`Classifyber`: a linear classifier of single streamlines for white matter bundle segmentation

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Introduction

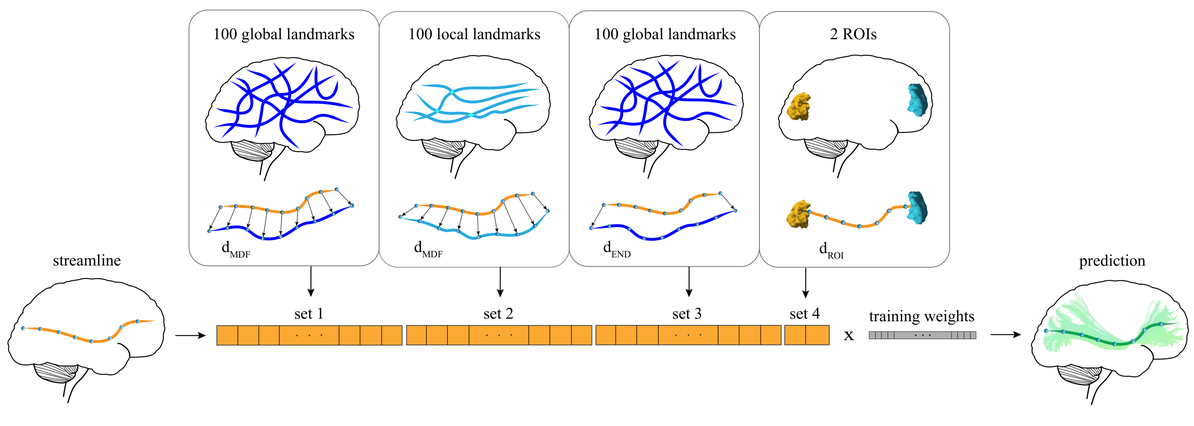
- **Motivation:** Pre-surgical planning and tractometry need virtual dissection of white matter bundles from diffusion Magnetic Resonance Imaging (dMRI) data.
- **State-of-the-art** of supervised bundle segmentation methods:
  - RecoBundles (Garyfallidis et al., 2018): Nearest-Neighbors.
  - LAP (Sharmin et al., 2018): Linear Assignment Problem.
  - TractSeg (Wasserthal et al., 2018): Deep Learning.
- **Major Issue:** results are not **robust** across different settings:
  - Data quality: research vs clinical.
  - Tractography: probabilistic vs deterministic.
  - Bundle size: large vs small.
- **Proposal:** `Classifyber`, a novel robust supervised linear classifier of single streamlines.

Methods

`Classifyber` predicts whether or not a streamline belongs to the bundle of interest, e.g. to the inferior fronto-occipital fascicle (IFOF).

The procedure comprises four steps:

1. **Feature extraction:** each streamline is transformed into a vector with information about the geometry of the streamline (set 1 and set 2), its connectivity pattern (set 3), and its relation to the anatomy of the bundle (set 4).
2. **Labeling:** each streamline/vector is labeled as 1 if it belongs to the bundle, or 0 if not.
3. **Training:** a linear model (Logistic Regression) is trained on streamlines/vectors from expert-made segmented bundles.
4. **Prediction:** after training, `Classifyber` predicts the label of the streamlines of the tractogram of a target subject, after vectorizing them.



Materials and Experiments

Four datasets of bundles segmented by experts, with different characteristics:

dataset	data quality	tractography	bundles	subjects	in-house
HCP-major	research	probabilistic	10 major-associative	105	✗
HCP-minor	research	deterministic	8 small-bundles	105	✓
HCP-IFOF	research	probabilistic	IFOF	30	✓
Clinical	clinical	deterministic	IFOF & AF	10	✓

