

White Matter Multi-Resolution Segmentation Using Fuzzy Set Theory

*Alessandro Delmonte^{1,2}, *Corentin Mercier^{1,3}, Johan Pallud⁴, Isabelle Bloch^{1,2}, Pietro Gori¹

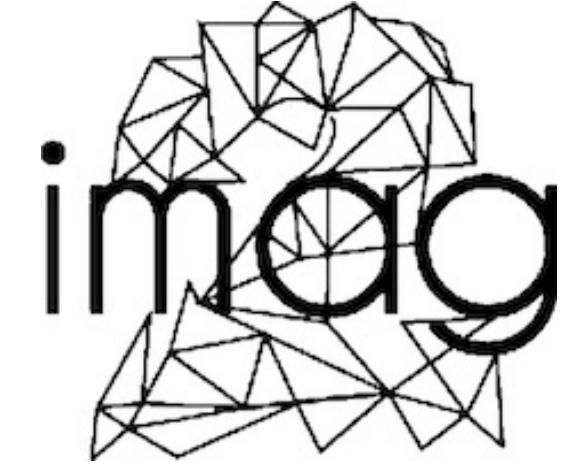
¹LTCI, Télécom ParisTech, Paris-Saclay University, Paris, France

²IMAG2 Laboratory, Imagine Institute, Paris, France

³LIX, Ecole Polytechnique, Palaiseau, France

⁴Neurosurgery Department, Sainte-Anne Hospital, Paris, France

* equally contributed to this work



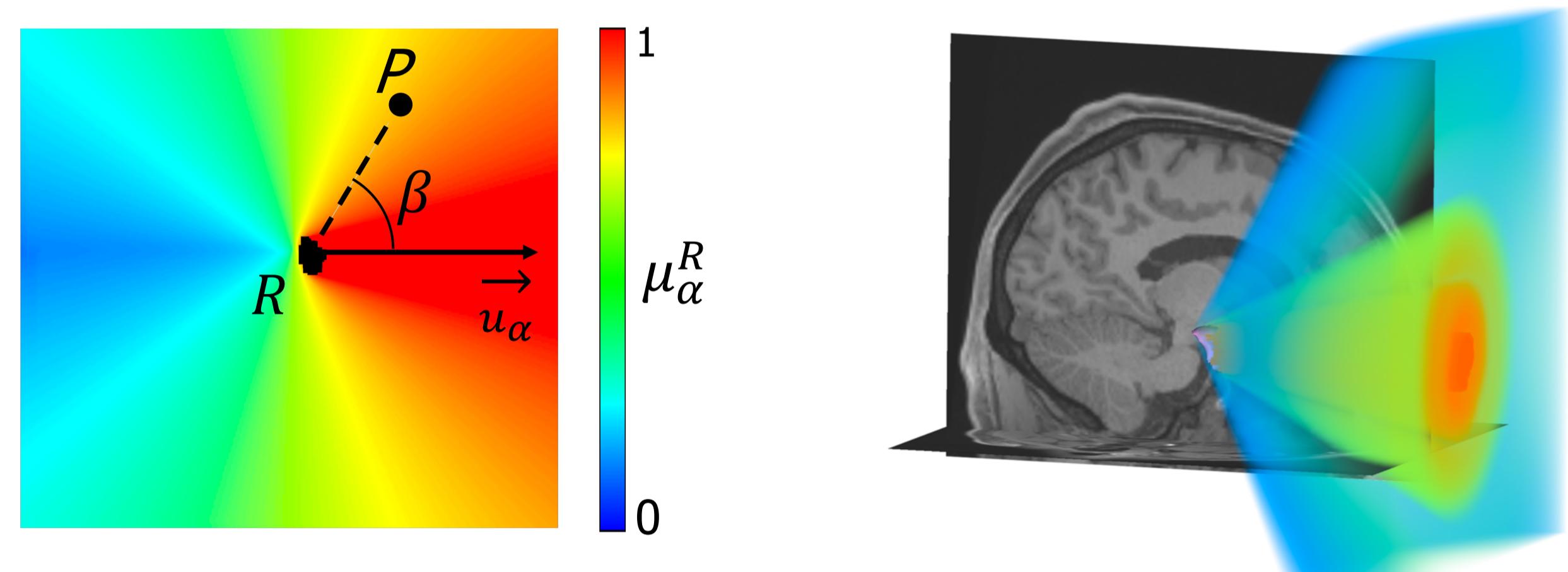
INTRODUCTION / OBJECTIVE

White matter fiber bundles are often described using qualitative and vague spatial indication. We propose to apply the fuzzy set theory to identify brain fibers bundles exploiting their spatial properties. To cope with the high redundancy of tractograms and ease interpretation we introduce an interactive navigation and exploration technique based on a multi-resolution representation.

