White Matter Multi-Resolution Segmentation Using Fuzzy Set Theory

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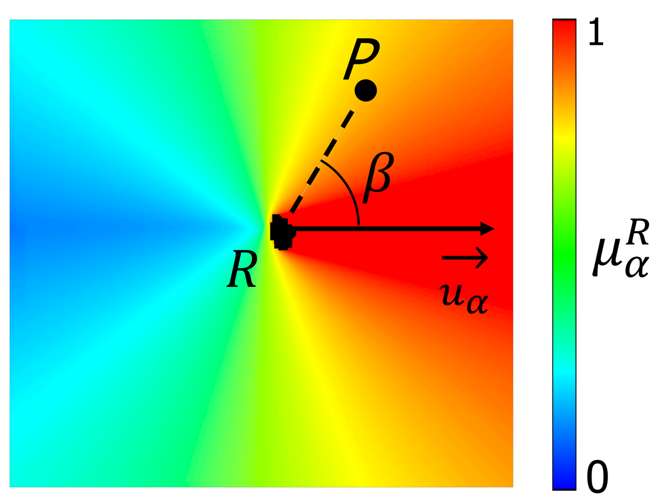
INTRODUCTION / OBJECTIVE

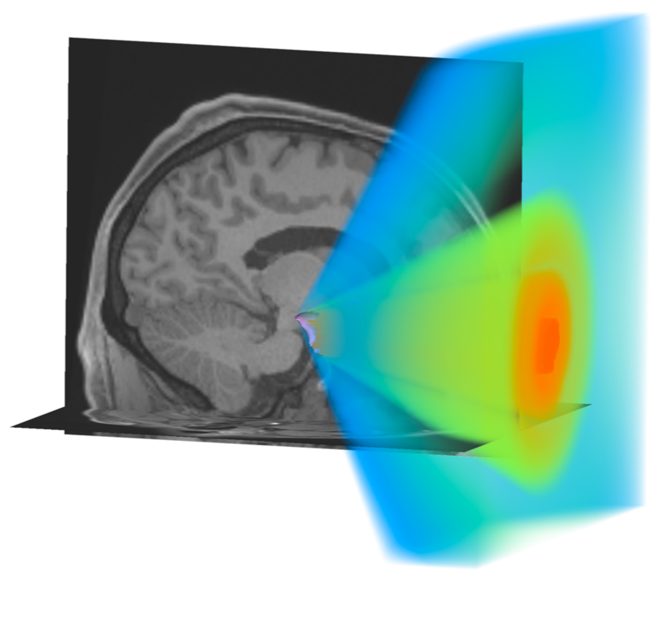
White matter fiber bundles are often described using qualitative spatial relationships (e.g. anterior of Amygdala) [0]. We propose to model their inherent vagueness using the theory of fuzzy sets. Furthermore, to cope with the high redundancy of tractograms and ease interpretation, we introduce an interactive navigation and exploration technique based on a multi-resolution representation.

SPATIAL RELATIONS MODELING

Bundles are defined as a logic combination of spatial (*anterior of*, …), connectivity (*endpoint in*, …) and trajectory (*crossing*, …) relations.

Every voxel *P* in the space is assigned a membership value μ describing the degree of satisfaction of the combined relations. A FS score is computed for each fiber (composed by *f* points) as the weighted average of μ values of the voxels the fiber passes through.





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

Endpoints: $EP = min_{r \in R}(e^{\frac{\|f-r\|_2^2}{\lambda^2}})$

An anatomical coherence score (ACS) [2] is obtained for each fiber/cylinder in a conjunctive way.

