White Matter Multi-Resolution Segmentation Using Fuzzy Set Theory

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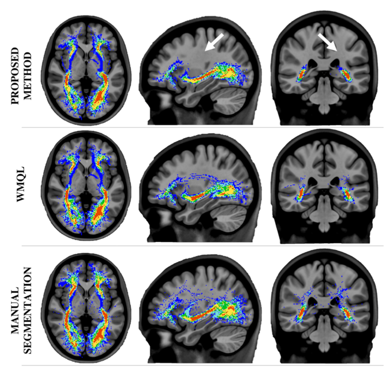
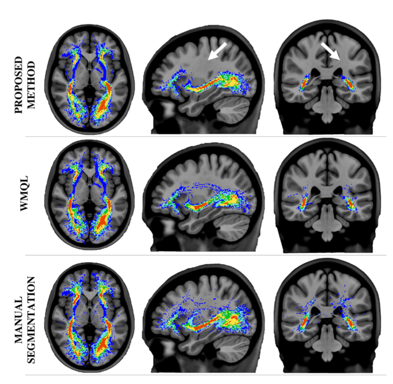
INTRODUCTION / OBJECTIVE

We propose a method for white matter segmentation exploiting spatial relations between brain regions. We model the relations inherent incertitude relying on the spatial fuzzy set theory [1,2]. We complement this approach introducing an interactive visualization and segmentation technique for the bundle of interest based on a multi-resolution brain fiber representation [3].

SPATIAL RELATIONS MODELING

Clinicians often describe white matter fiber tracts based on their spatial properties relatively to known brain references. These descriptions are intrinsically vague, thus the need for an appropriate modelling framework. We apply spatial fuzzy set theory to represent the fibers degree of uncertainty to spatial, connectivity and trajectory properties (e.g. anterior of).





For each tract we assign an anatomical coherence score (ACS) combining, with the fuzzy t-norm and t-conorm operators, the final satisfaction degree to the provided information. Users are able to interactively select the bundles that mostly fit their need with an ACS thresholding operation.

