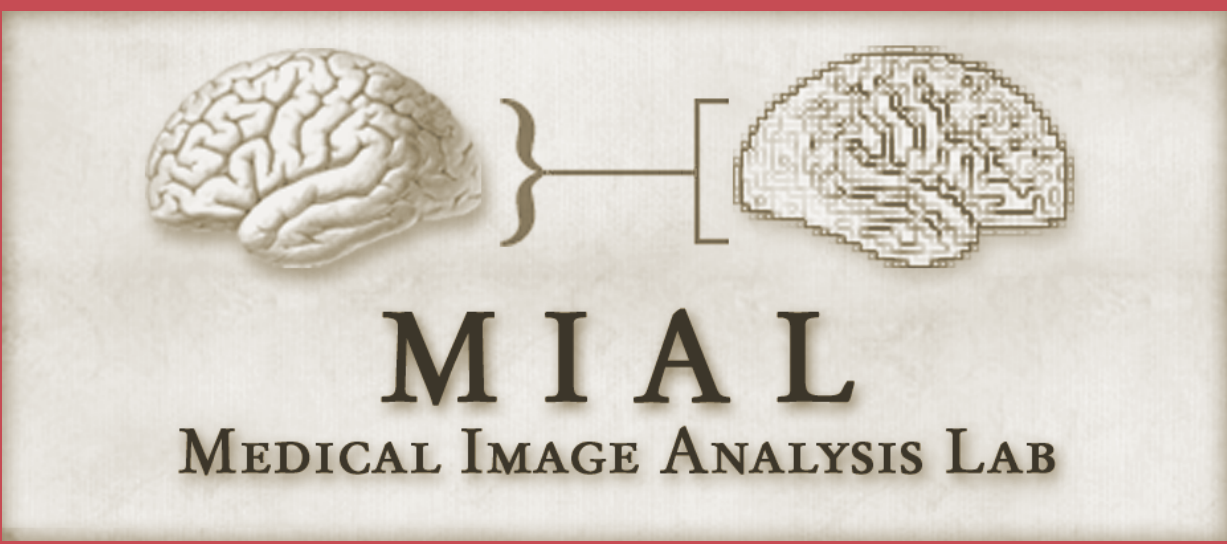




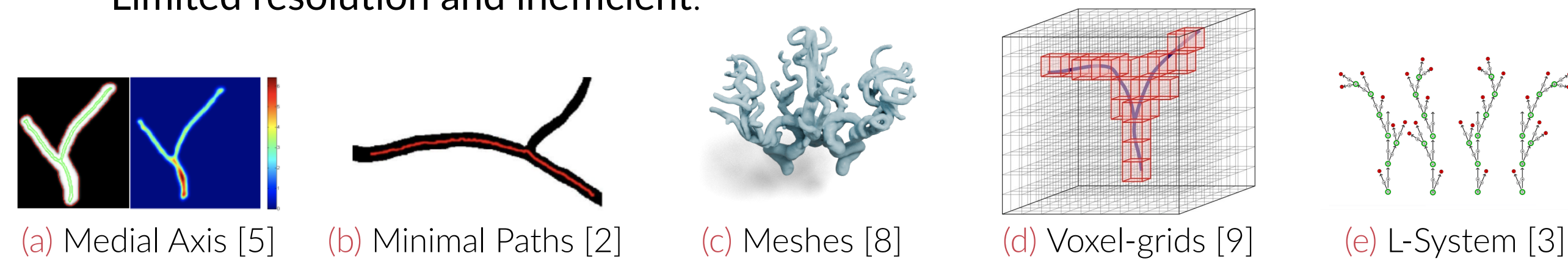
Representing Anatomical Trees by Denoising Diffusion of Implicit Neural Fields

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Motivation

- Anatomical trees are **ubiquitous**, eg., brain vessels and airways. Important for clinical diagnosis and surgical planning.
- Difficult to represent. Varying and **complex topology and geometry**.
- Traditional medical imaging methods. **Limited resolution and inefficient**.



