

Two-Level Transfer Functions Using t-SNE for Data Segmentation in Direct Volume Rendering



Sangbong Yoo¹, Seokyeon Kim², and Yun Jang³

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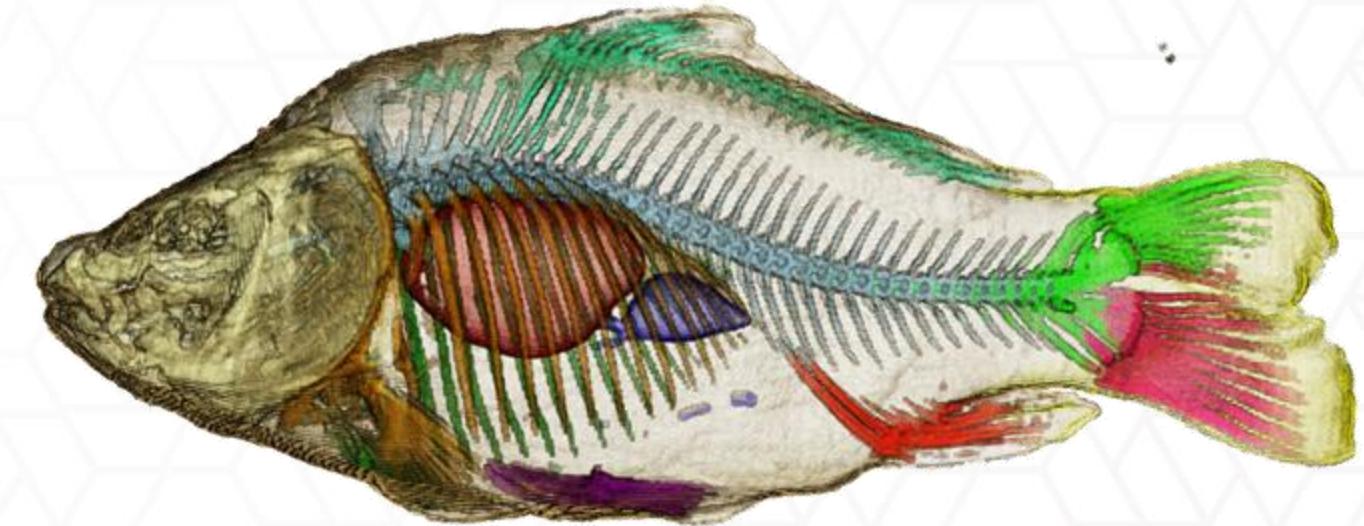
¹ Korea Institute of Science and Technology (KIST), Seoul, South Korea

² Hyundai Glovis, Seoul, South Korea,

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Data Visualization Lab



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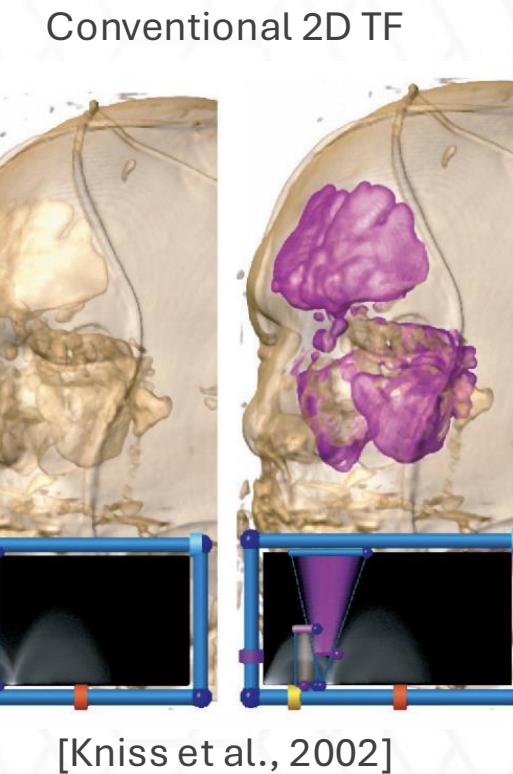
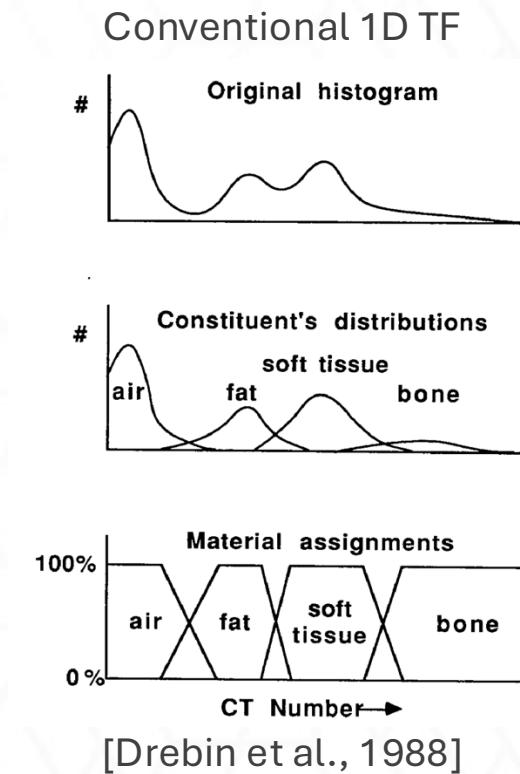
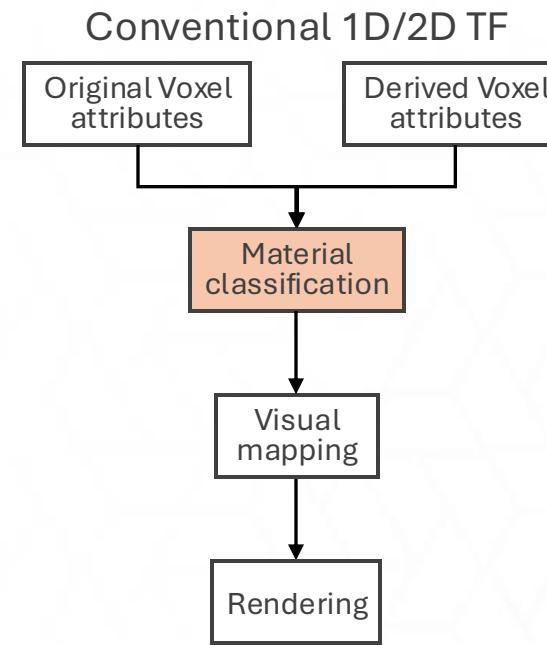
Data Visualization Lab

Today, What We Talk

- Why separating voxel features is challenging
- How “Two-Level Transfer Functions” works ($2D\ TF \rightarrow t\text{-SNE}\ TF$)
- Volume rendering using two-level TFs
- Limitations & future work

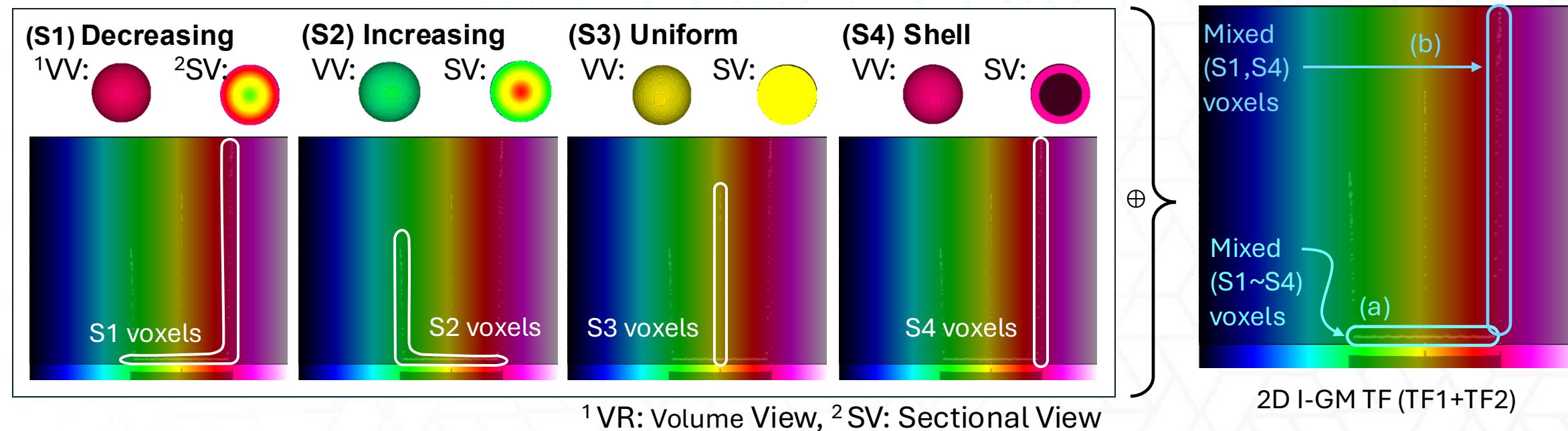
Conventional Transfer Function (TF)

- Voxel selection on histograms for material classification
- Conventional TFs: Histogram TF, I-GM TF, LH histogram, etc.



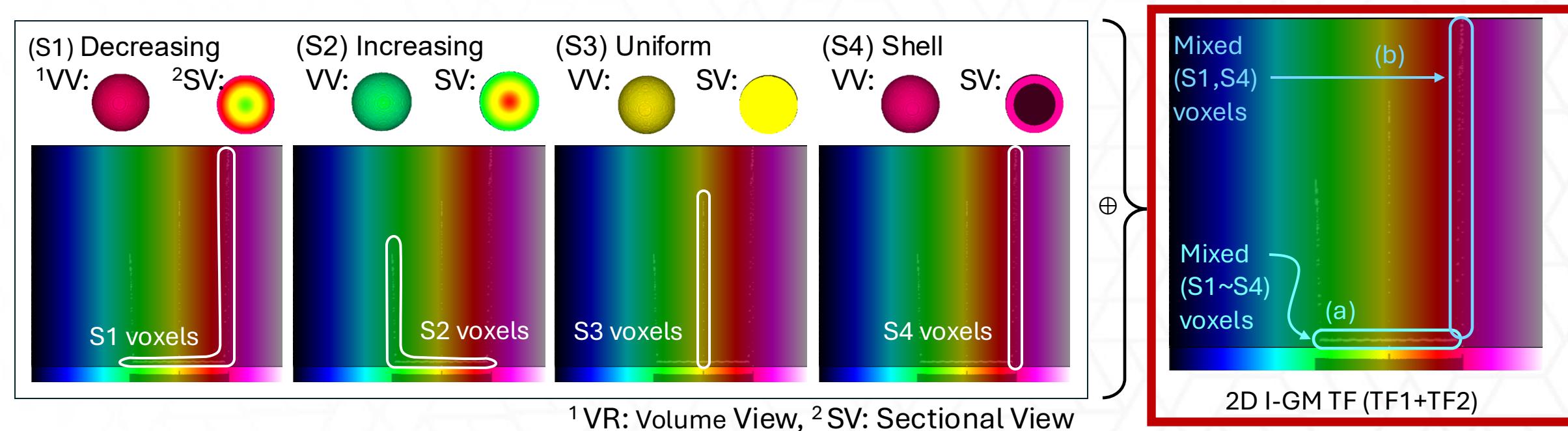
Limitations of Conventional TFs

- Voxel distributions of the sphere dataset in the 2D I-GM TFs
- Four sphere types representing different intensity distributions
-



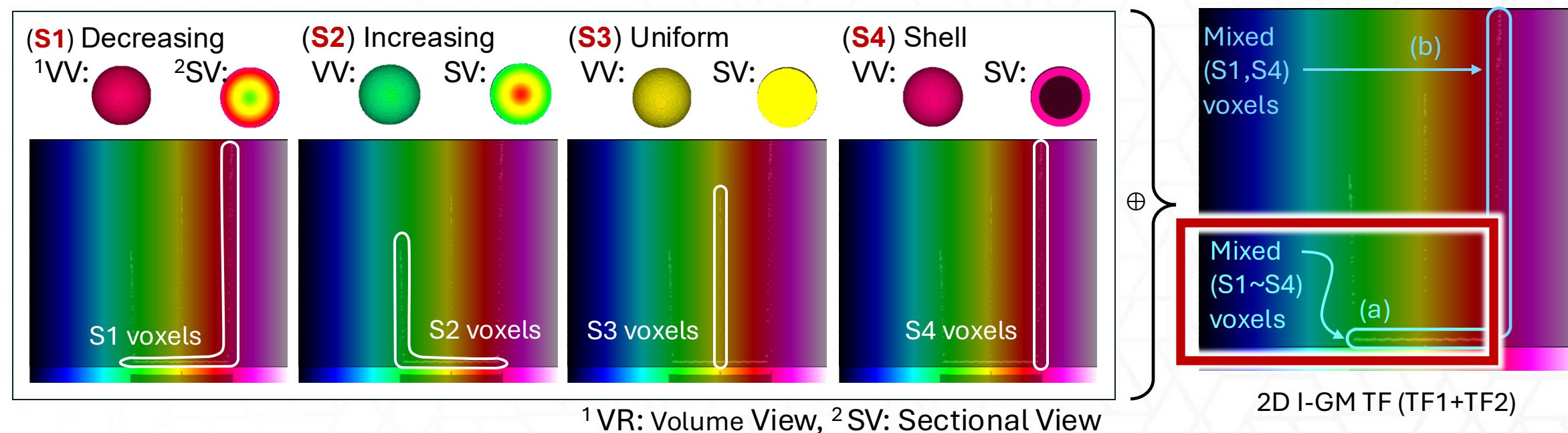
Limitations of Conventional TFs

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- Individual spheres indistinguishable in 2D I-GM TF:
 - (a): mixed voxels from S1–S4, (b): mixed voxels from S1 and S4