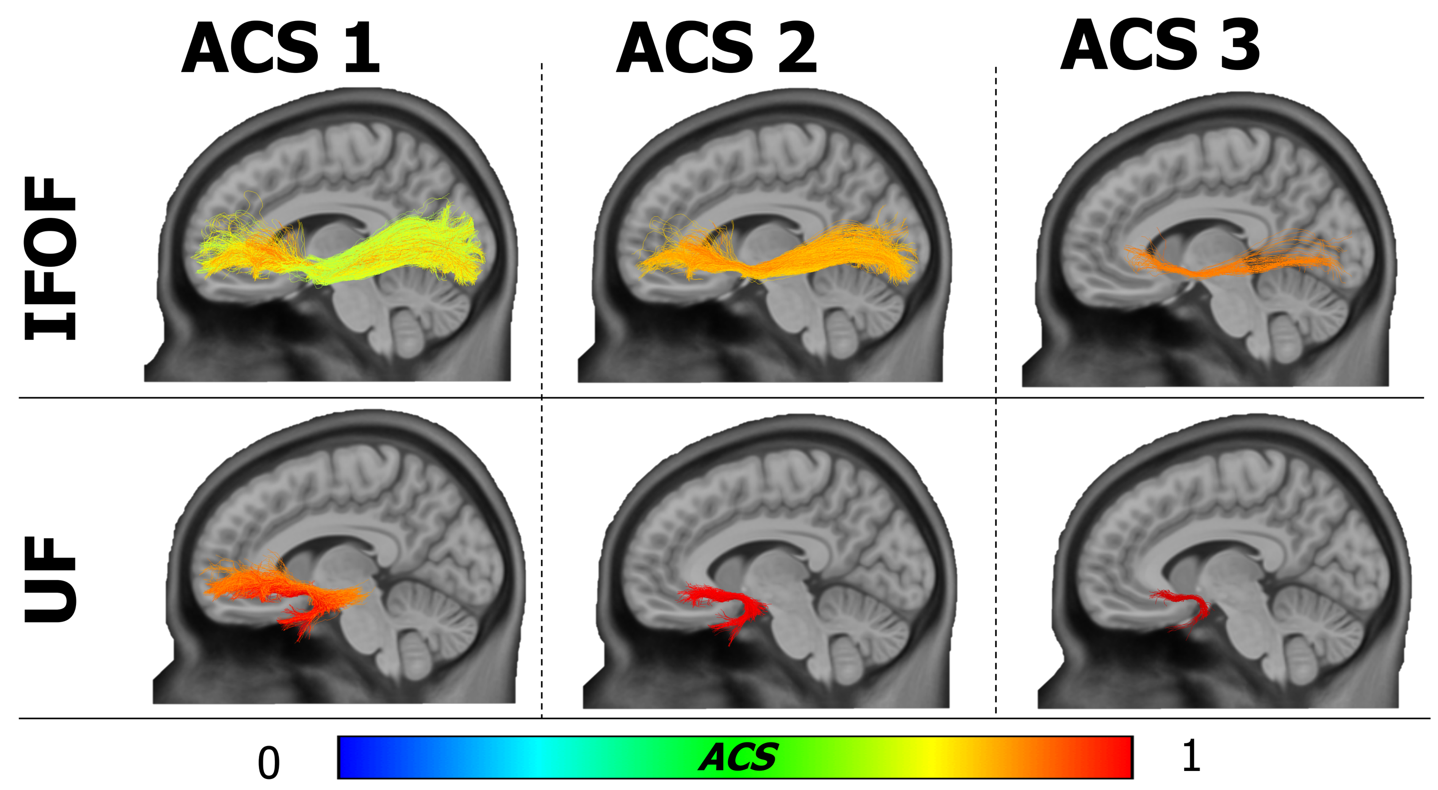


Fig. 1: Thresholding IFOF and UF

MULTI-RESOLUTION REPRESENTATION

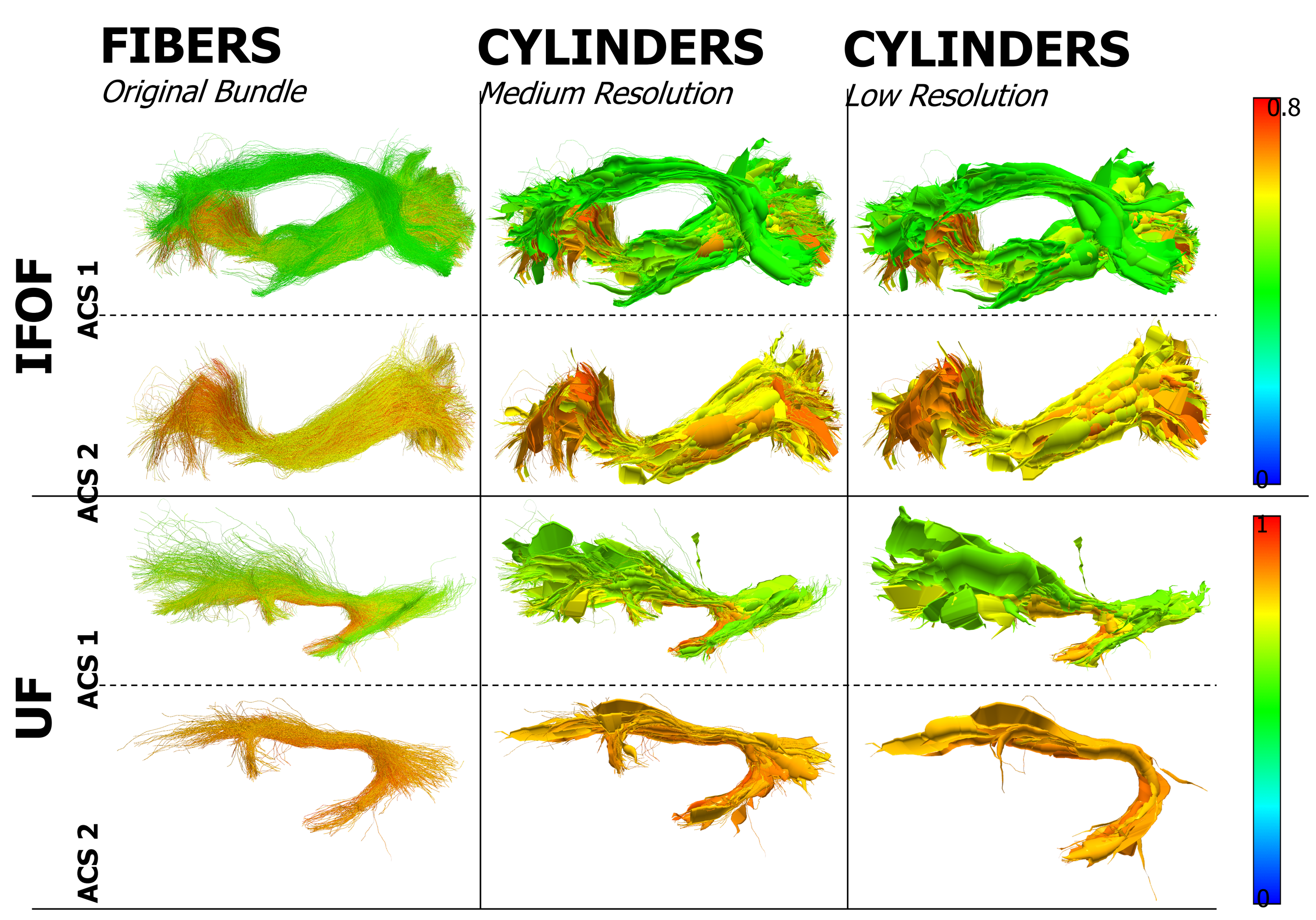
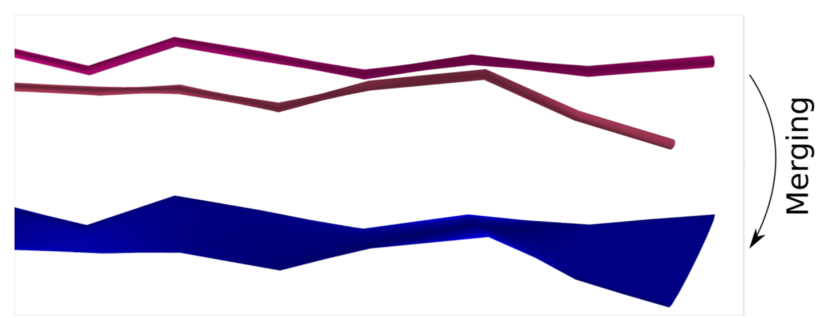


Fig. 2: Multi-resolution visualization of fiber bundles

In order to ease understanding of the segmentation and give interactivity, we create a multi-resolution representation of the tractogram using [3]. This is performed by progressively merging fibers together according to their similarity measure.

We introduce a new term in this measures to take into account the ACS difference between fibers X and Y, assuming K a gaussian kernel:



$$WC_{ext} = K(|ACS_X - ACS_Y|) * WC \quad [4]$$

Doing so, we make it feasible to navigate between thresholds in an interactive way, using the simplified geometry of the multi-resolution representation.

RESULTS

- We validated our results on 5 unrelated healthy adults subjects from the *HCP* dataset.
- Compared to *WMQL* [4] and manual segmentation, our technique presents less scattered fibers (dispersion), especially in the arc connecting the temporal and frontal lobe, as shown in the dispersion colormap of figure 3.
- The interactive analysis allowed neurosurgeons to better identify ACS thresholds producing the results that best fit the clinical reality.
- ACS thresholds were found to be reproducible among our different testing.