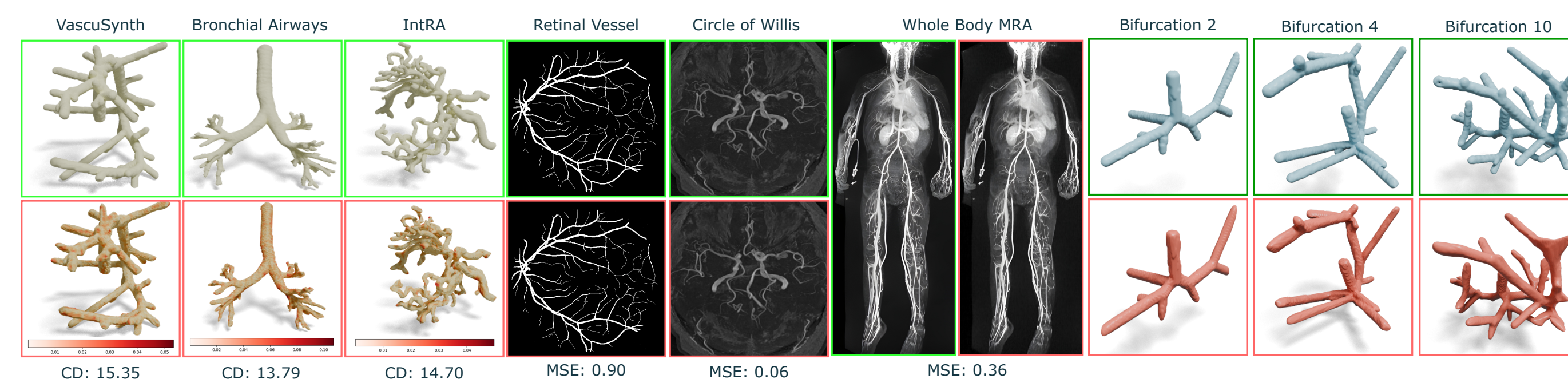
Goal

Represent anatomical trees accurately and efficiently using implicit neural representations (INRs), and learn a distribution of trees using denoising diffusion on the space of INRs.

Contributions

- First work to represent complex anatomical trees with INRs.
- First work to utilize INRs for segmenting tree-structure from medical images.
- First work to perform diffusion on the space of INR-represented trees for learning tree distributions and generating plausible novel trees with complex topology.
- Demonstrate adaptability across trees of different dimensions, complexities, and anatomy.
- Qualitatively and quantitatively evaluate representation compactness and reconstruction accuracy at high resolutions.