SPATIAL RELATIONS MODELING

Bundles are defined with spatial (*anterior of*, ...), connectivity (*endpoint in*, ...) and trajectory (*crossing*, ...) indication using a structured language.

For each descriptor, spatial membership functions [1] model the satisfaction degree of all the image voxels.



$$\mu_{\alpha}^R(P) = \max(0, g(\beta_{min})), g(\beta_{min}) = \frac{1-2\beta_{min}}{\pi}$$

Bundles spatial relations are combined to form a final fuzzy space. An anatomical coherence score (ACS) [2] is obtained for each fiber/cylinder by integration.

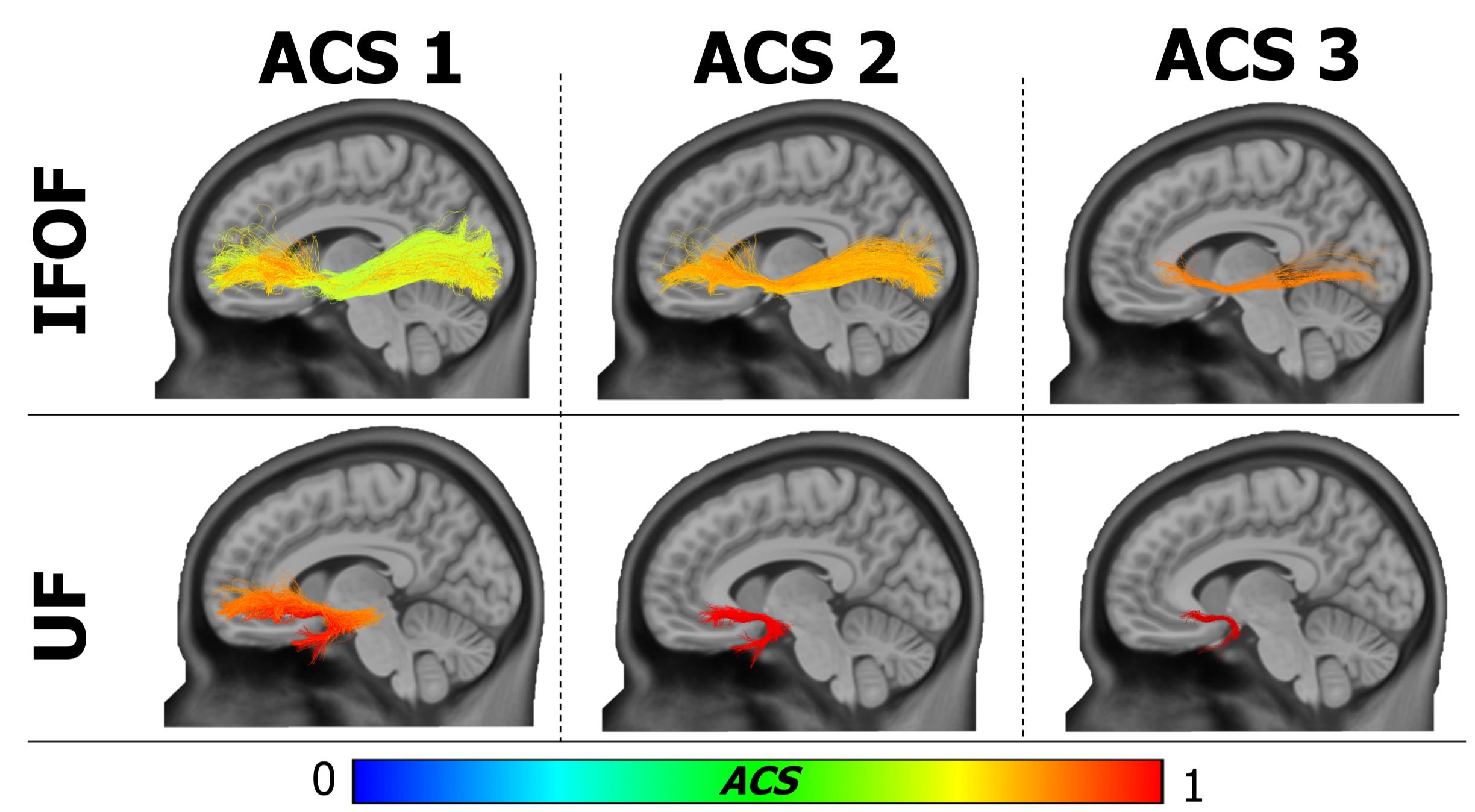


Fig. 1: Thresholding IFOF and UF

Fibers of interest can be selected via an ACS based thresholding operation.