$$ACS = FS * EP$$

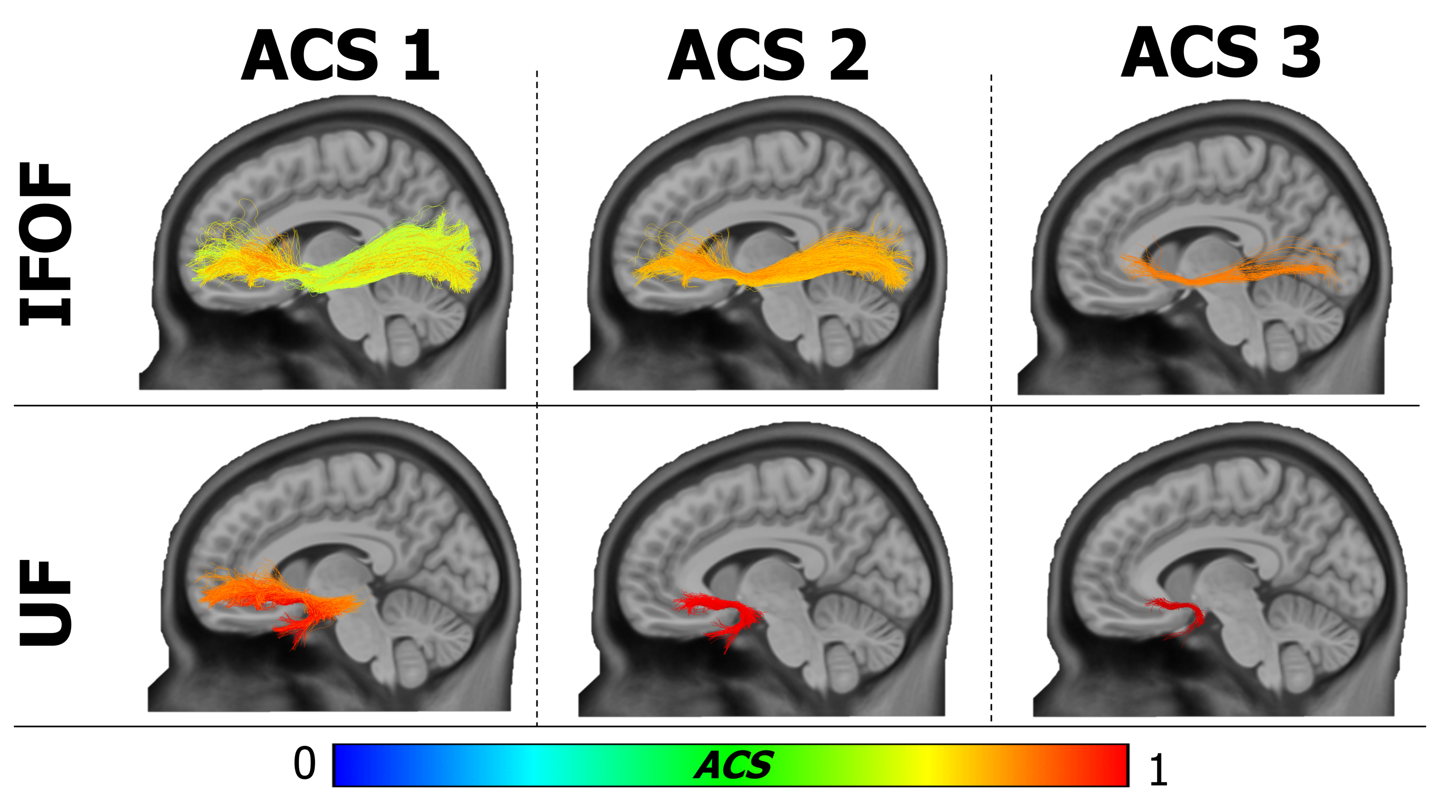


Fig. 1: Fibers of interest can be selected via an ACS based thresholding operation.