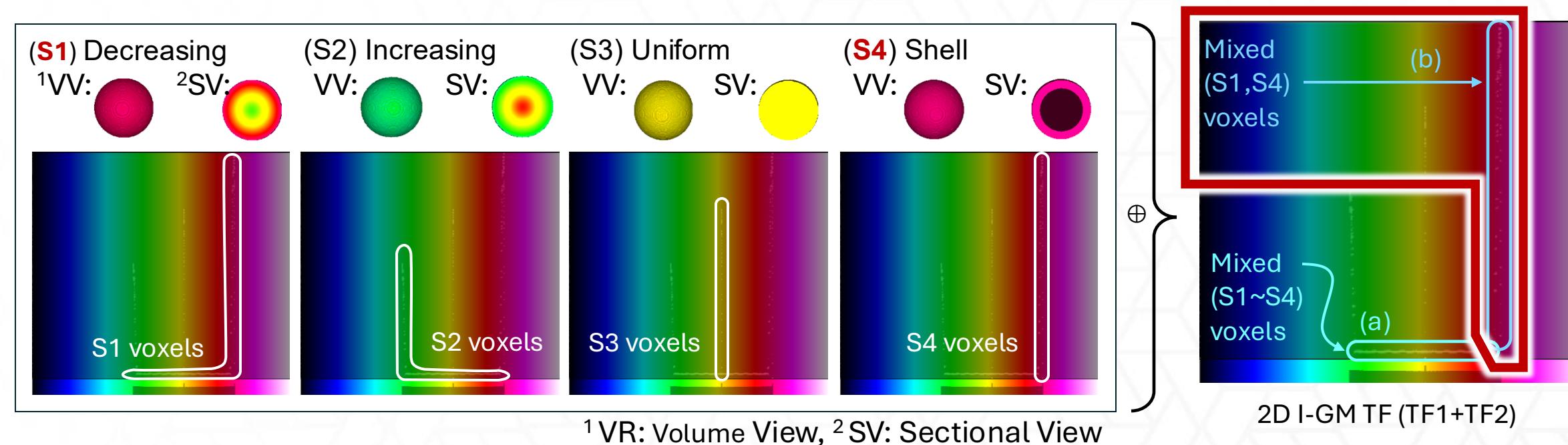
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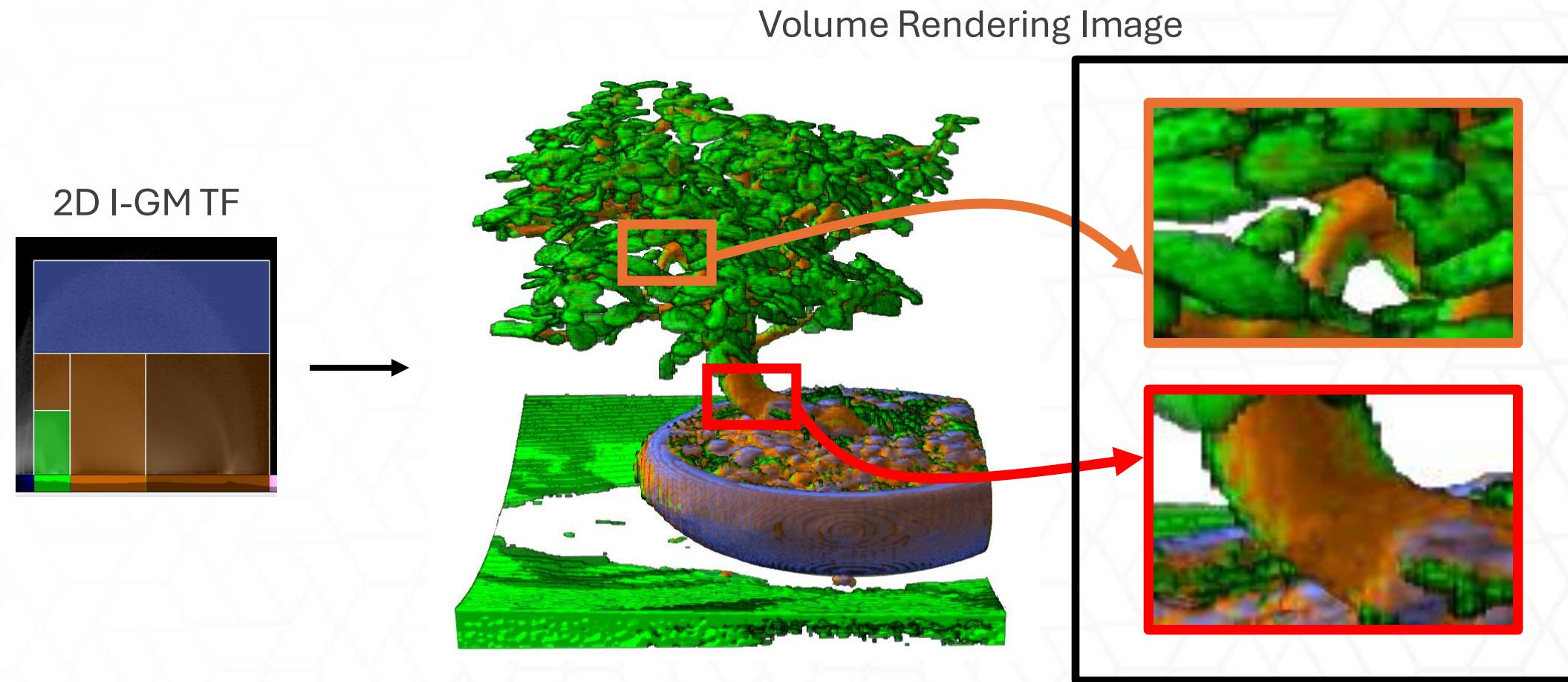
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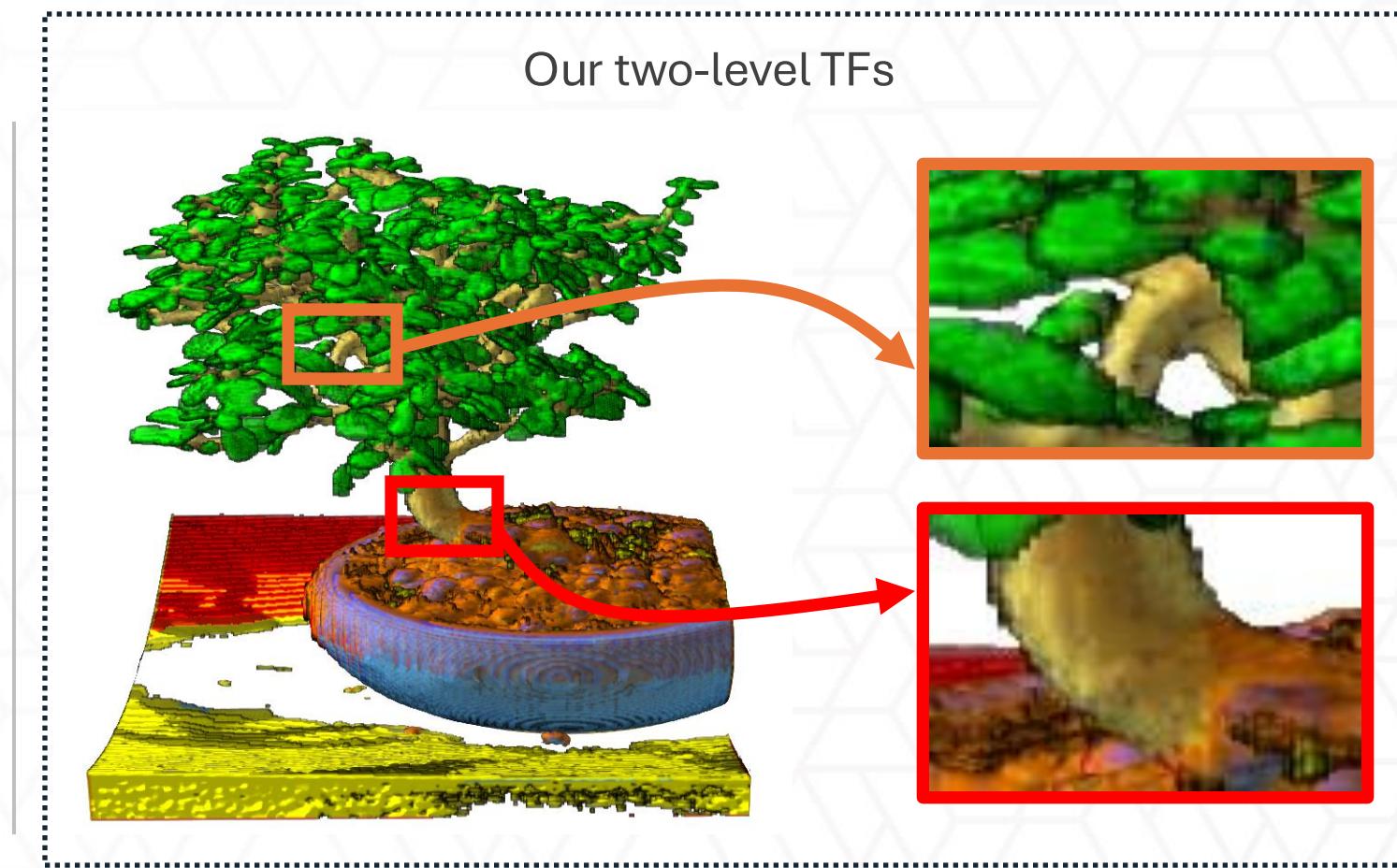
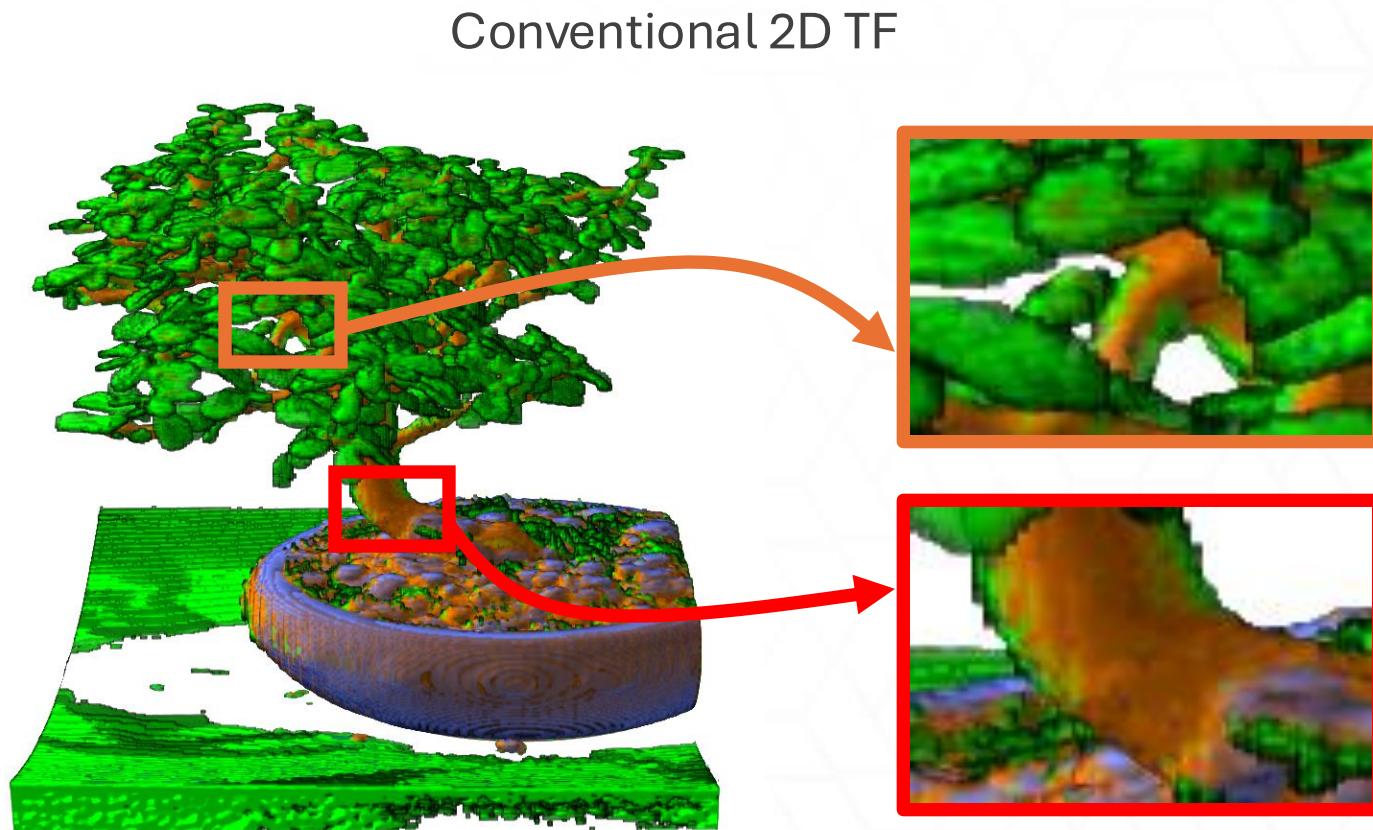
Limitations of Conventional TFs

- Voxel feature segmentations in 2D I-GM TF
- Overlapping voxel features in highlighted (**brown/red**) regions



What We Want

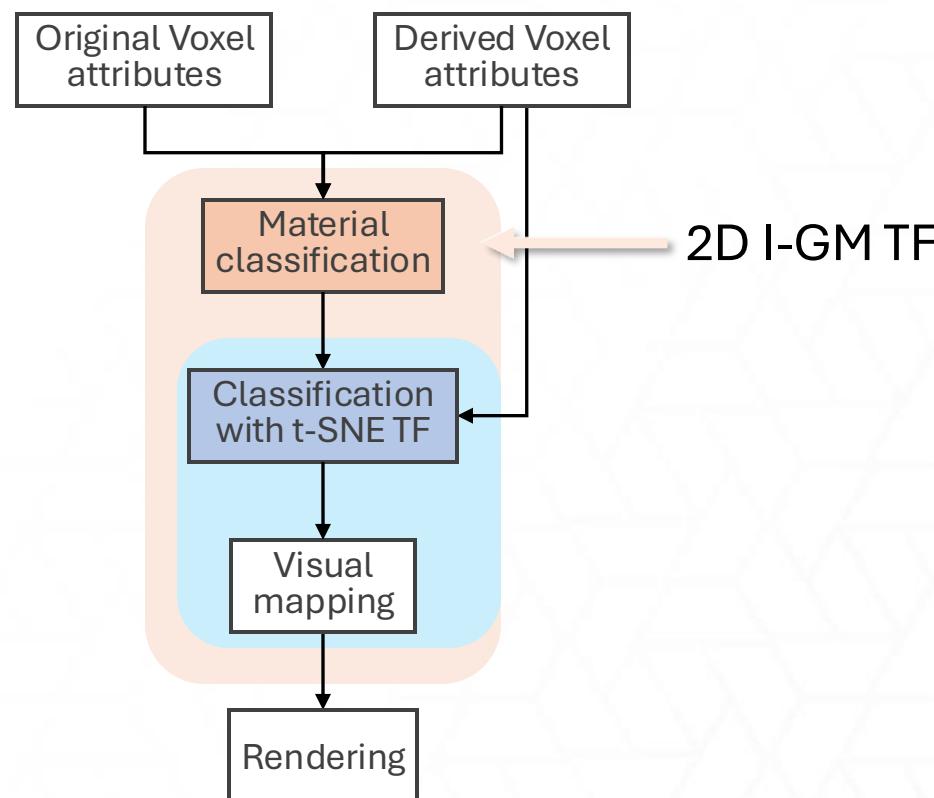
- Clear feature separation and visually distinguishable boundaries



