Topology-Aware Learning of Tubular Manifolds via SE(3)-Equivariant Network on Ball B-Spline Curve Supplementary Material

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Abstract

This section serves as the supplementary material to the full paper, providing additional details for the Circle of Willis (CoW) case study that is not fully covered in the main text. We present a brief analysis of several representative samples selected from the test set of SE(3)-BBSCformerGCN, focusing on cases where the model makes prediction errors and which exhibit notable topological heterogeneity.

A Case Study

We conduct a case study on Circle of Willis (CoW) clinical data collected from a collaborating medical institution, focusing on samples where SE(3)-BBSCformerGCN makes prediction errors and which exhibit certain topological heterogeneity. As shown in Figure 1, the first row presents a complete CoW structure, a configuration that only accounts for about 20%–25% of real-world cases. In the remaining samples with topological variations, most commonly observed is the absence of the bilateral posterior communicating arteries (PcoA-L and PcoA-R), which connect the upper and lower parts of the CoW. In the fourth row, a more severe case of unilateral absence is observed.

Beyond topology, geometric heterogeneity within the same type of branch also poses challenges. For instance, the MCA-L2 branch highlighted in green in the third row is noticeably longer than its counterparts in other samples, while the ICA-R1 branch in the fourth row, marked in ochre, is significantly thicker than in the other cases. Such variations in both topology and geometry contribute to the clinical difficulty of accurately classifying CoW branches.

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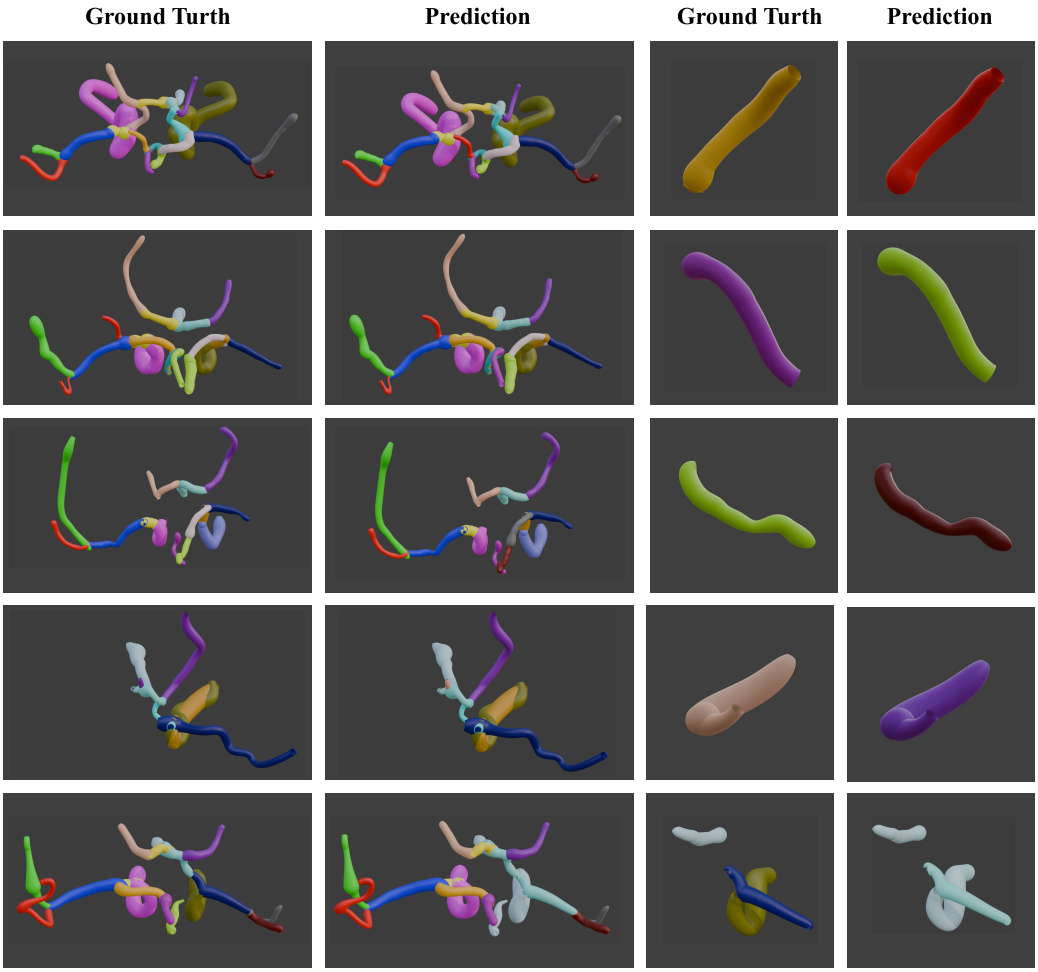

Figure 1: Clinical CoW samples with topological heterogeneity and the corresponding mispredicted structures by SE(3)-BBSCformerGCN. The first two columns show the complete CoW structures, while the last two columns highlight the misclassified branches.