MULTI-RESOLUTION REPRESENTATION

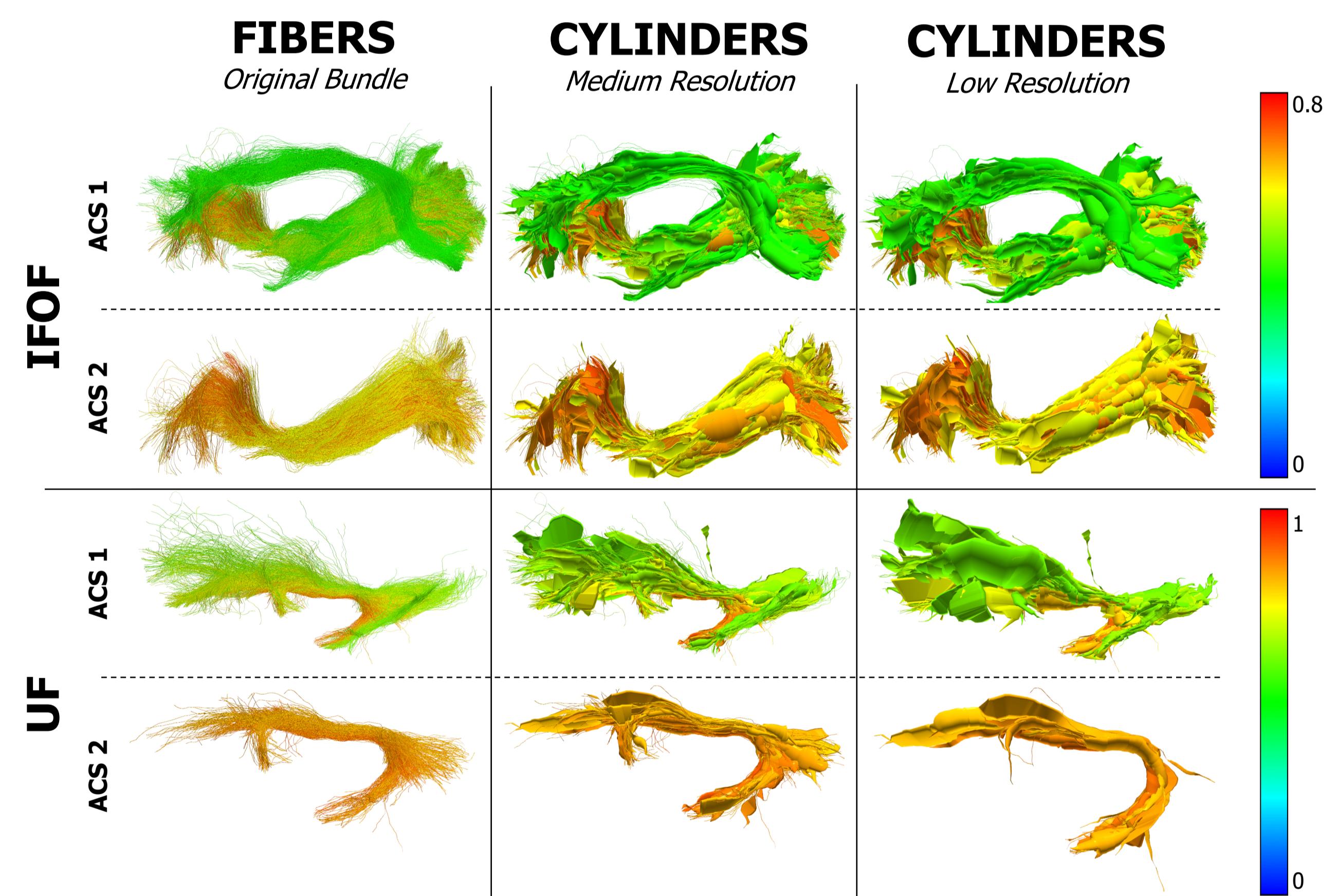


Fig. 2: Multi-resolution visualization of fiber bundles

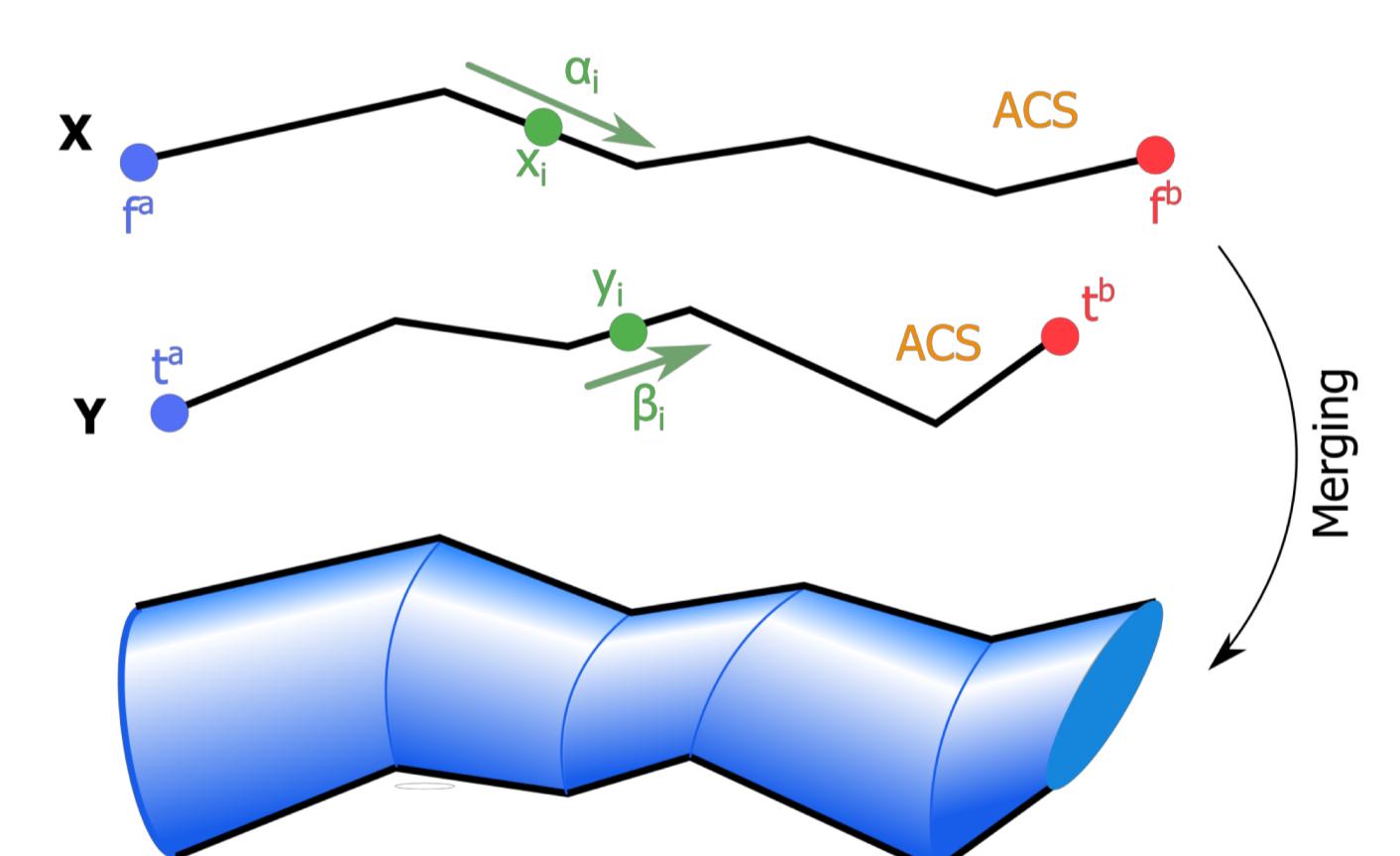
White matter multi-resolution [3] progressively merges fibers together in generalized cylinders.

Similar fibers are selected using an extension of the Weighted Currents [4] similarity containing the ACS:

$$WC_{ext} = K_c(|ACS_X - ACS_Y|)K_a(\|f_a - t_a\|_2)K_b(\|f_b - t_b\|_2) \left[\sum_{i=1}^{N-1} \sum_{j=1}^{M-1} \alpha_i^T K_g(\|x_i - y_j\|_2) \beta_j \right]$$

With $K_c(|A - B|) = 1 - |A - B|$, and K_a, K_b, K_g being gaussian kernels.