How We Address the Limitations

- Two-level transfer function combining 2D I-GM TF and t-SNE
-

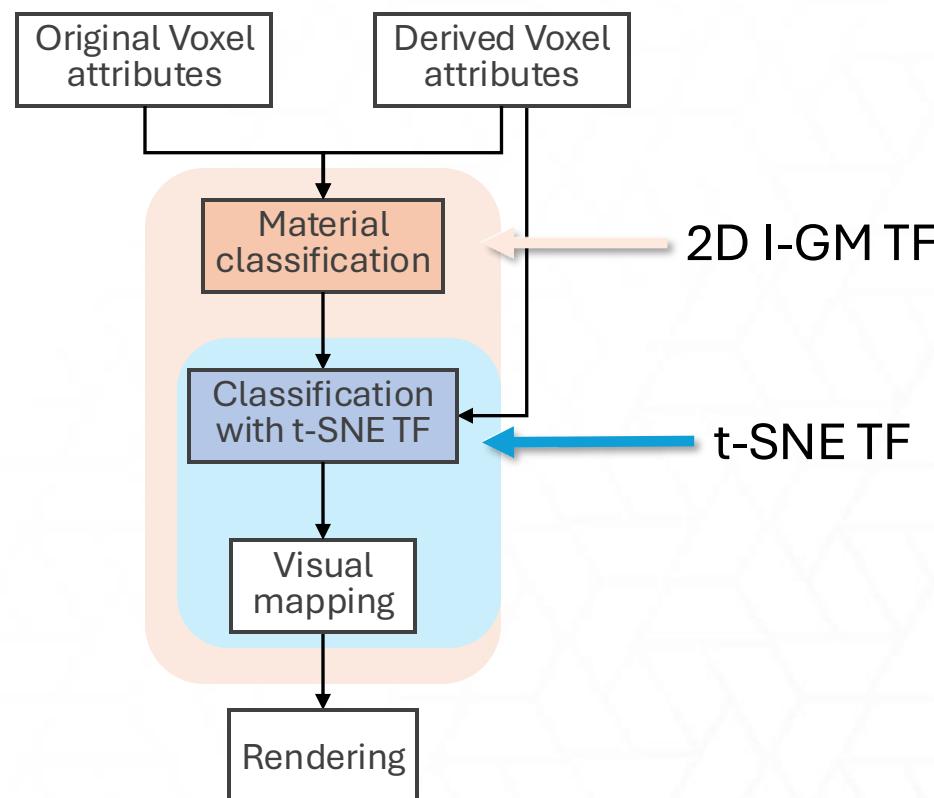
Our Two-Level TFs



How We Address the Limitations

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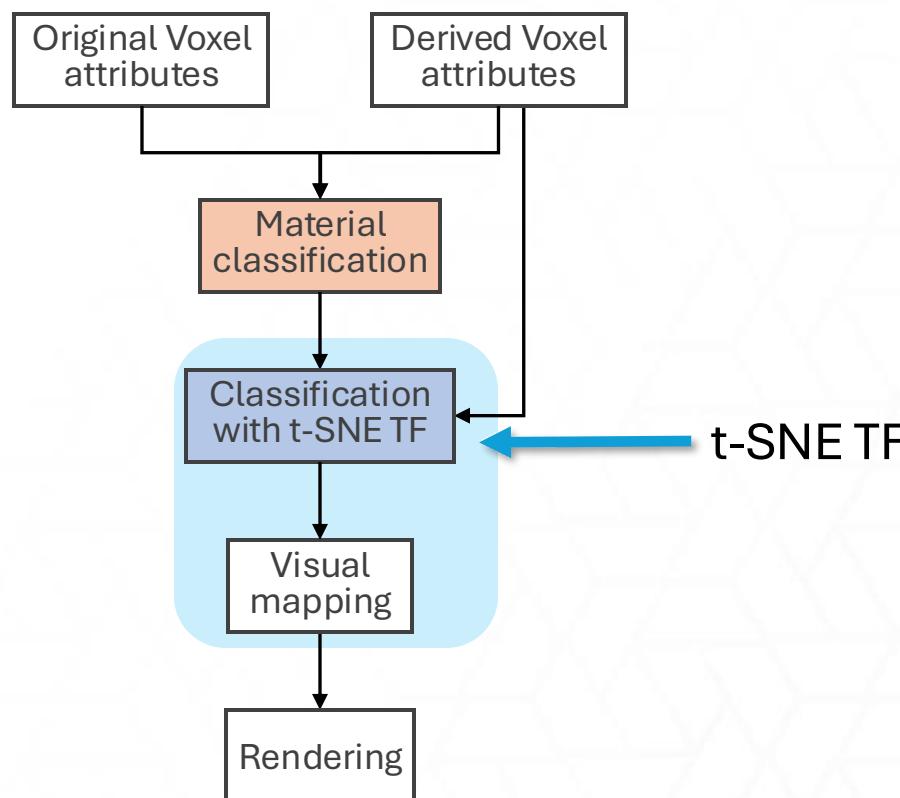
Our Two-Level TFs



How We Address the Limitations

- Two-level transfer function combining 2D I-GM TF and t-SNE
- Multidimensional voxel attributes for t-SNE TF generation

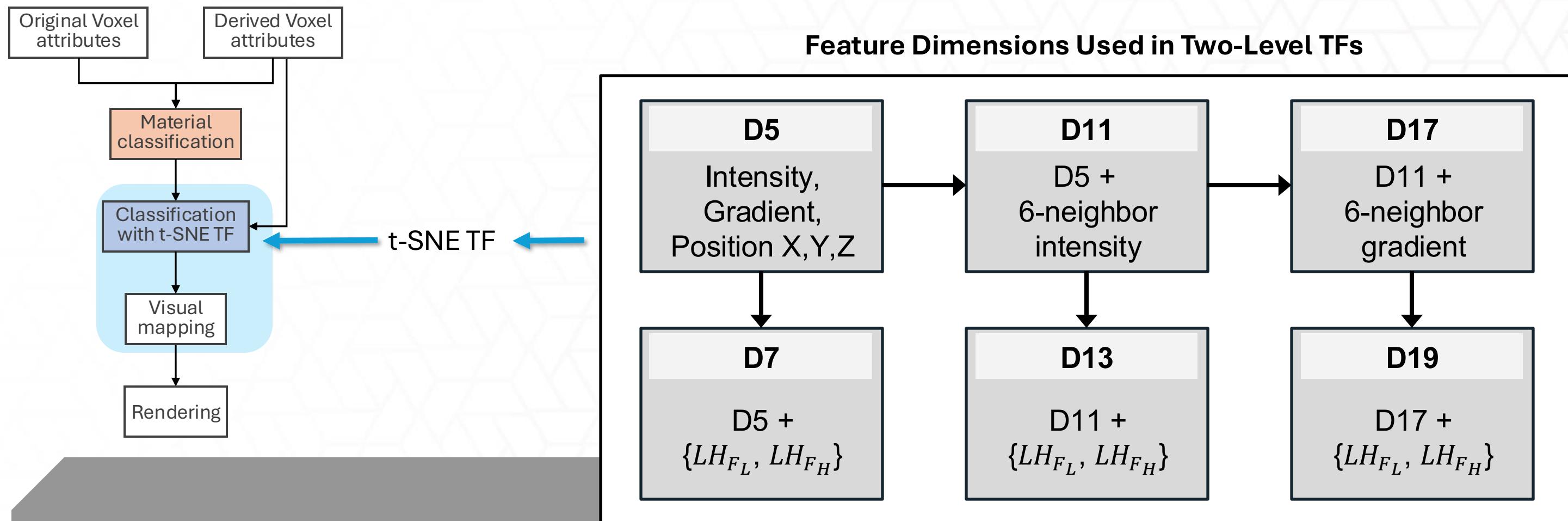
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How We Address the Limitations

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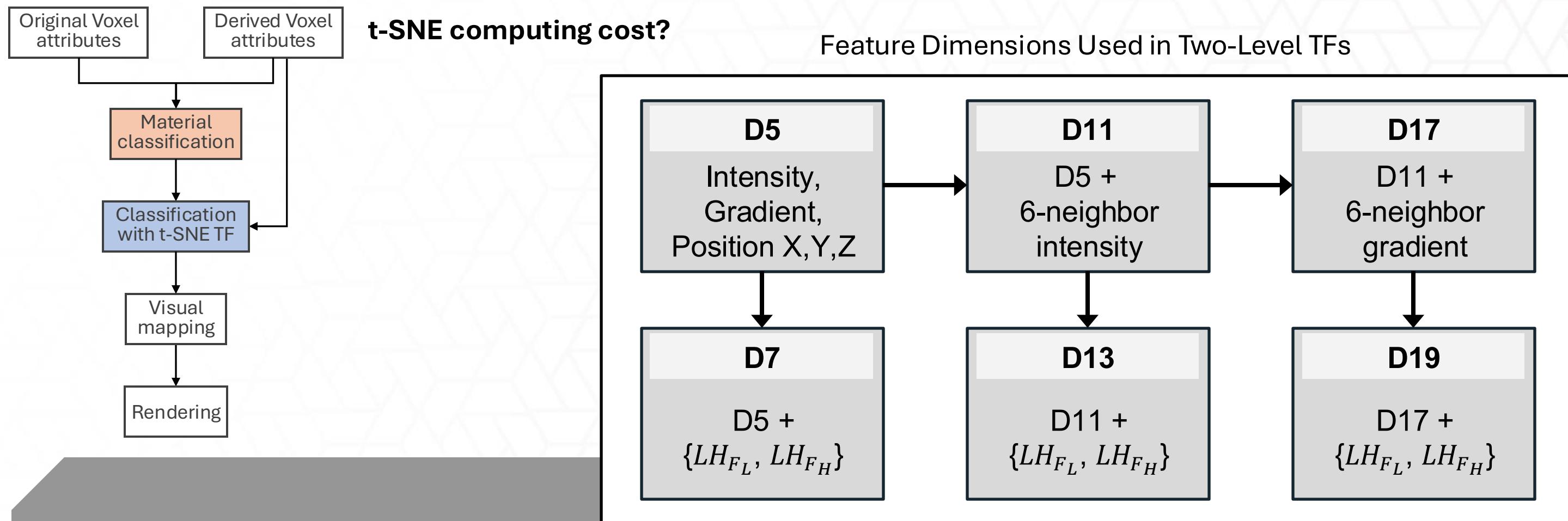
Our Two-Level TFs



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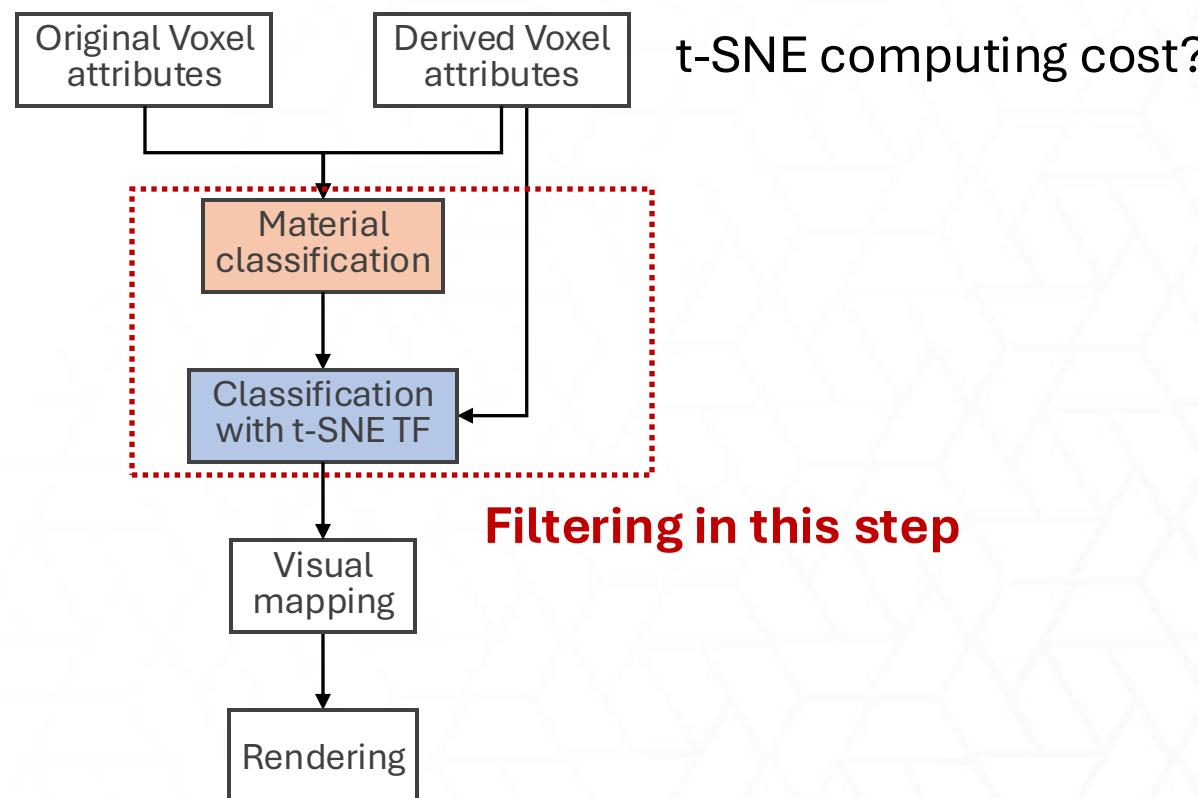
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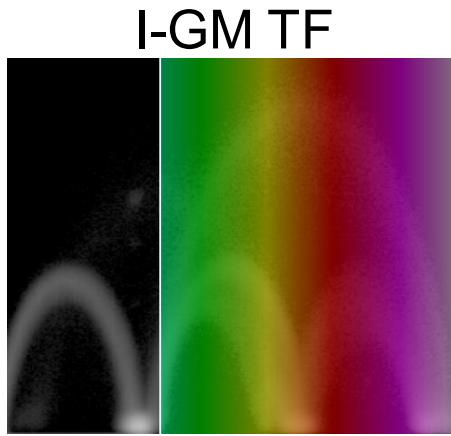
Our Two-Level TFs



Workflow of Two-Level TFs using t-SNE

- Step 1: I-GM TF Filtering and t-SNE Generation

Step 1: I-GM TF Filtering



Volume View

t-SNE TF

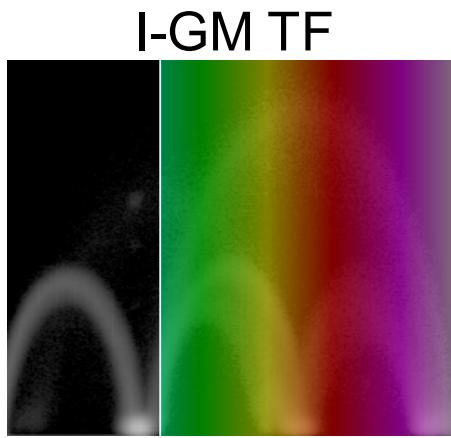
Sectional View

Step 2: Fine-tuning t-SNE TF

Workflow of Two-Level TFs using t-SNE

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Volume View

t-SNE TF

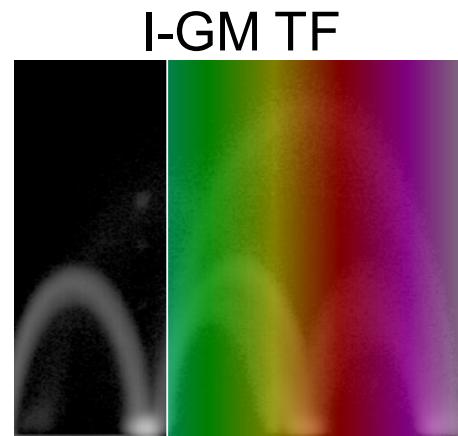
Sectional View

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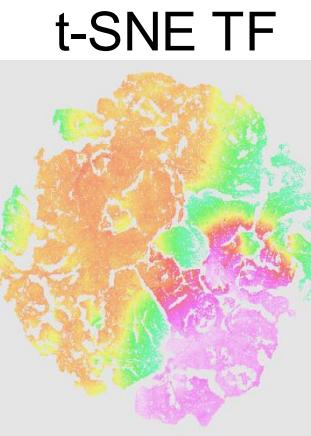
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Volume View



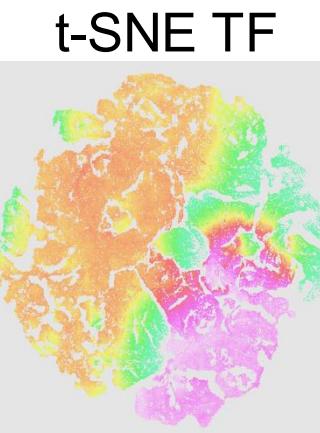
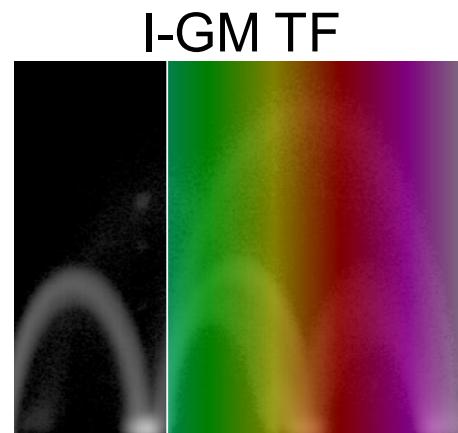
Sectional View

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Workflow of Two-Level TFs using t-SNE