Versatility across modalities (2D/3D/CT/MRI), organs & complexities



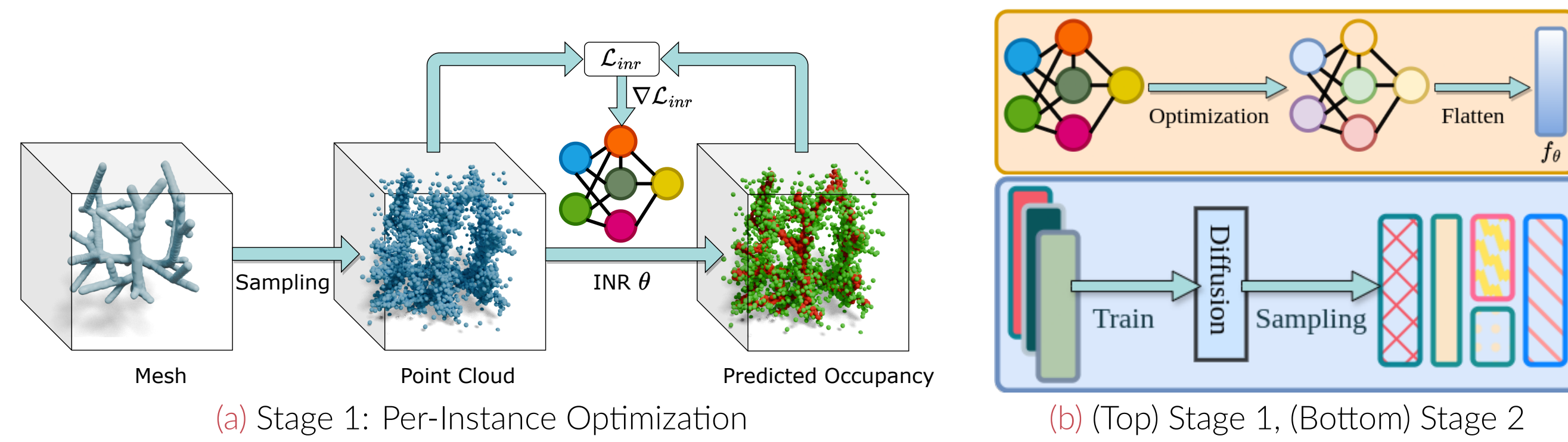
Quantitative Results

Modality	Rel. Error (%)	Input Size (MB)	INR Size (MB)	Metric	Value
DRIVE (RGB) [7]	0.018	0.37 ± 0.0055	$0.066 \downarrow \times 5.60$	MMD $\downarrow$	13.36 ± 8.37
DRIVE (Mask) [7]	1.204	0.02 ± 0.0013	$0.003 \downarrow \times 6.60$	COV $\uparrow$	0.46 ± 0.11
BraTS [4]	0.039	68.11 ± 0.00	$0.753 \downarrow \times 90.45$	1-NNA (%) $\downarrow$	87.49 ± 8.99
HAN-Seg [6]	5.627	12.1 ± 1.55	$0.630 \downarrow \times 19.20$		

Representing tree structures across medical imaging modalities with INRs.

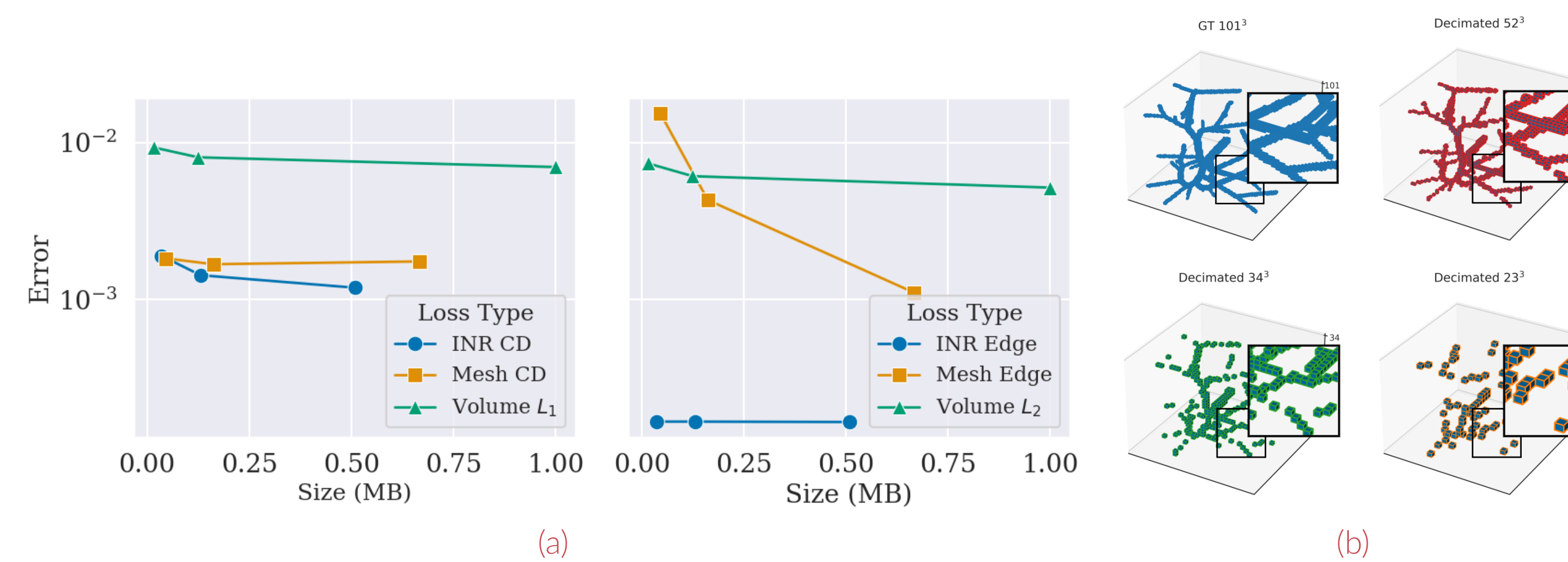
Novel tree generation on VascuSynth dataset.