- Real-time multi-resolution navigation
- Interactive ACS thresholding for segmentation



RESULTS

- We validated our results on 5 unrelated healthy adults subjects from the HCP dataset.
- The interactive analysis helped neurosurgeons to better understand the structure of the bundles and find an optimal ACS threshold for the segmentation of IFOF and UF.
- A smaller fiber dispersion, compared to state-of-the-art methods, can be observed.
- ACS thresholds were reproducible among different subjects.

FUTURE WORKS

We plan to extend the proposed technique to more tract bundles, implementing more fuzzy relations, and perform statistical analyses.

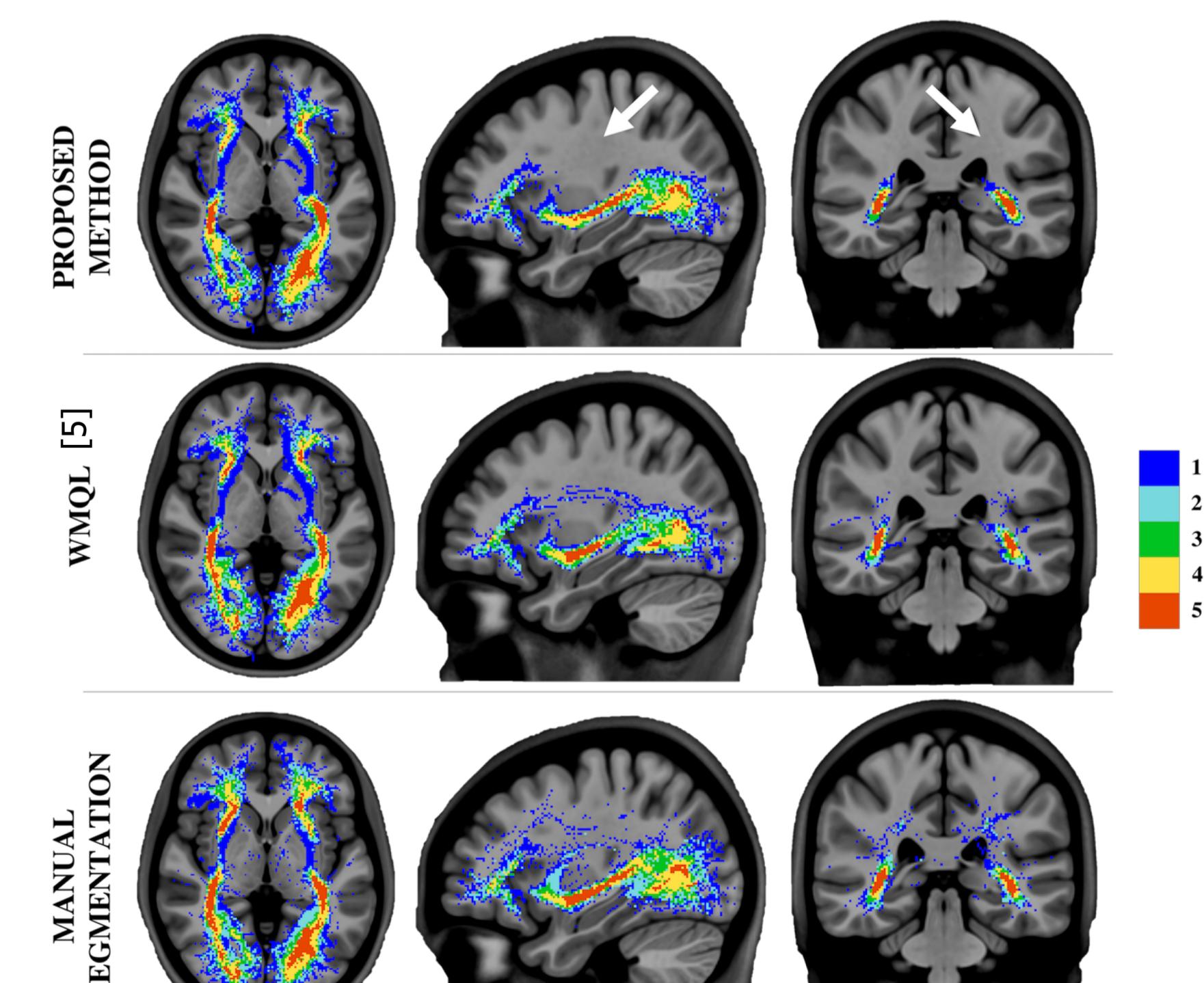


Fig. 3: Tracts dispersion map



References

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- [5] D. Wassermann *et al.*, "The white matter query language: a novel approach for describing human white matter anatomy," *Brain Structure and Function*, vol. 221, no. 9, pp. 4705–4721, 2016.