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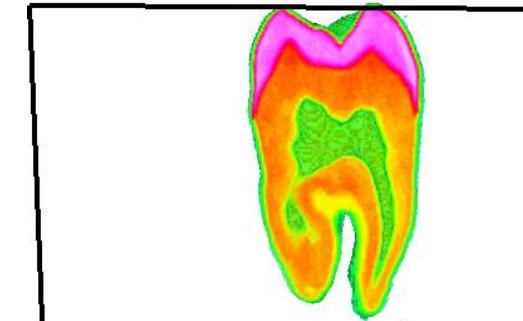
Step 1: I-GM TF Filtering



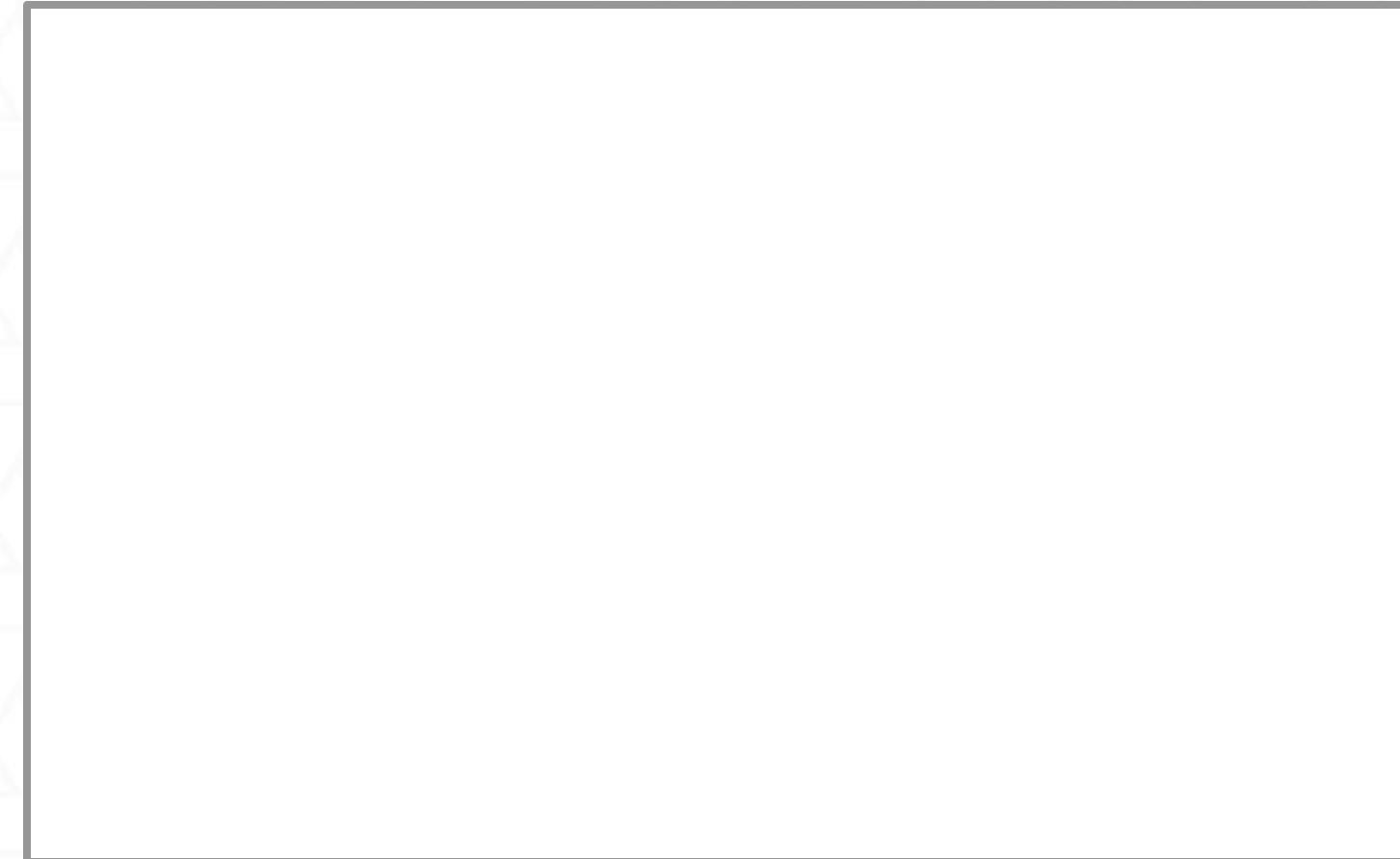
Volume View



Sectional View



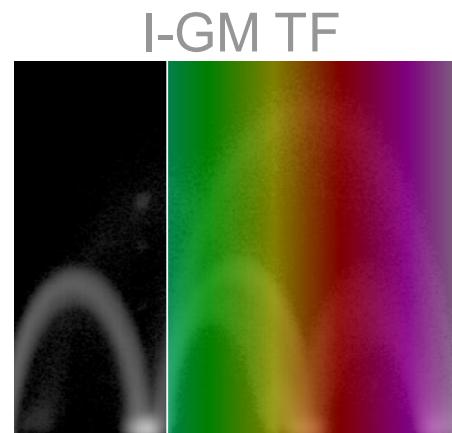
Step 2: Fine-tuning t-SNE TF



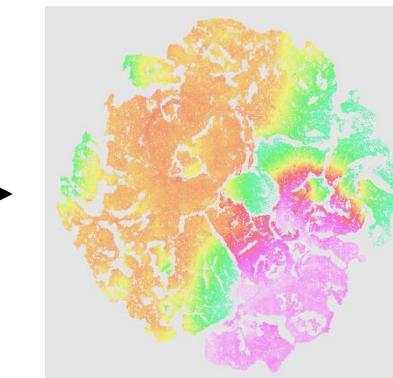
Workflow of Two-Level TFs using t-SNE

- Step 2: Fine-tuning t-SNE TF

Step 1: I-GM TF Filtering



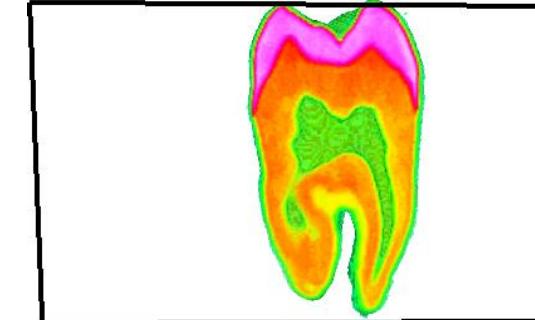
t-SNE TF



Volume View



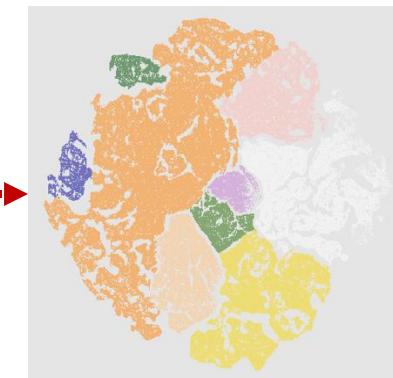
Sectional View



Step 2: Fine-tuning t-SNE TF

Fine-Tuning

t-SNE TF



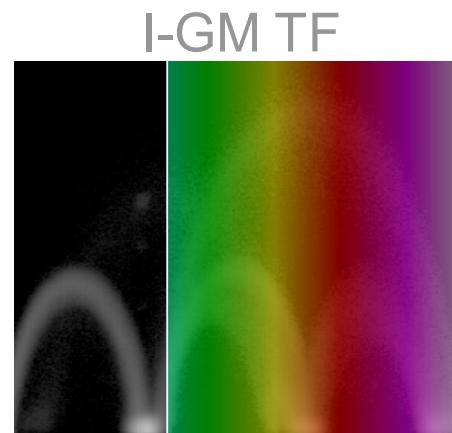
Volume View

Sectional View

Workflow of Two-Level TFs using t-SNE

- Step 2: Fine-tuning t-SNE TF

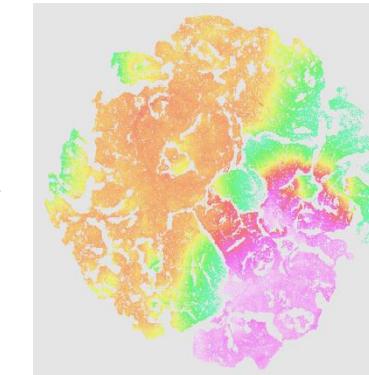
Step 1: I-GM TF Filtering



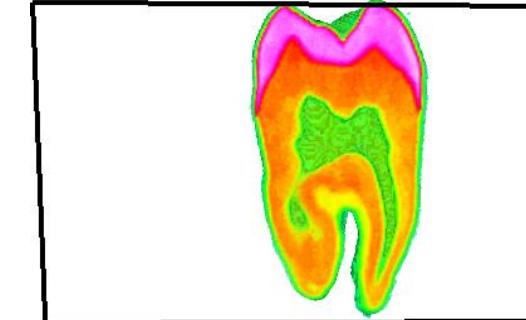
Volume View



t-SNE TF



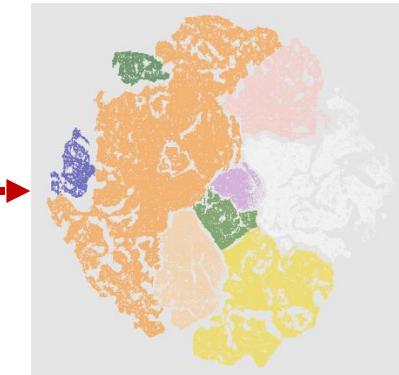
Sectional View



Step 2: Fine-tuning t-SNE TF

Fine-Tuning

t-SNE TF



Volume View

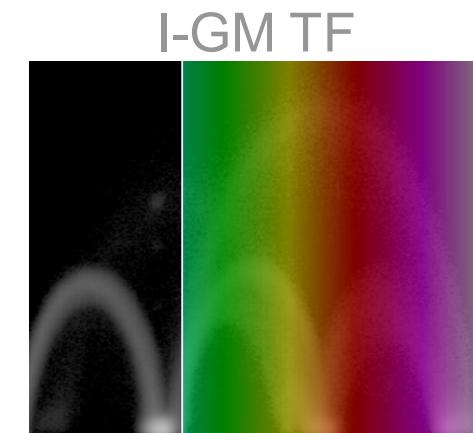


Sectional View

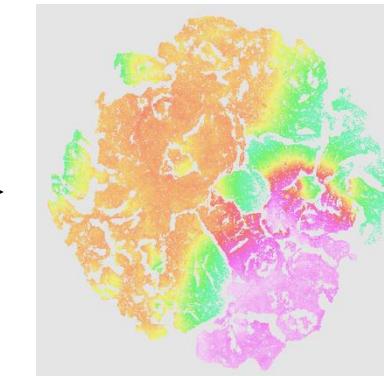
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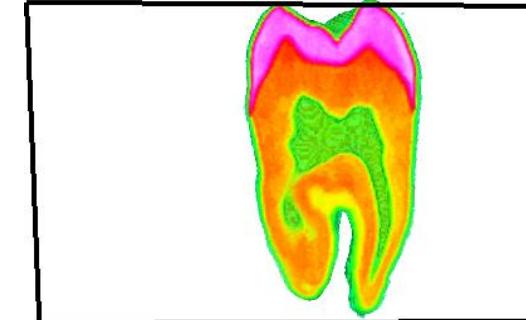
t-SNE TF