MULTI-RESOLUTION REPRESENTATION

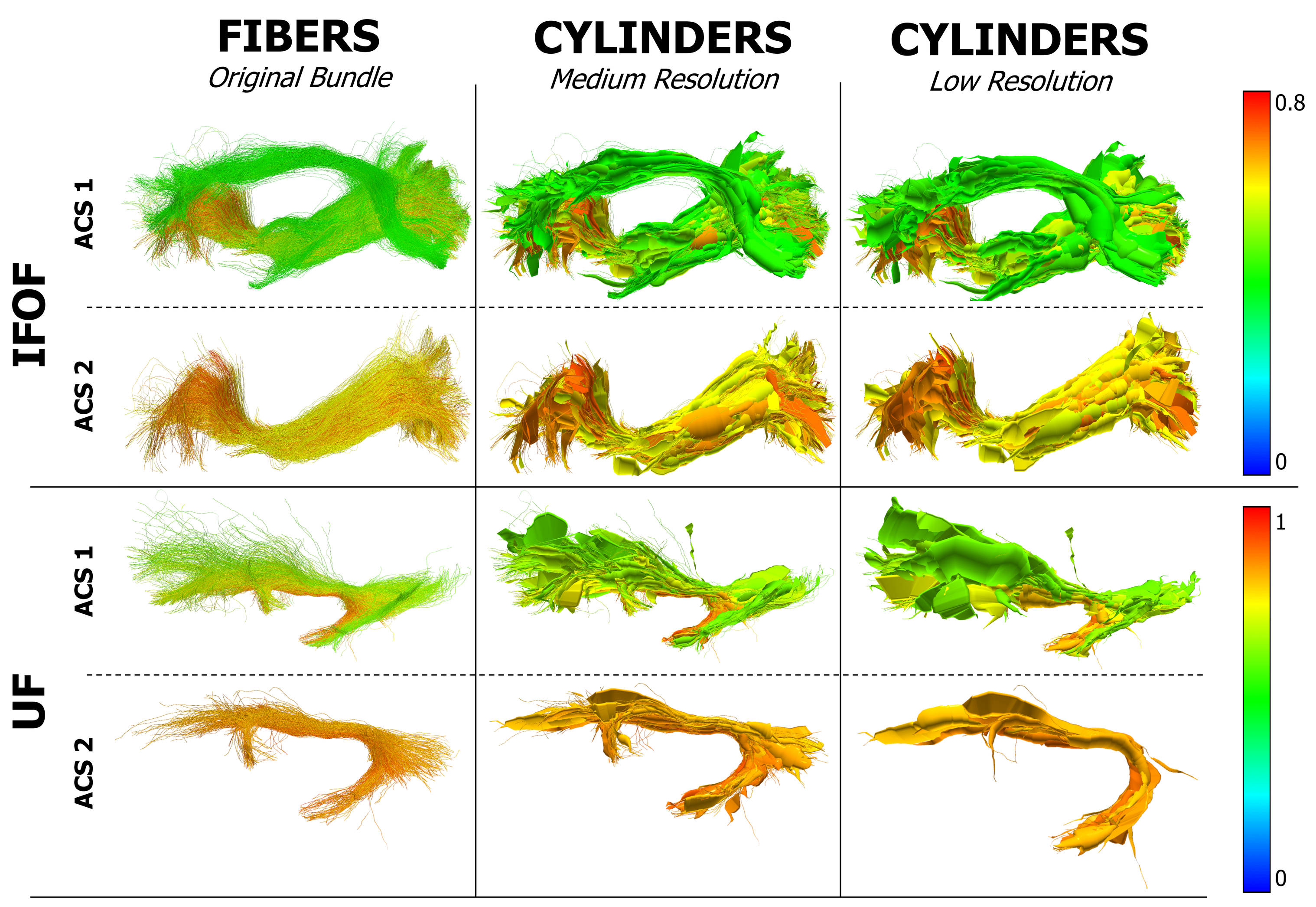


Fig. 2: Multi-resolution fiber bundles visualization

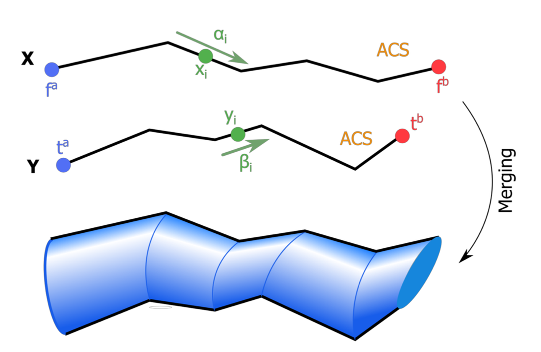
White matter multi-resolution [3] technique progressively merges fibers together in generalized cylinders.

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

Fibers are selected using an extension of the Weighted Currents [4] similarity, containing an ACS term.

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

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



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.

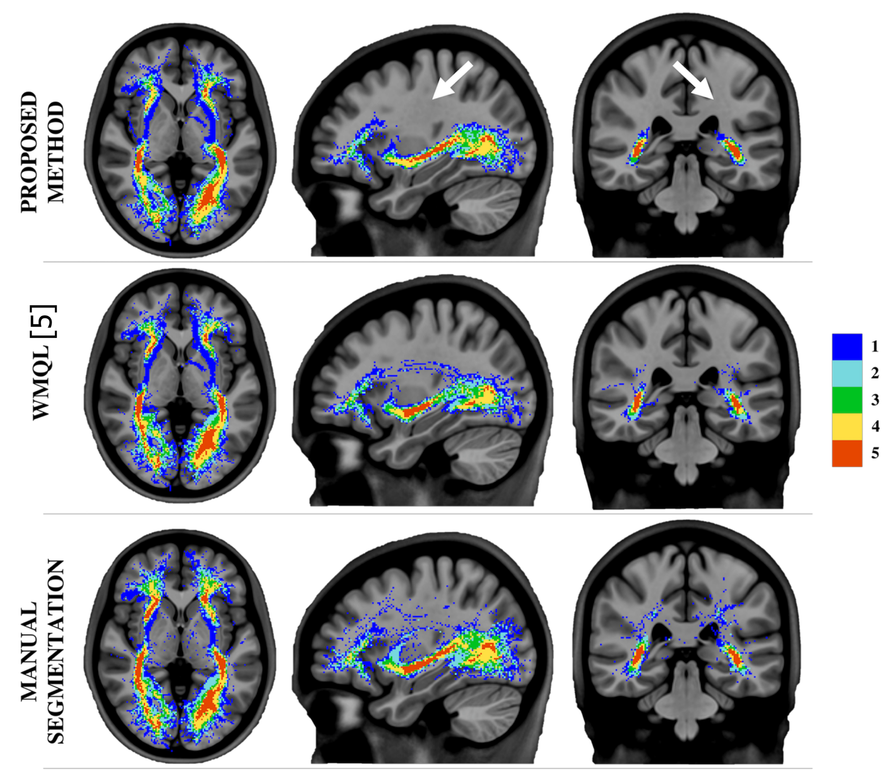


Fig. 3: Tracts dispersion map

FUTURE WORKS

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

References [0]
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Poster n°**582**

https://github.com/CorentinMercier/FBTS

IEEE International Symposium on Biomedical Imaging – 2019 – Venice (IT) April 8-11, 2019

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