Methodology



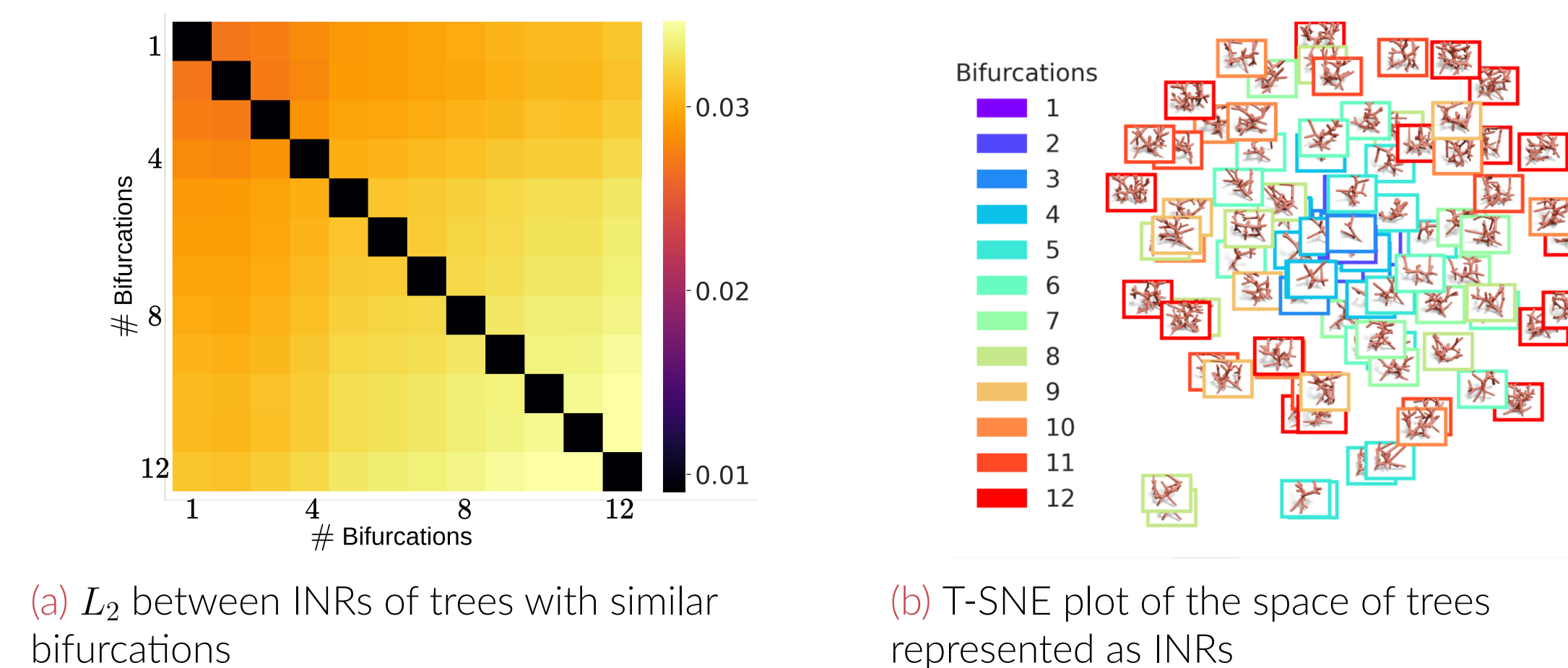
(a) Given a 3D mesh, optimize an INR for occupancy (i.e., inside/outside). (b) Model diffusion process on flattened vectors of optimized INRs to learn the data distribution, and sample novel INRs during the reverse diffusion process.