Volume View



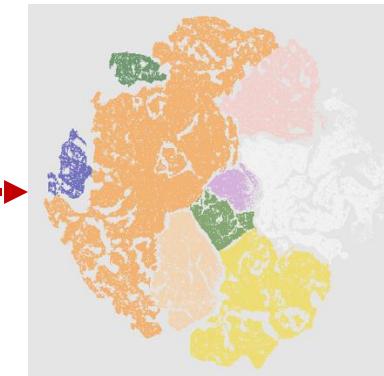
Sectional View



Step 2: Fine-tuning t-SNE TF

Fine-Tuning

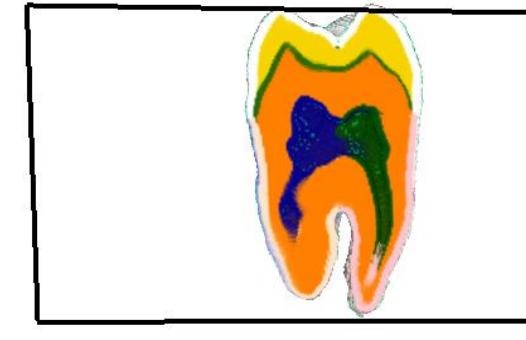
t-SNE TF



Volume View

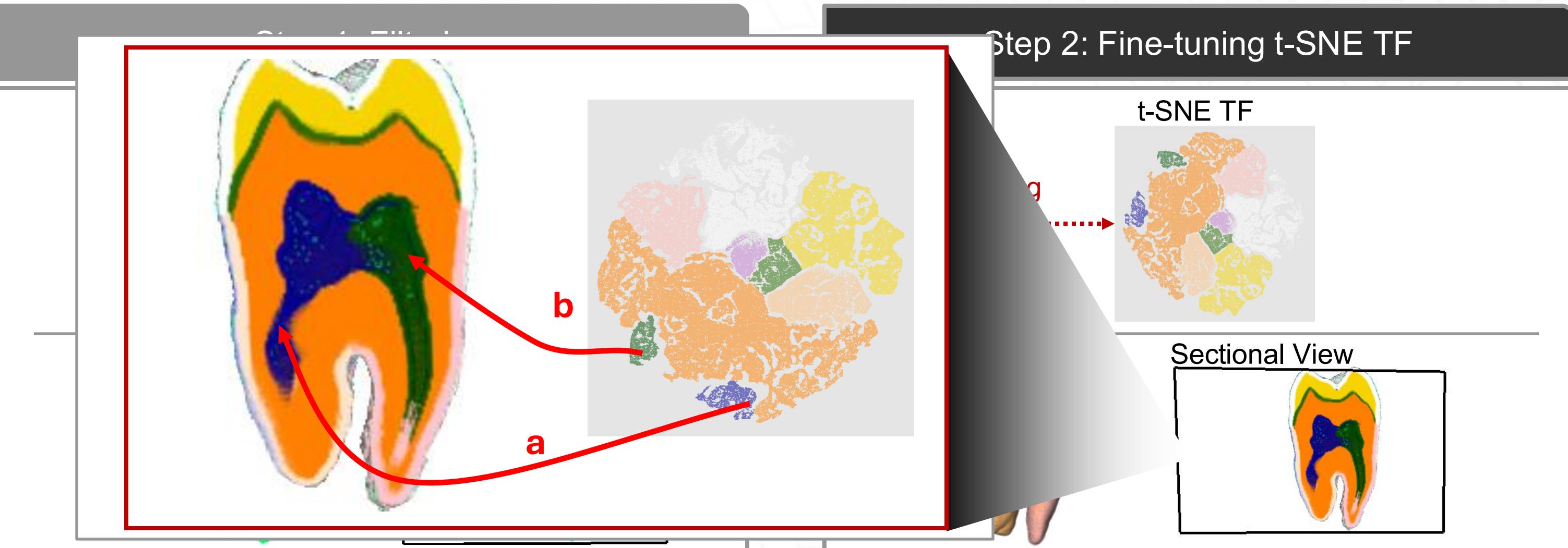


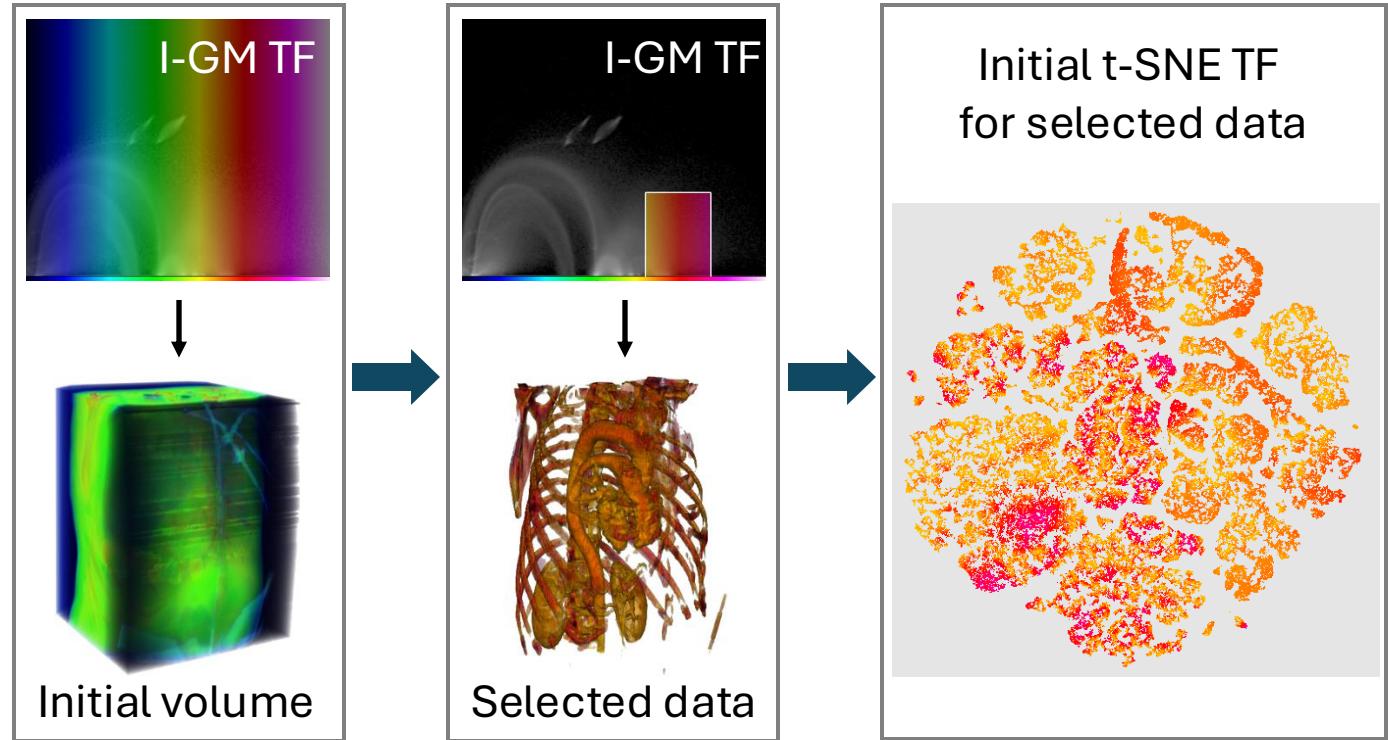
Sectional View



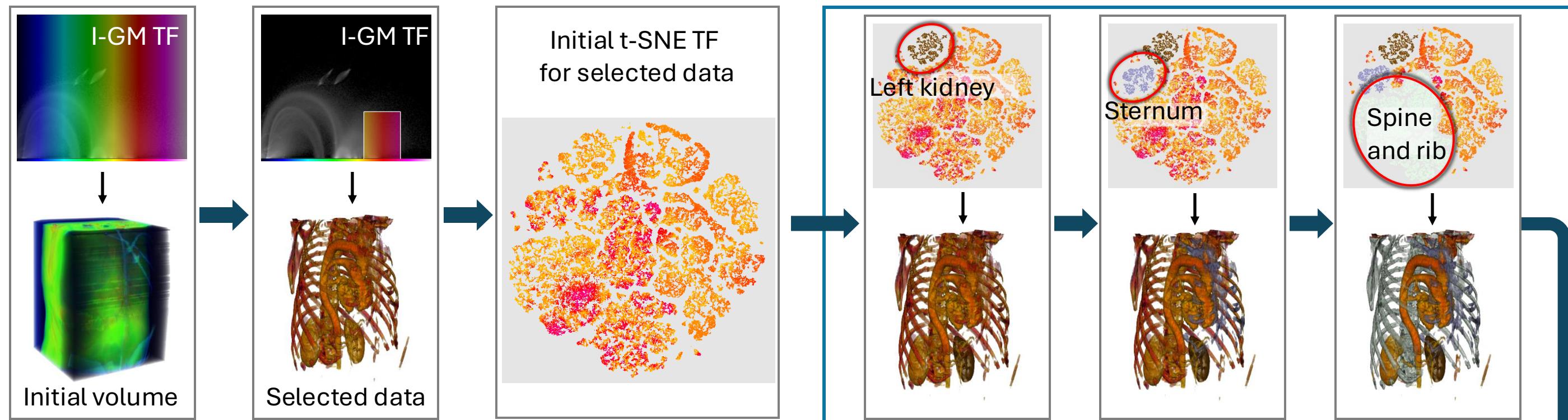
Workflow of Two-Level TFs using t-SNE

- Step 2: Fine-tuning t-SNE TF



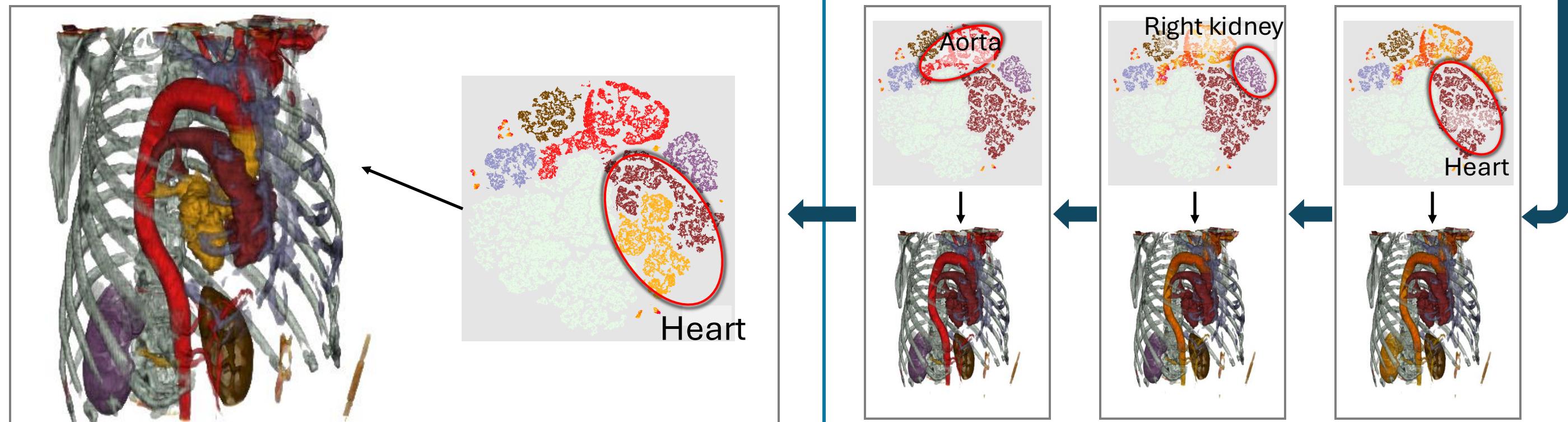


Step 1: Data filtering in 2D I-GM TF



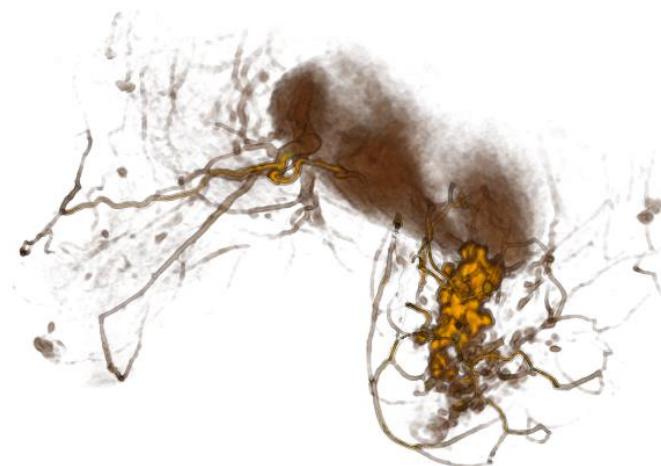
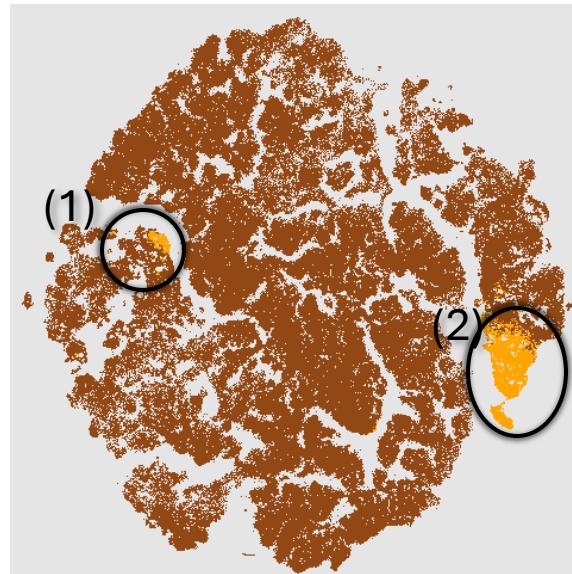
Step 1: Data filtering in 2D I-GM TF

Step 2: Fine-tuning t-SNE TF



Classification Strategy for Two-Level TFs

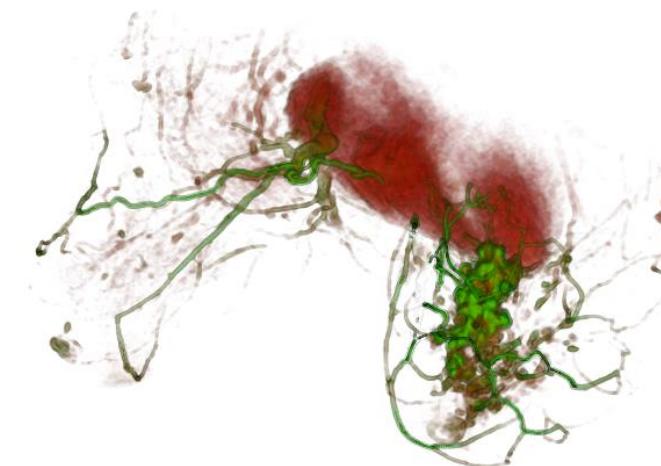
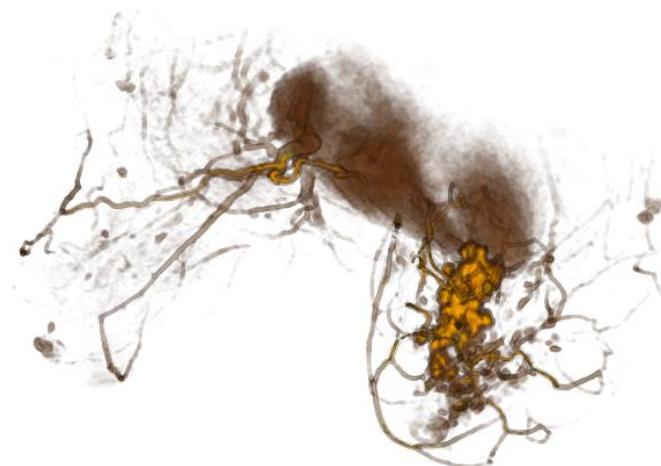
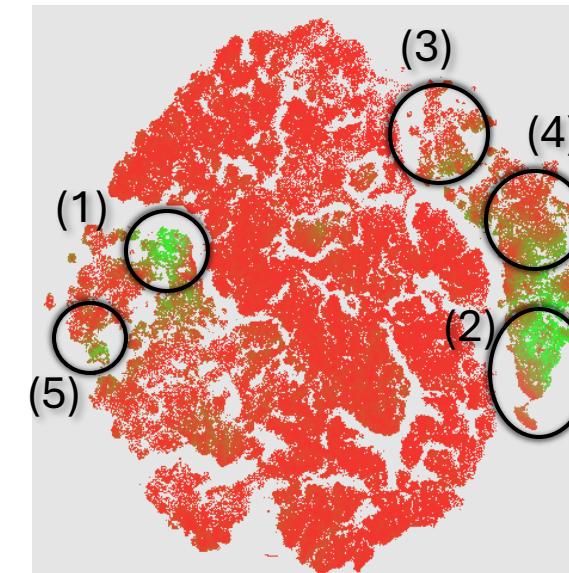
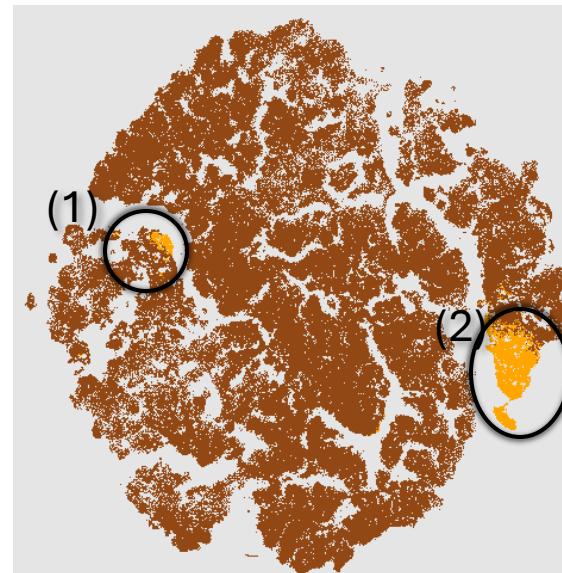
- [Step 1] 2D I-GM TF: High-intensity voxels →
-



