A robust Reeb graph model of white matter fibers

A Reeb graph-based approach discovers the branch and merge structure of the streamlines that unravels a topological understanding of white matter fibers.

Introduction

- Tractography generates billions of complex curvilinear fibers (streamlines).
- Streamlines are usually noisy, and in turn affect structural brain connectivity analysis.

Objective

- Problem: To model the bundling structures of streamlines.
- Solution: We propose a computational geometry approach using Reeb graphs.

Results

Reeb graph representation of major tracts from International Society for Magnetic Resonance in Medicine (ISMRM) dataset [4].

Runtime: CA (4s), CP(5s), SCP_L(21s), SCP_R(34s)

Complexity: $O(N \log N)$

Algorithm

Step 1: Processing trajectories $T_1, T_2, T_3, T_4$

Step 2: Computing Reeb graph:

We solve a subtrajectory clustering problem by maintaining a spatially dynamic graph $G$ representing the $\varepsilon$-connected relation.

Steps:
1. Construct dynamic graph $G$.
2. Find connected components in $G$.
3. Compute $R$.

Key idea: If a continuous portion of a set of fibers are “close”, they share a common anatomical behavior.

Robustness

$\varepsilon$ – distance between a pair of streamlines in a bundle that defines its sparsity

$\alpha$ – spatial length of the bundle that introduces persistence

$\delta$ – the bundle thickness

Applications

- Ranking, quantification, and comparing disease-relevant region of interests.
- Reeb graph skeletons for active diagnosis with increasing age and physiological changes in the brain.

Conclusion

- We present a computational model of spatial evolution of neuronal trajectories to encode the critical points of the pathways.
- Point correspondence of the critical coordinates in the 3D brain is an essential requirement of the tract-orientated quantitative analysis.

*Anterior Commissure (CA) *

*Posterior Commissure (CP) *

*Superior Cerebellar Peduncle (SCP-L, R) *

*Relevant brain regions for Alzheimer’s Disease show severe decrements in the fiber density (ROIs marked with *).*

References


shailja@ucsb.edu

RAMI/UCSB-VRL/ReebGraph

We would like to thank Vikram Bhagavatula and Angela Zhang for their insightful discussion on the research project. This research was supported by NSF award: SSI # 1664172.