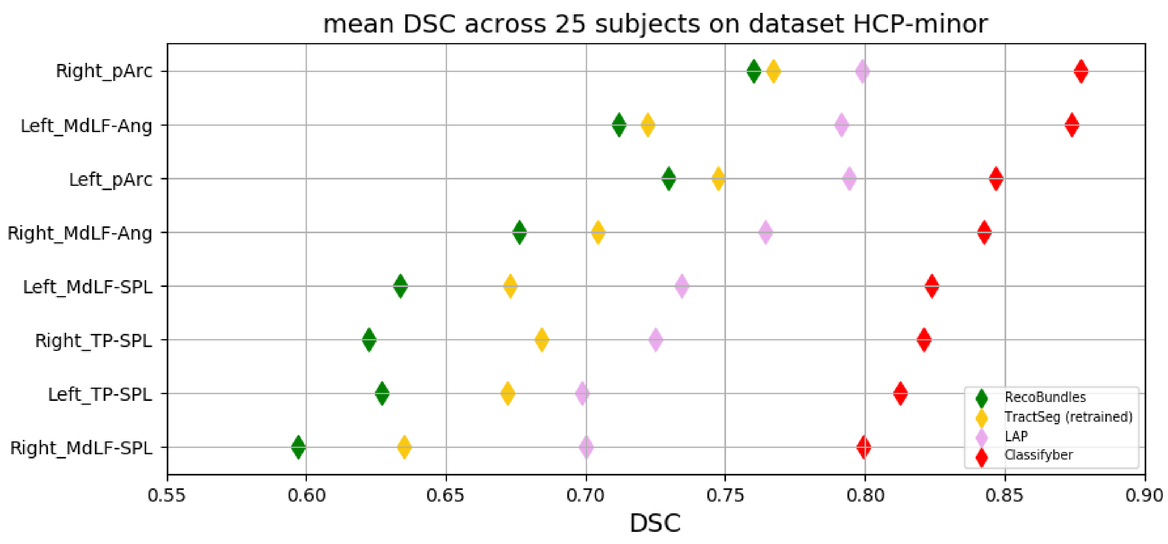
We ran multiple experiments and segmented approximately 500 bundles with RecoBundles (Garyfallidis et al., 2018), LAP (Sharmin et al., 2018), TractSeg (Wasserthal et al., 2018) and `Classifyber` and evaluated their performances through the Dice Similarity Coefficient (DSC) score at the voxel level (the higher the better).

Results

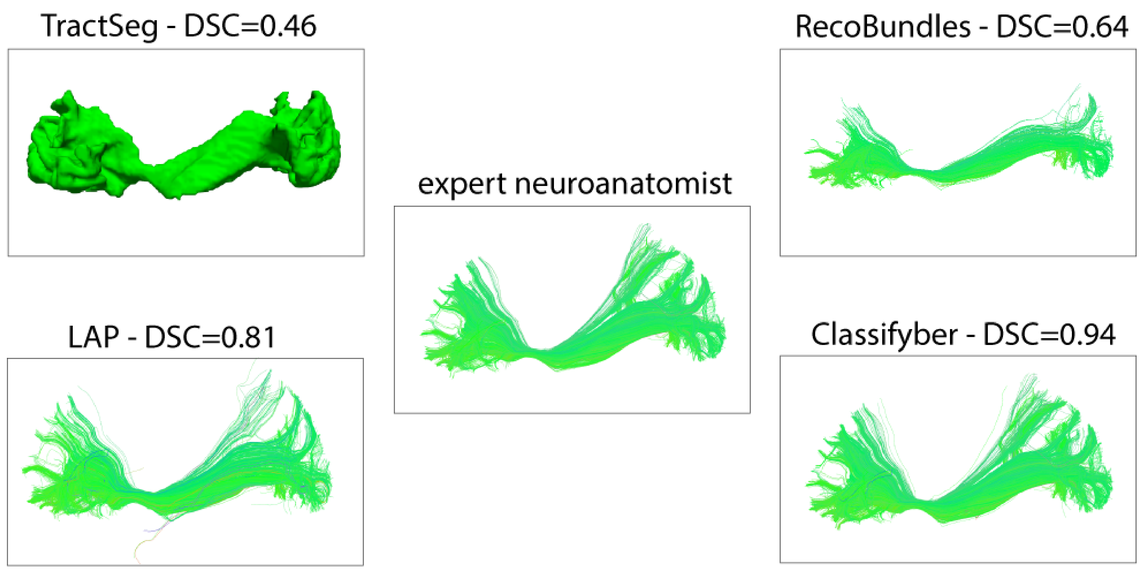
We report the DSC (mean ± sd) across all datasets and methods:

dataset	RecoBundles	TractSeg	LAP	`Classifyber`
HCP-major	0.60 ± 0.17	0.81 ± 0.04	(unfeasible)	**0.85** ± 0.05
HCP-minor	0.67 ± 0.08	0.70 ± 0.06	0.75 ± 0.06	**0.84** ± 0.05
HCP-IFOF	0.53 ± 0.18	0.44 ± 0.06	0.77 ± 0.06	**0.90** ± 0.03
Clinical	–	0.32 ± 0.10	–	**0.91** ± 0.04

Example of per-bundle average DSC for each method, on small bundles:



Paradigmatic example of an IFOF segmented by each method and the expert:



Conclusions

`Classifyber` clearly outperforms the other methods in all cases, by a substantial margin, and segments bundles very accurately. This occurs across different kinds of bundles, tractography techniques, expert-made segmentations, and quality of data, i.e. research vs clinical.

F.A.I.R. implementation on BrainLife.io

`Classifyber` is freely available on the online platform BrainLife.io both as the algorithm implementing training and test phases, and as a pre-trained method:
`https://doi.org/10.25663/brainlife.app.228`
`https://doi.org/10.25663/brainlife.app.265`

References

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