(a) High intensity selected from I-GM TF

Classification Strategy for Two-Level TFs

- [Step 1] 2D I-GM TF: High-intensity voxels → High-gradient voxels
-

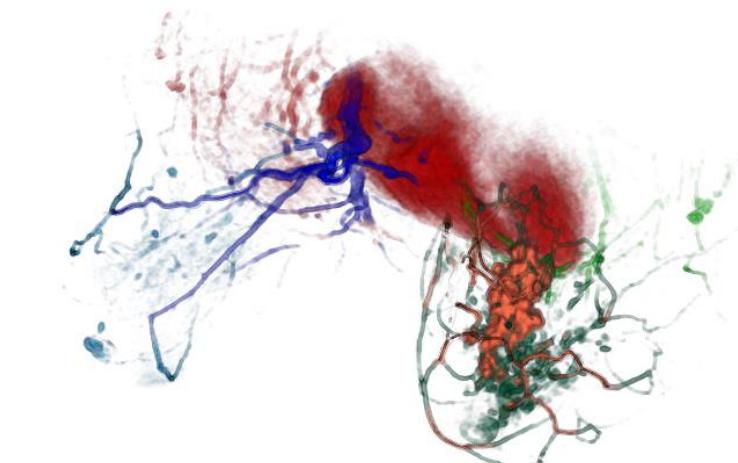
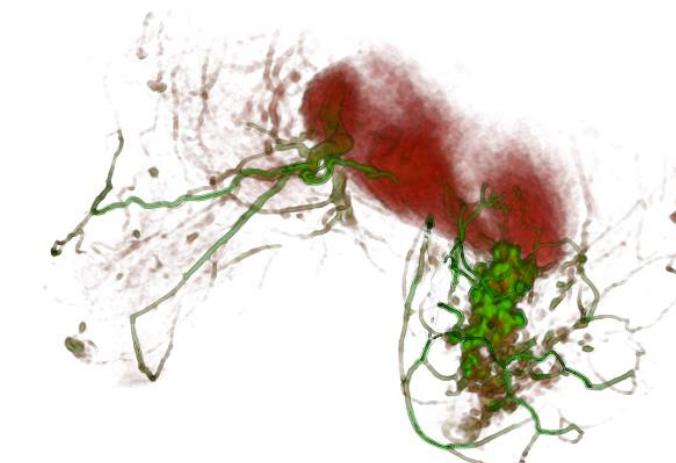
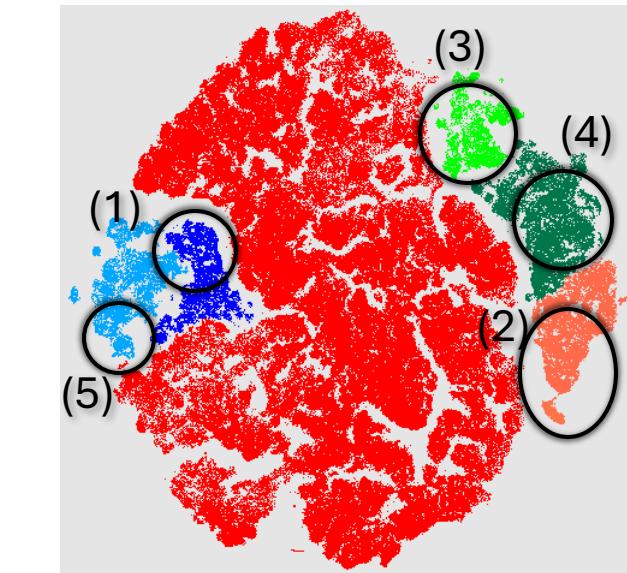
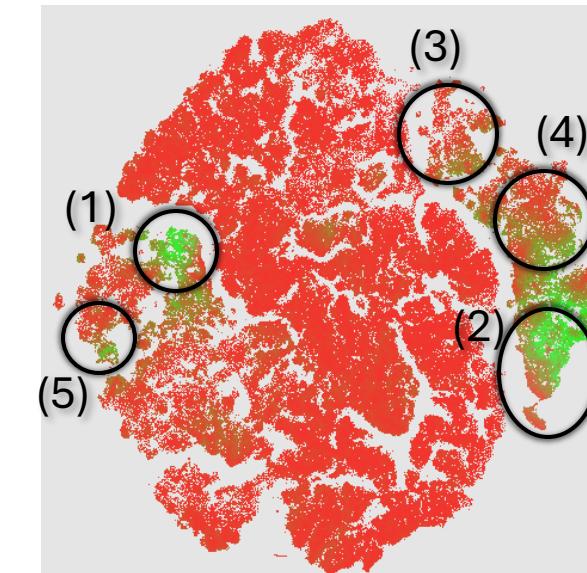
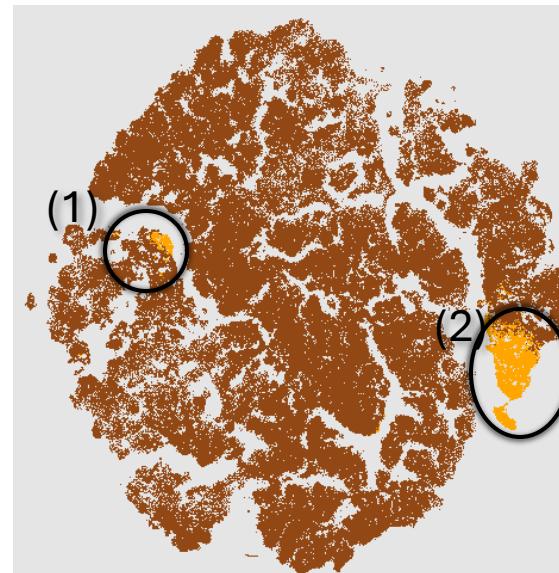


(a) High intensity selected from I-GM TF

(b) High gradient from I-GM TF

Classification Strategy for Two-Level TFs

- [Step 1] 2D I-GM TF: High-intensity voxels → High-gradient voxels
- [Step 2] t-SNE TF: Fine-tuning



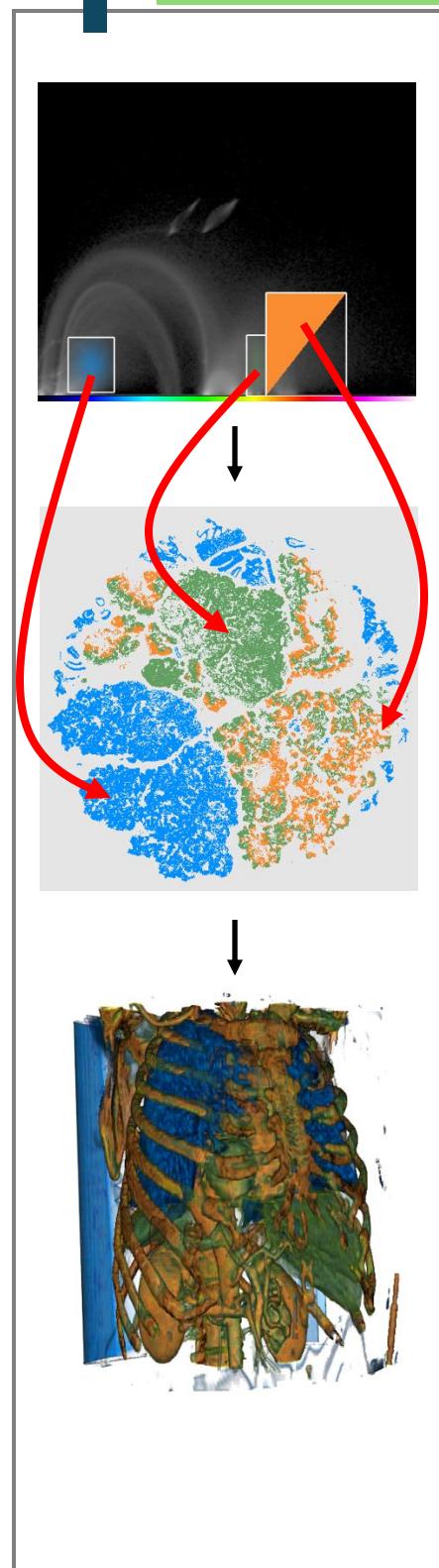
(a) High intensity selected from I-GM TF

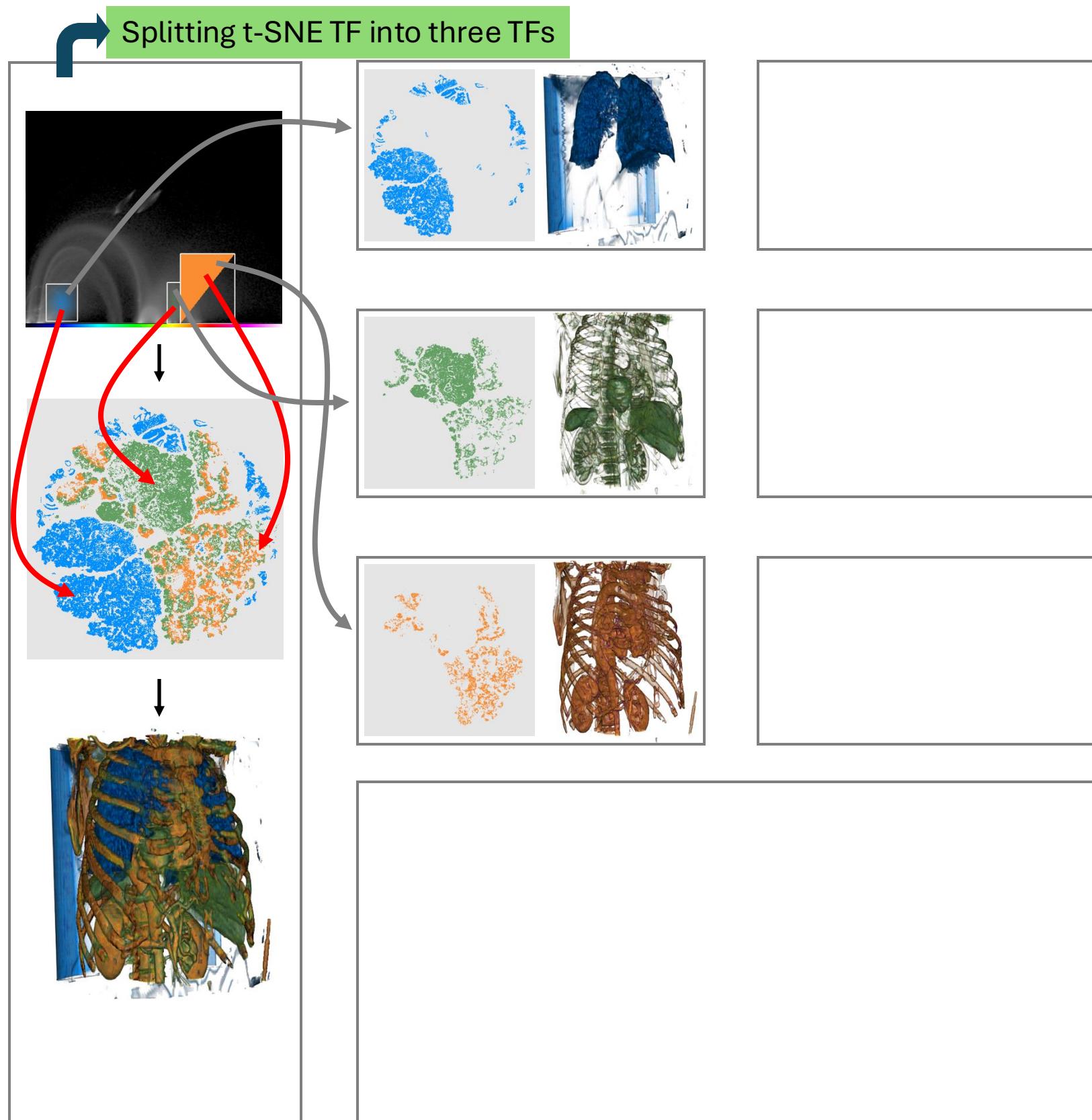
(b) High gradient from I-GM TF

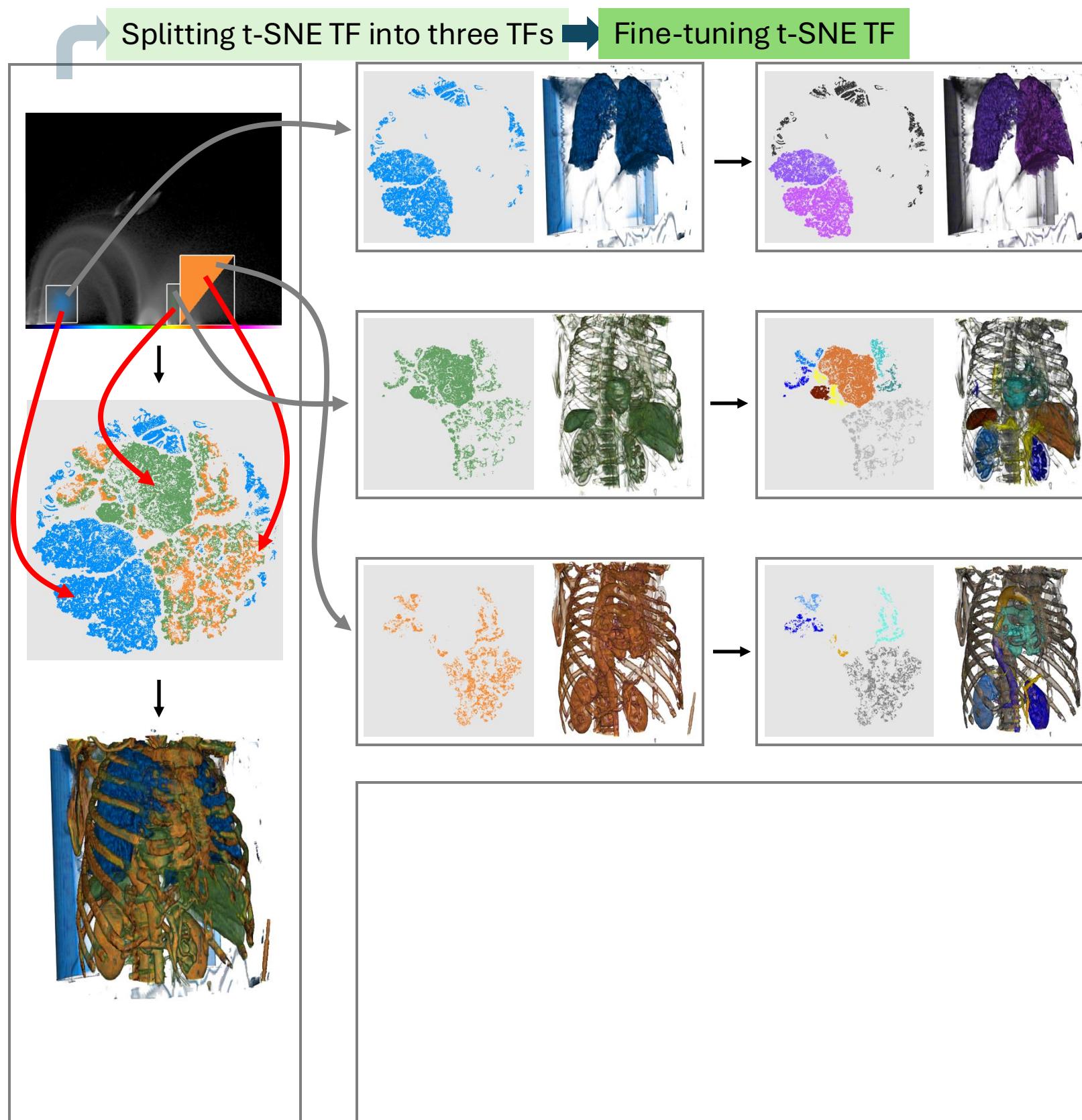
(c) Fine-tuning t-SNE from (b)

