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A Digital Topology Framework for High-Resolution Brainstem MRI Reconstruction, Automated Segmentation, and Clinical Neuro-Diagnostics

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Abstract

High-resolution Magnetic Resonance Imaging (MRI) of the human brainstem is critical for the early diagnosis and tracking of neurodegenerative and psychiatric disorders. However, due to its small size, deep anatomical location, and susceptibility to physiological motion artifacts, reconstructing and segmenting brainstem structures often introduces geometric distortions and pixel-level noise that can obscure vital clinical pathways. To address these computational challenges, this study introduces a novel image processing framework based on digital topology to enhance multi-contrast MRI reconstruction and structural connectivity analysis.

In this presentation, we focus on leveraging digital metric spaces and topological data analysis to establish robust, connectivity-preserving algorithms for brainstem MR image reconstruction at the software level. We will demonstrate how these topological invariants can be integrated into automated image post-processing workflows to achieve high-fidelity segmentation of complex subcortical nuclei and maintain topological consistency during multi-modal data standardization. Furthermore, we discuss the clinical translation of this framework, showing how topological feature extraction can serve as a non-invasive, quantitative biomarker to detect subtle structural alterations in clinical neuro-diagnostics. By bridging pure mathematical topology with advanced neuroimaging and clinical practice, this framework provides a scalable computational foundation to enhance the precision of brainstem health assessments.

***K*eywords** Digital Topology · Brainstem MRI

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