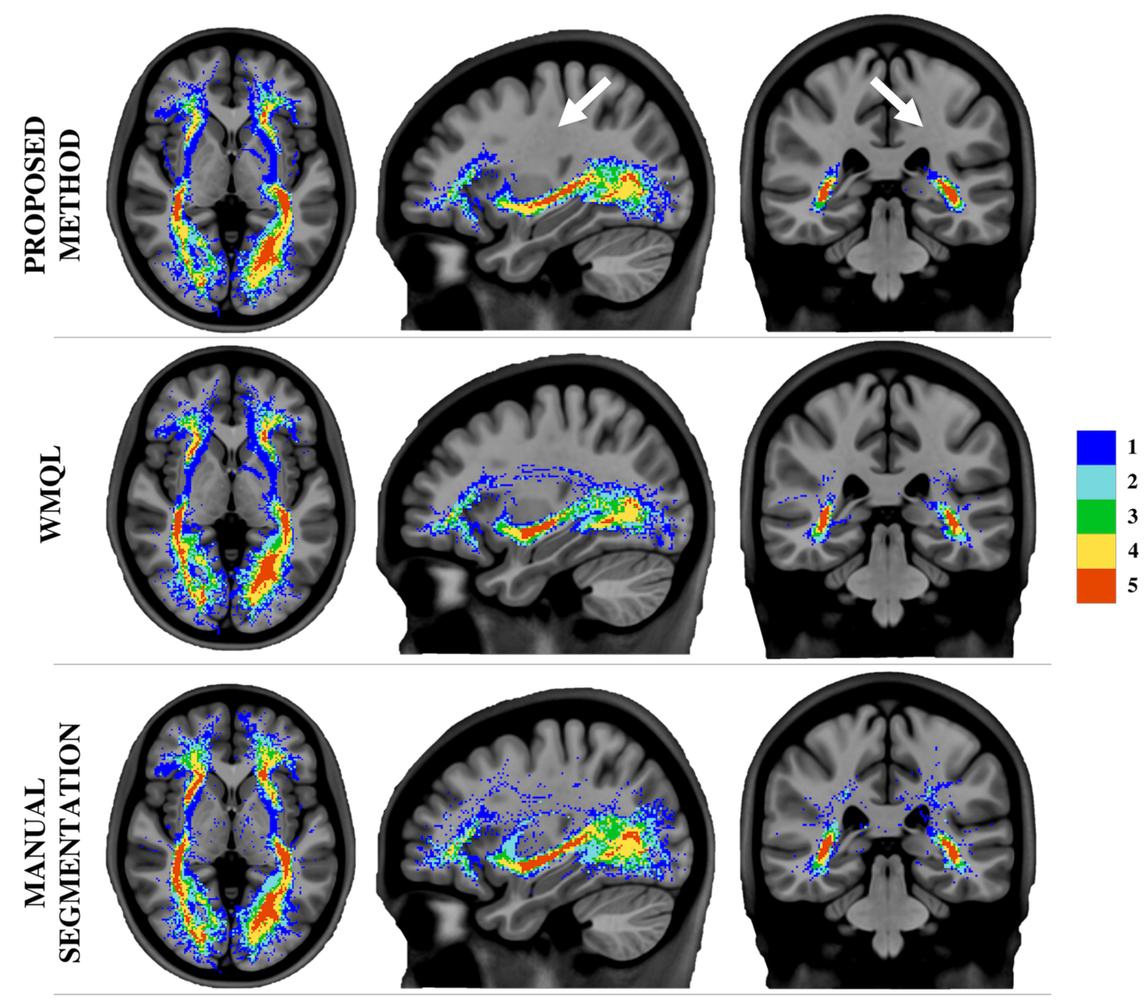


Fig. 3: Tracts dispersion map

FUTURE WORKS

We plan to extend the proposed technique to other tracts and use it in statistical analyses.

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References
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https://github.com/CorentinMercier/FBTS

Poster n°582

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