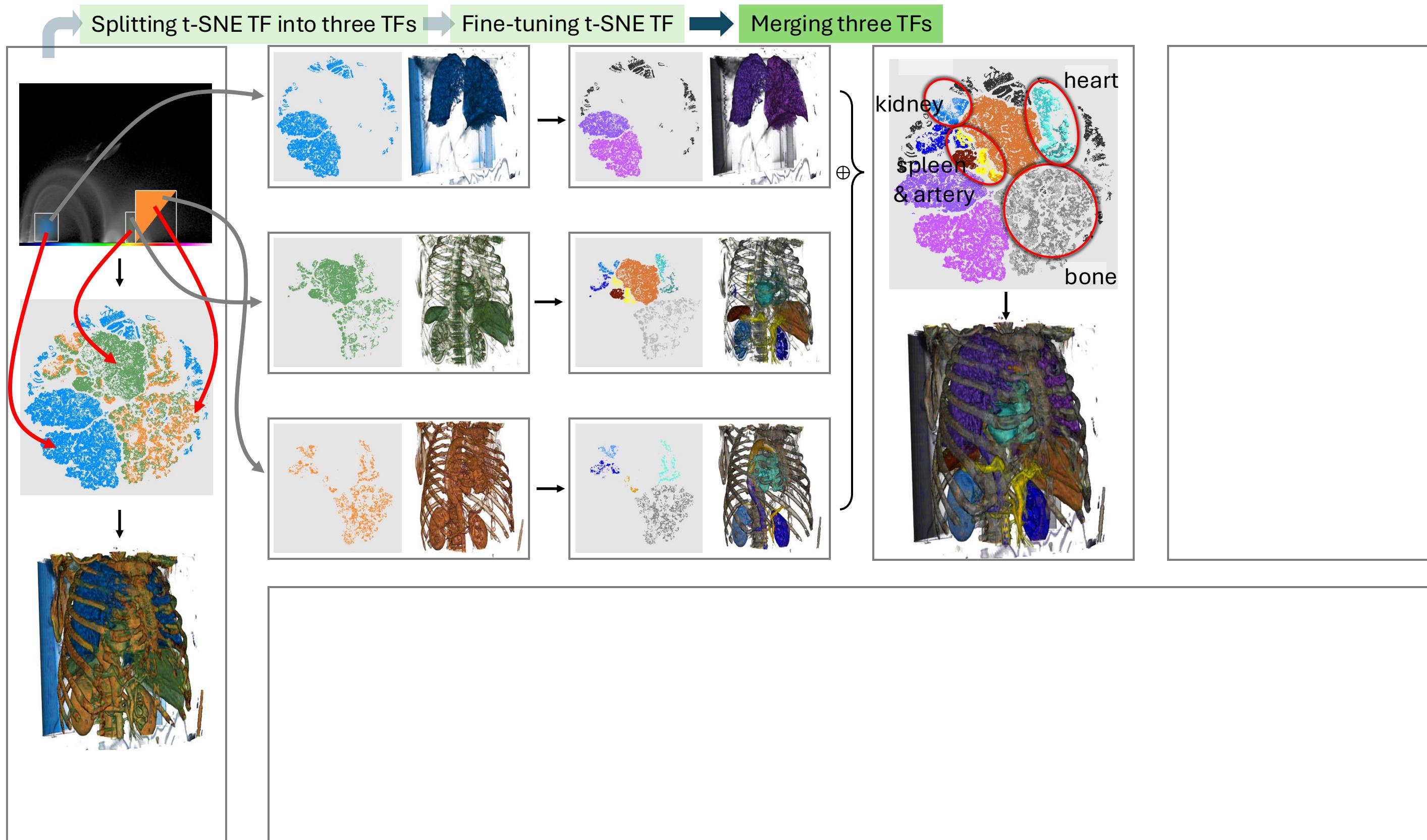
Splitting t-SNE TF into three TFs

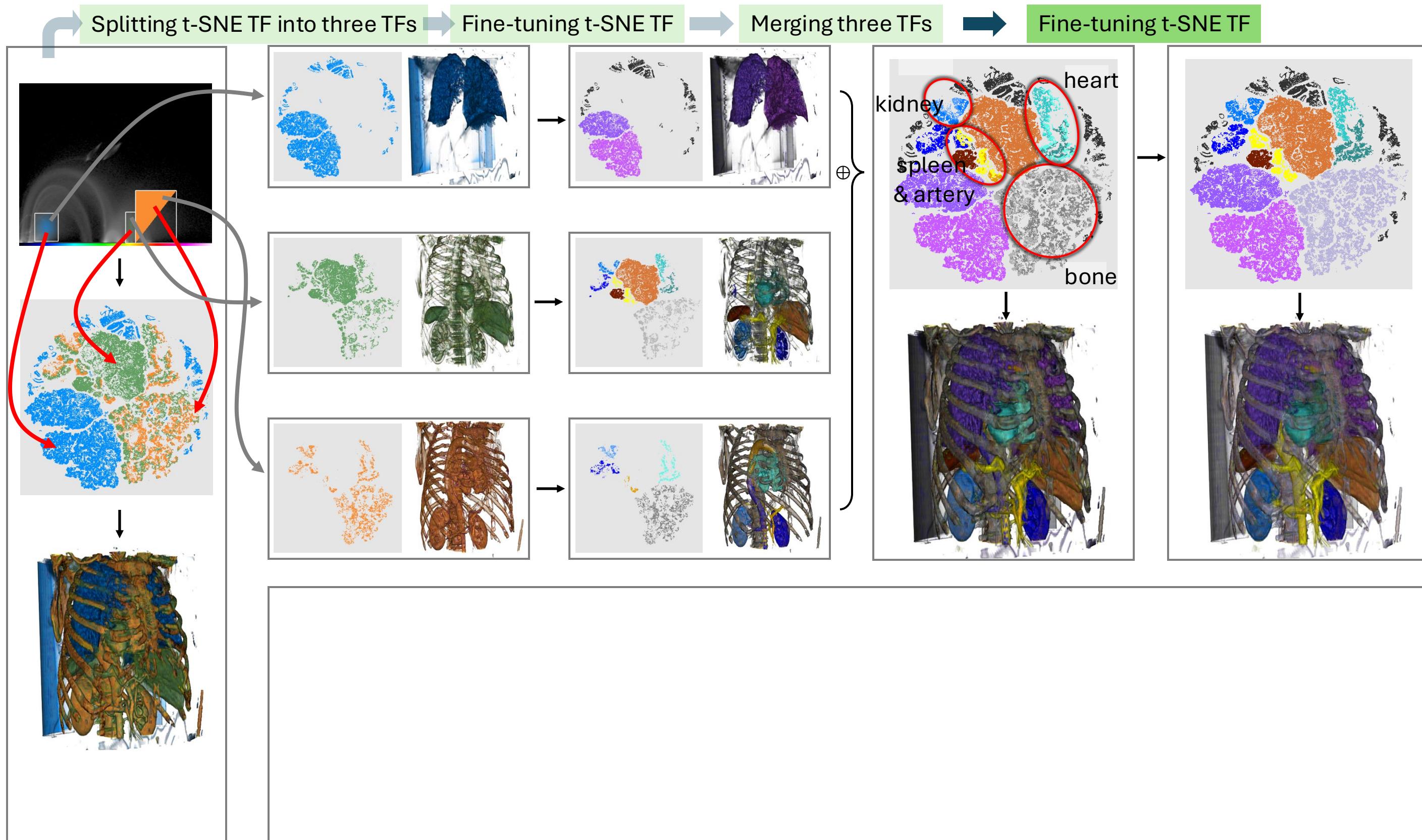
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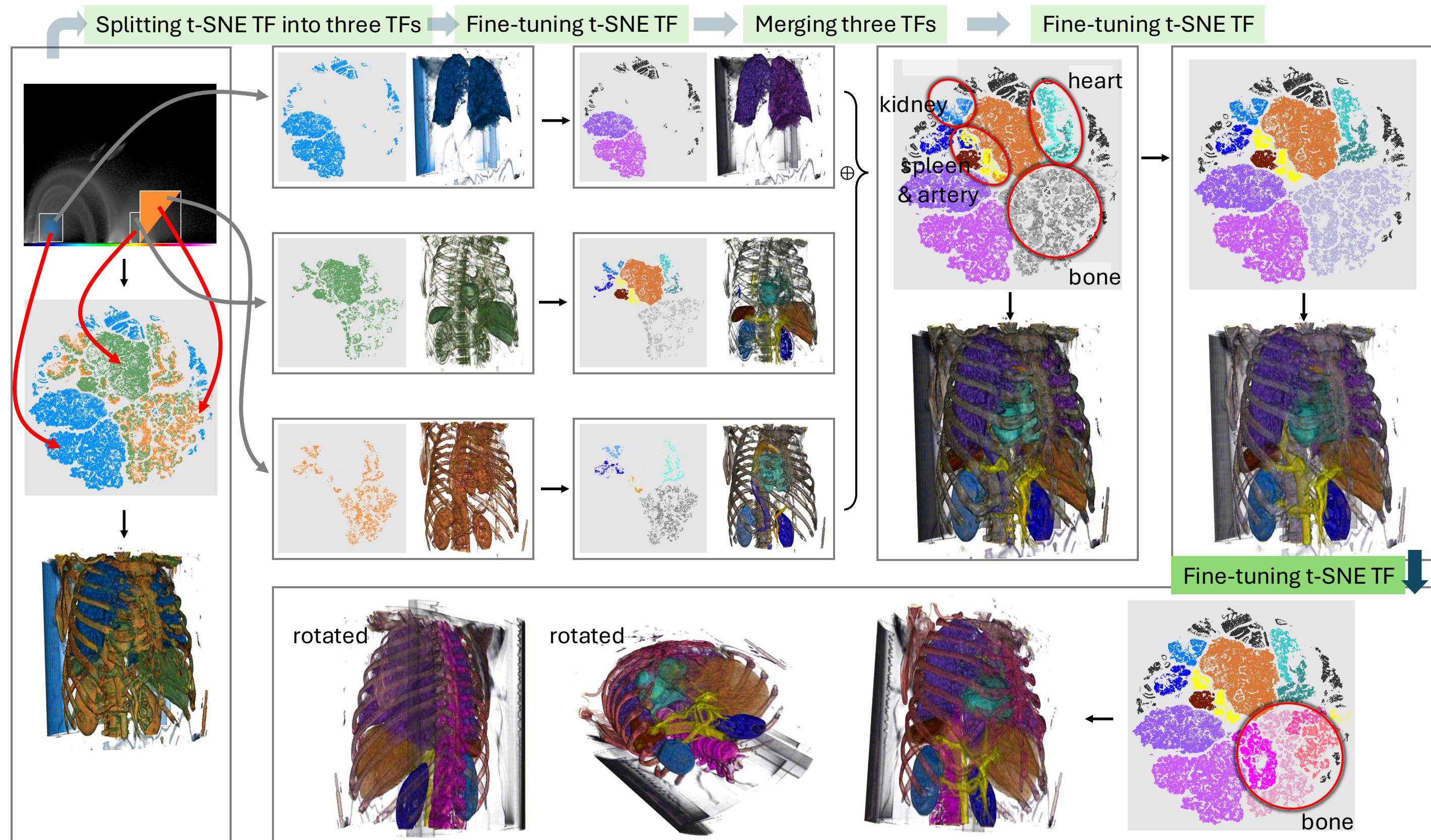