Compression vs Reconstruction Accuracy of INRs/Meshes/Volumes



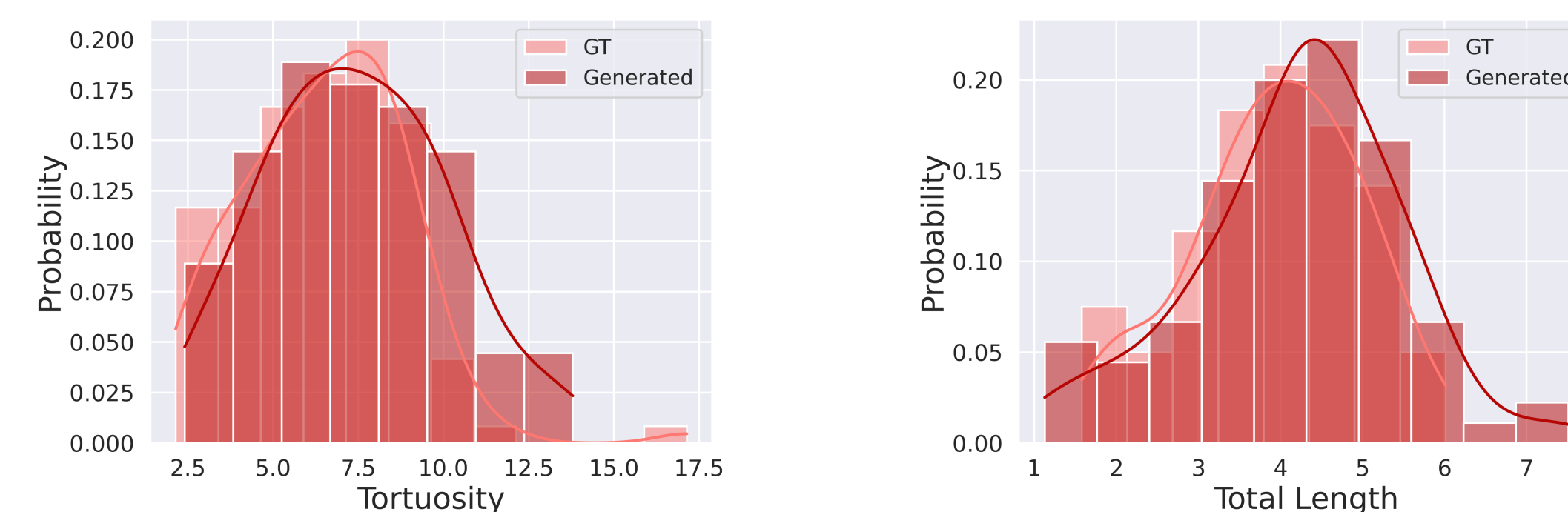
(a) For approx. the same memory space, meshes and volumes have higher reconstruction error w.r.t INRs. (b) Notice the disconnected components in low-res volumes.

Tree Statistics: Do INRs have an understanding of the underlying signal?

