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Brain Structure Visualization using Spectral Fiber Clustering

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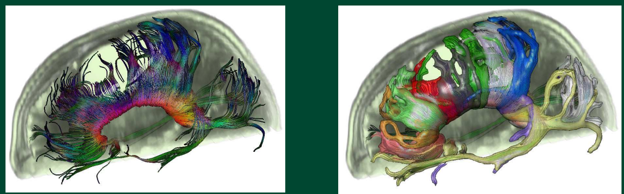
Introduction

An explicit geometrical reconstruction of white matter fiber tracts has become a hot topic in medical visualization [1]. Fiber clustering algorithms have been proposed for improving the perception of fiber bundles and connectivity in the human brain by grouping anatomically similar or related fibers [2,3].



Left: color-coded fibers showing the corpus callosum, the largest white matter structure in the human which is made up of 250 million nerve fibers. Right: using our extended spectral clustering algorithm, the fibers are grouped into clusters.

Fiber Similarity

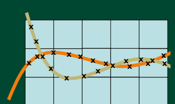
For clustering, a similarity measure has to be defined, typically by a feature space (FS) and a distance function.

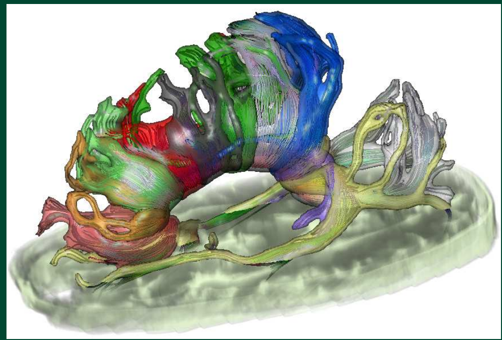
Problems of a FS:

- manual fine-tuning of parameters to a fiber set
- parameters can influence number and constellation of clusters in an unpredictable way.

Thus, we propose our fiber grid where each point p of a fiber i is assigned to cell (x,y,z) with weight $w_{i,p}(x,y,z)$.

$$a_{ij} = \sum_{(x,y,z)} w_i(x,y,z) \cdot w_j(x,y,z)$$
$$w_i = \sum_{p \in (x,y,z)} w_{i,p}(x,y,z)$$



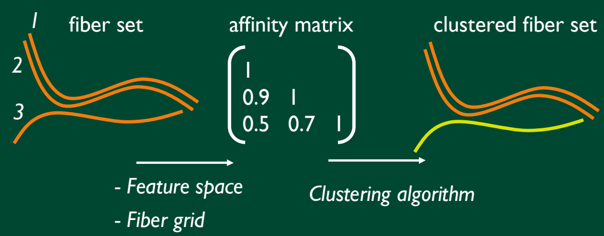


The perception of fiber tracts of the human brain can be improved by our novel clustering framework (implemented using MeVisLab[6]).

Spectral Fiber Clustering

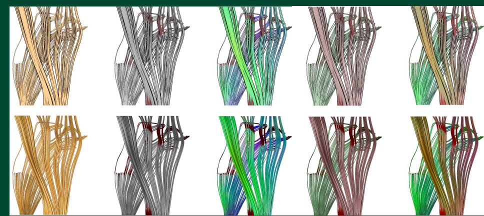
Using the affinity matrix A, our spectral algorithm (an extension of [4]) first determines its eigenvalues and eigenvectors, that, after a transformation, can easily be clustered by any hierarchical clustering method.

The number of clusters is automatically determined by our new eigenvalue regression. The idea is to perform a linear regression of the eigenvalues of the affinity matrix to find the point of maximum curvature in a list of descending order.



Enhancing Spatial Perception

The visualization of spatial relations and the separation of adjacent fibers becomes difficult when color is used to encode spatial and non-spatial properties.



Top row: non-photorealistic rendering, bottom row: streametubes.

We utilize and extend on non-photorealistic rendering techniques [5] to emphasize spatial depth and topology with only limited use of color. A new GPU-based hatching algorithm as well as distance-encoded, stroke-shadows improve the perception of spatial relations, such as curvature.

Conclusion

Our methods allow for an automatic and efficient visualization of white matter fiber tracts. Our spectral clustering provides a better understanding and perception of the anatomy. As an alternative to streamtube visualization, new algorithms for the spatially accentuated illustration of fibers have been developed so that color may be used to encode additional information.

[1] L. Ibanez et al. 2005. Hot topics in 3D medical visualization. SIGGRAPH 2005 tutorial.
[2] A. Brun et al. 2004. Clustering fiber tracts using normalized cuts. MICCAI, 368–375
[3] L. O'Donnell et al. 2006. A Method for Clustering White Matter Fiber Tracts. AJNR, 27(5), 1032–1036
[4] A. Ng et al. 2002. On spectral clustering: Analysis and an algorithm. NIPS, 849–856
[5] T. Strothotte et al. 2002. Non-Photorealistic Computer Graphics. Modeling, Rendering, and Animation. Morgan Kaufmann Publishers
[6] MeVisLab 1.4, www.mevislab.de