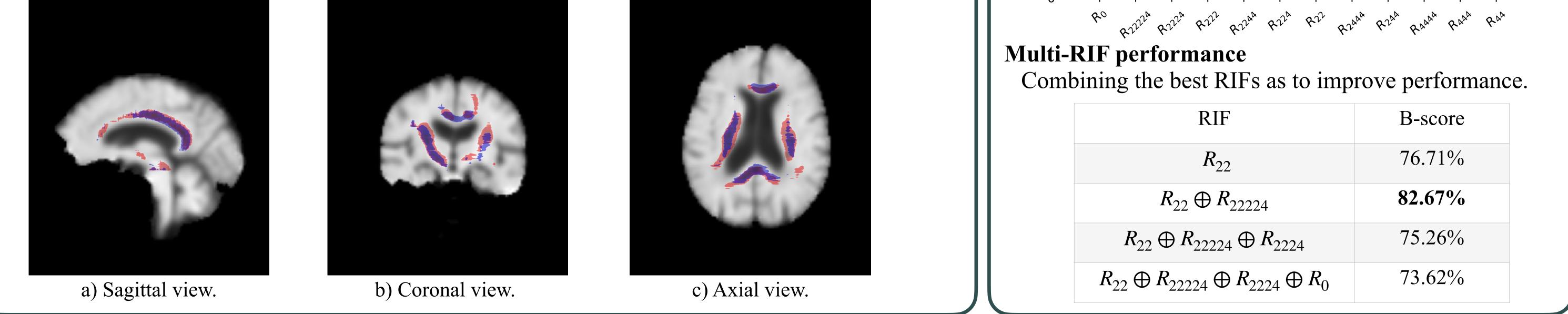
Fn

GAP









Conclusion

This work allows us to conclude that the 12 algebraically independent 4th order RIFs contain information that is very useful to AD identification and we can achieve a high performance on the ADNI-SIEMENS data set. It can also be noted that not all the RIFs are equivalently informative to the task at hand and careful RIF selection is important.

References

[1] Mauro Zucchelli, Samuel Deslauriers-Gauthier and Rachid Deriche. A computational framework for generating rotation invariant features and its application in diffusion MRI. Medical Image Analysis (2020). [2] Zhou Bolei, Khosla Aditya, Lapedriza Agata, Oliva Aude, Torralba Antonio. Learning deep features for discriminative localization. CVPR (2016).

1. Alzheimer's Disease Neuroimaging Initiative website : https://adni.loni.usc.edu/

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