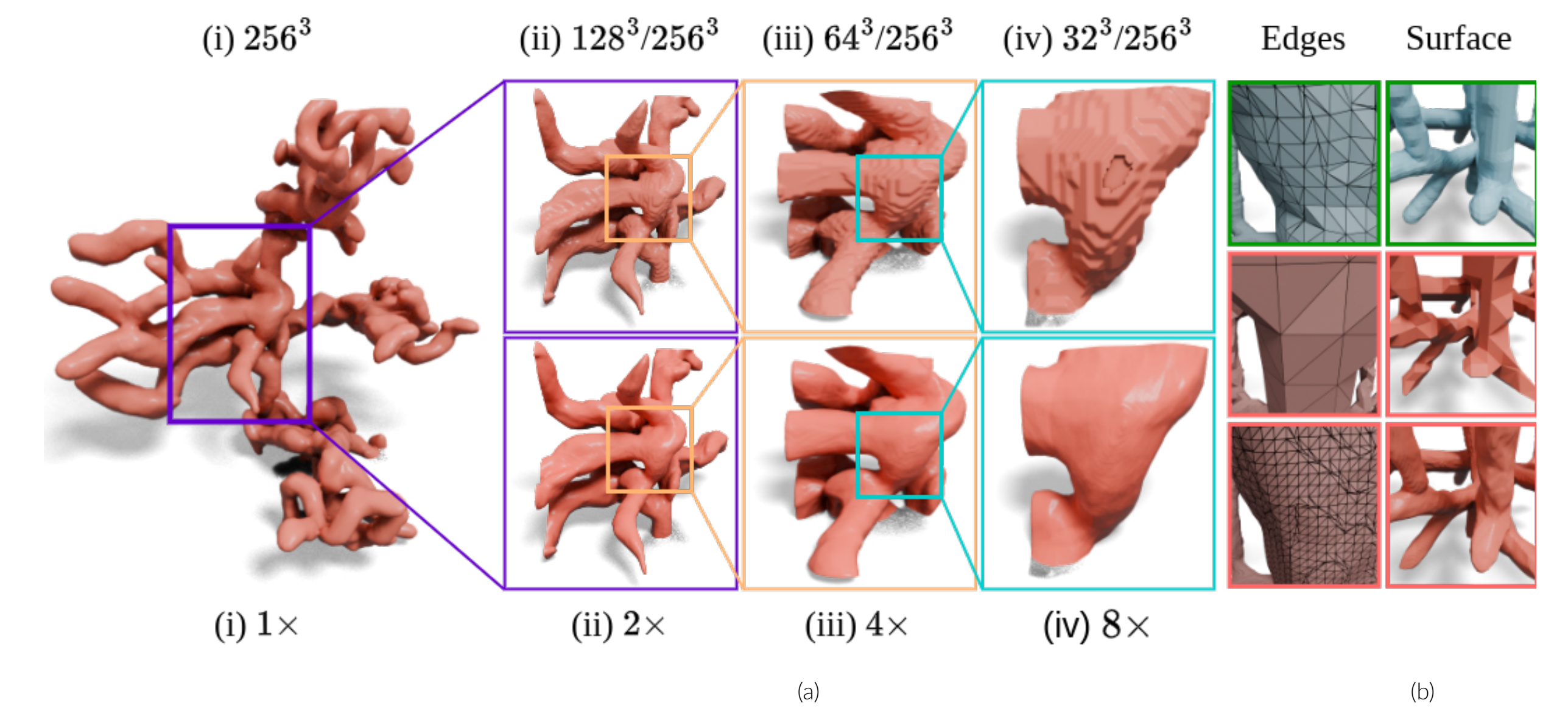


(a) L_2 between INRs of trees with similar bifurcations

(b) T-SNE plot of the space of trees represented as INRs

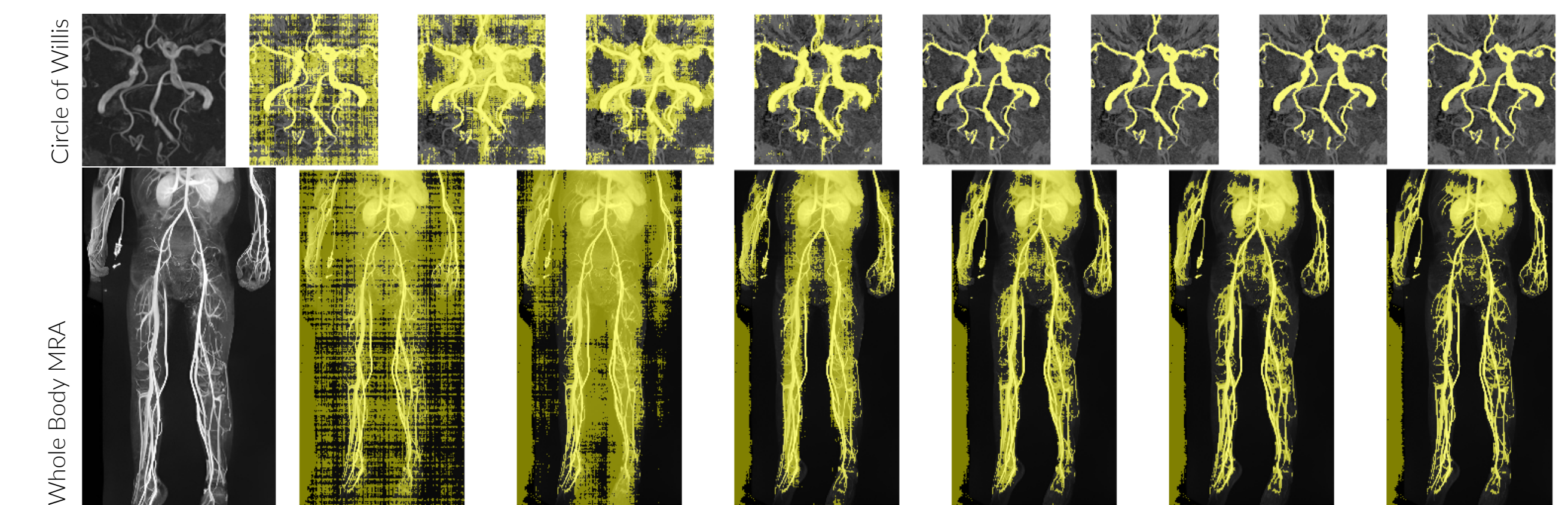


Arbitrary Resolution: Volumetric grids vs INRs



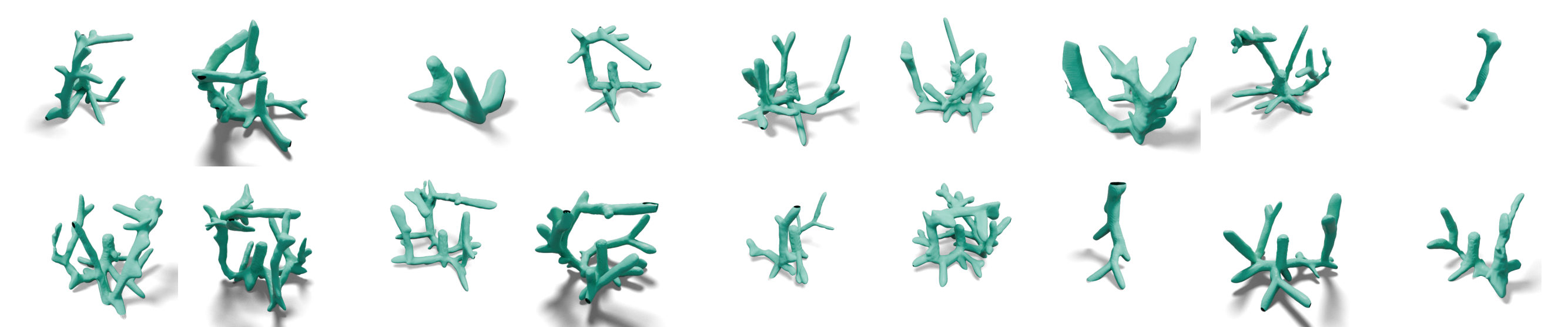
(a) Comparison of 2x, 4x, and 8x zoom. (b) Zoomed-in regions of a mesh reconstructed from INRs and ground truth at different mesh resolutions.

INR-based Image Segmentation



Similar to Mumford-Shah based segmentation [1], we use a piecewise-constant version of the INR to perform segmentation during optimization.

Tree Synthesis using Denoising Diffusion



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