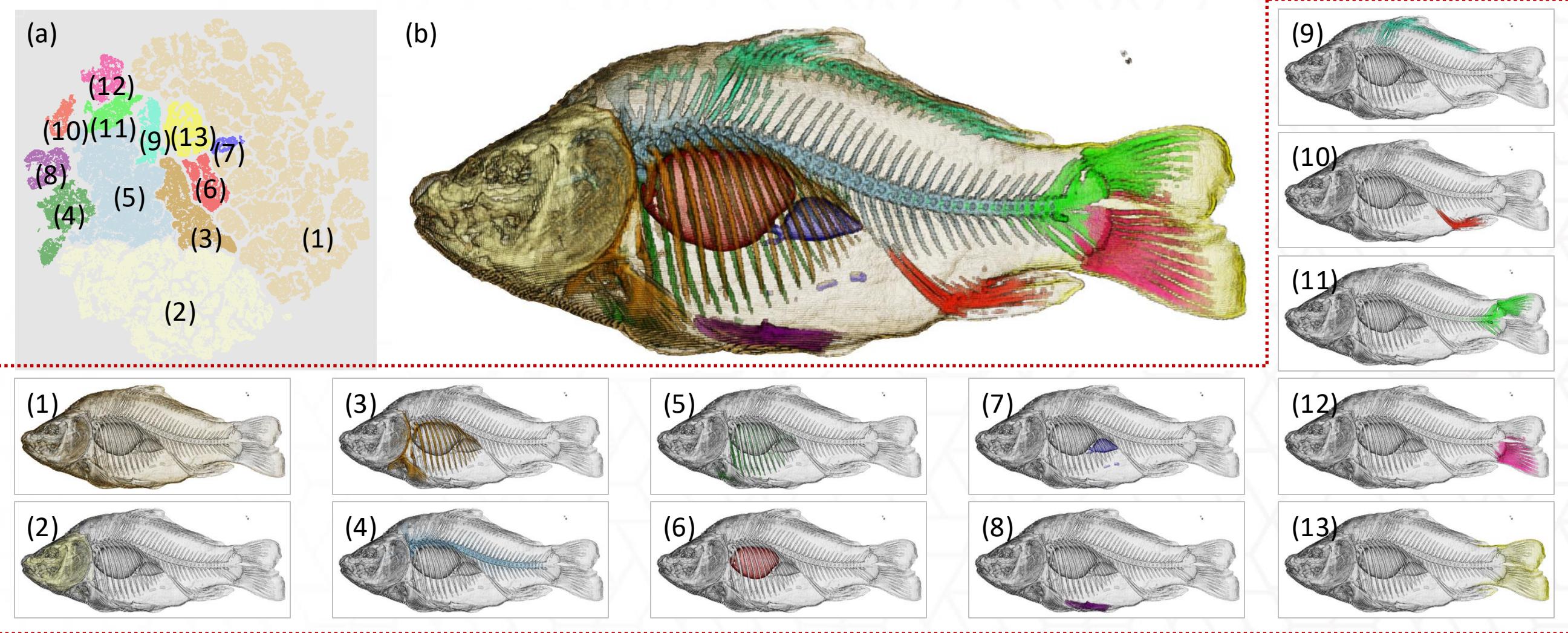






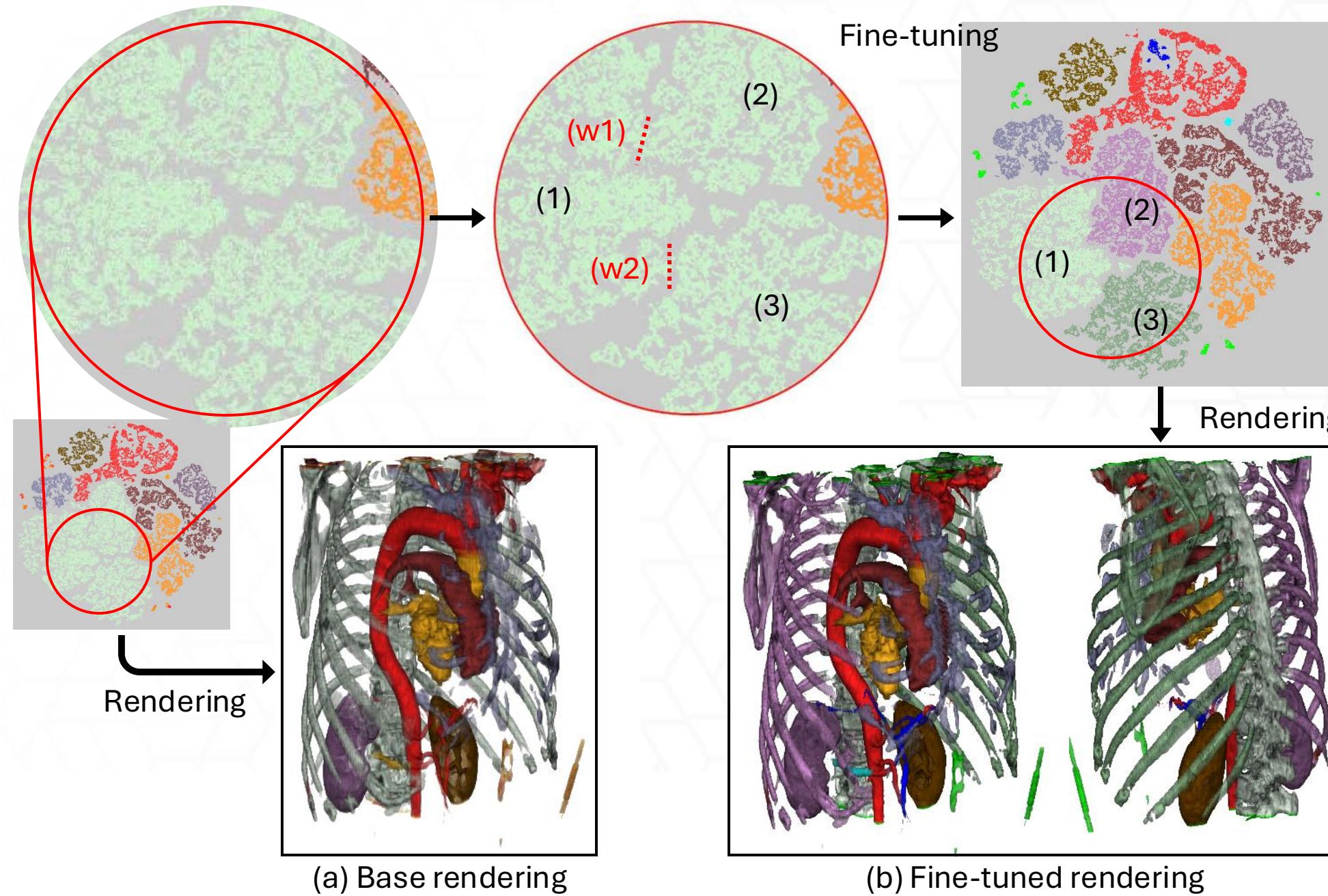
Carp Dataset

- (a): t-SNE TF, (b): Volume Rendering Image, (1) – (13): Segmentations



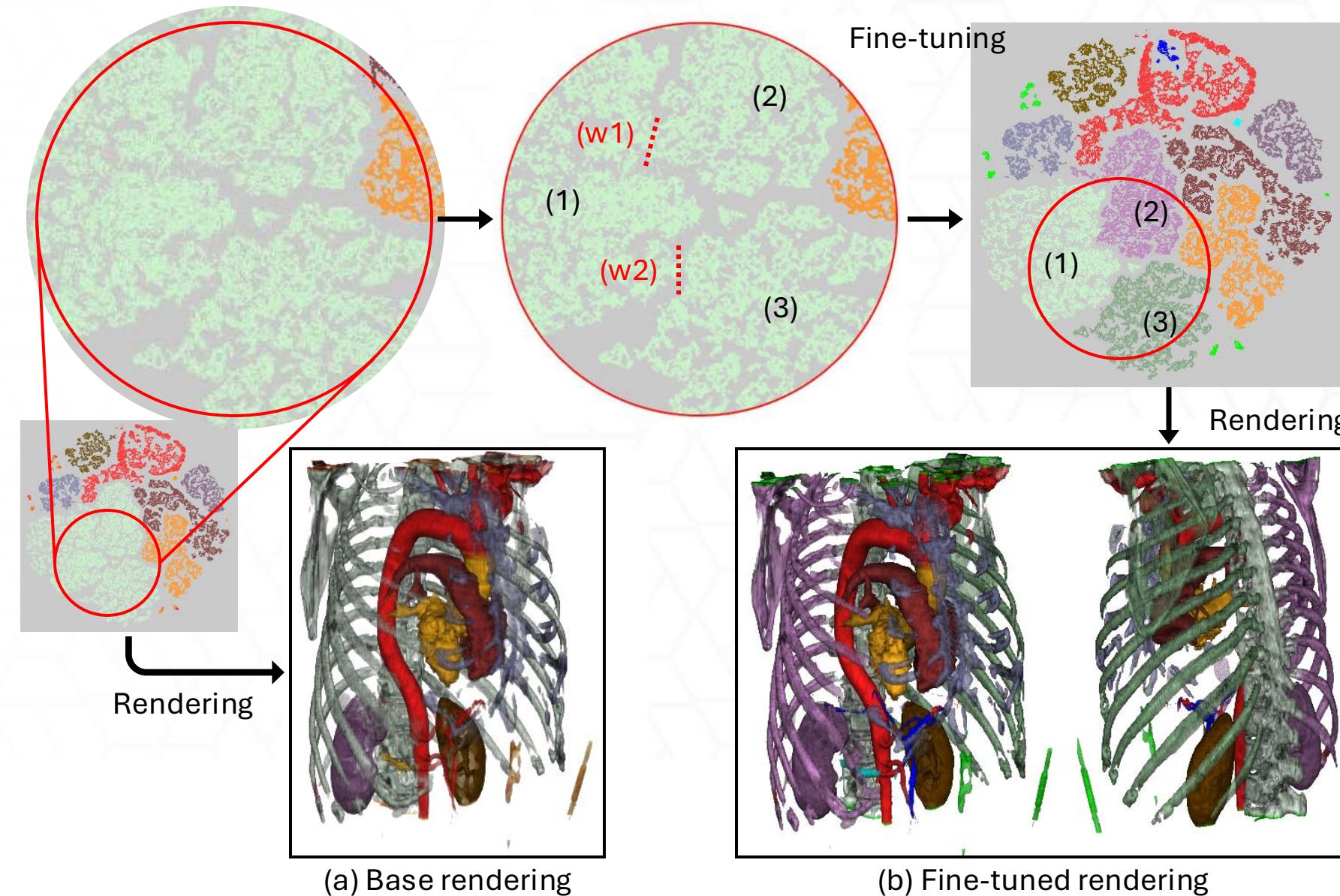
Limitation

- Partially connected clusters (1–3) requiring manual fine-tuning via weak links (w_1 , w_2)



Future work

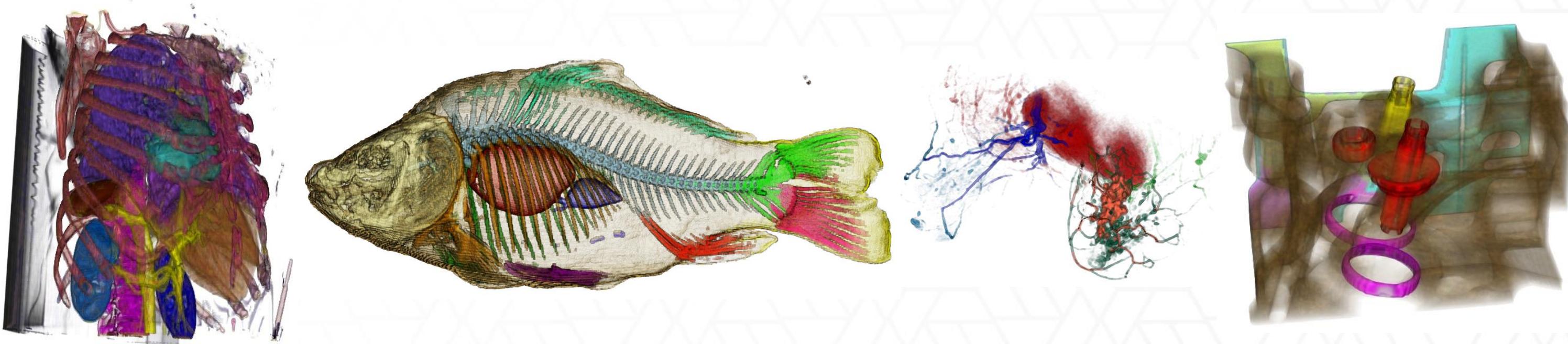
- Automatic cluster separation: Concave hull or OPFSemi* classifier (semi-supervised learning)
- Rendering-guided selection: Random seed visiting + volume rendering comparison



*[OPFSemi]
Amorim et al.
“Improving semi-supervised learning through optimum connectivity”,
Pattern Recognition, Vol. 60, 2016.

Takeaways

- Two-level TFs: integration of conventional TF with Dimensionality Reduction
- Improved feature separation and material classification in DVR
- Mitigation of overplotting through split selection and voxel filtering
- Future work: automate fine-grained segmentation by improving cluster separation



Two-Level Transfer Functions Using t-SNE for Data Segmentation in Direct Volume Rendering

Sangbong Yoo, Seokyeon Kim, and Yun Jang



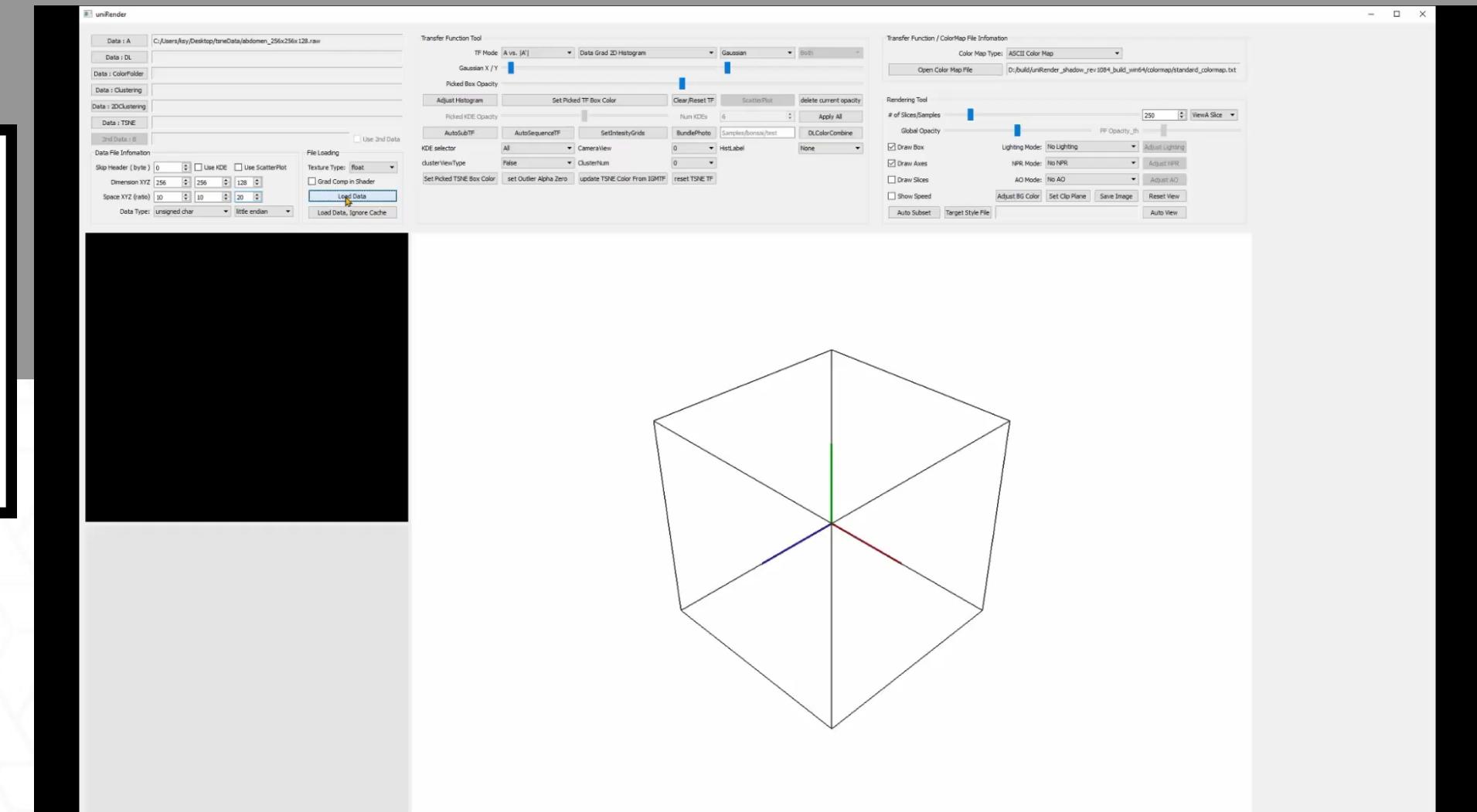
Sangbong Yoo



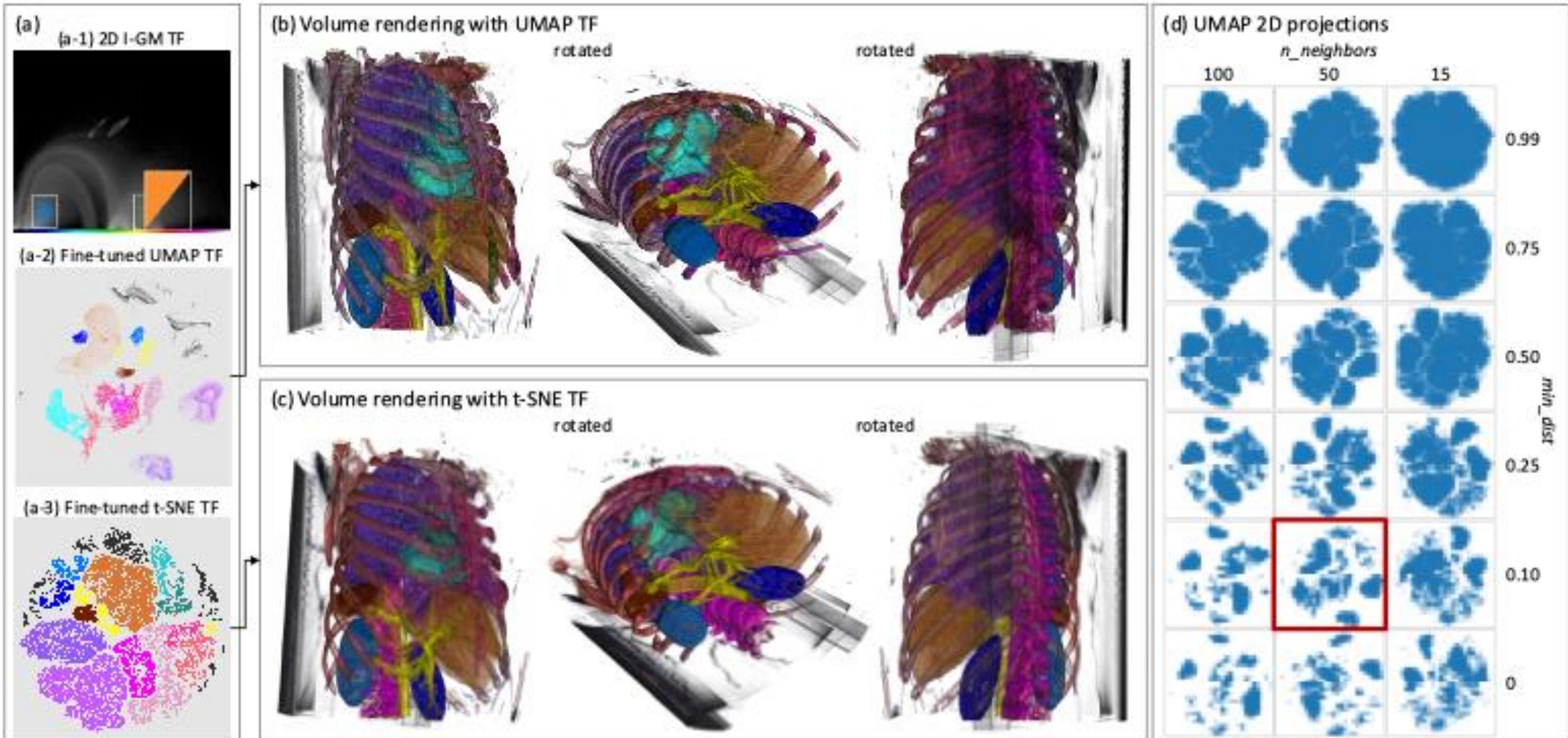
VIS Lab, Yun Jang



Contact: usangbong@gmail.com

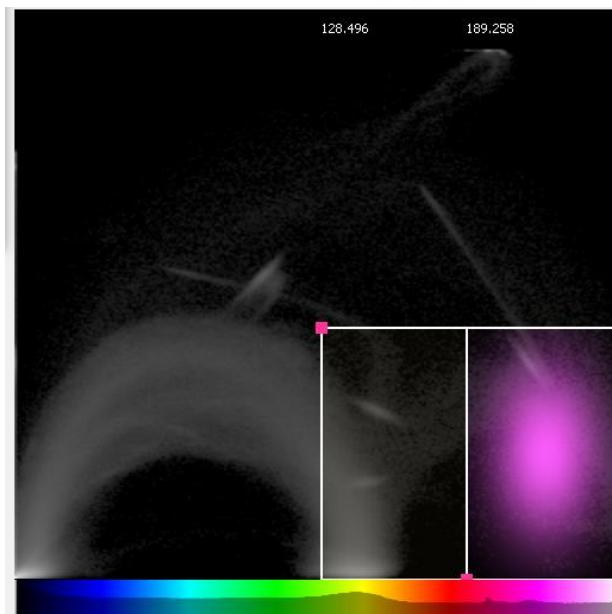


Dimensionality Reduction with UMAP

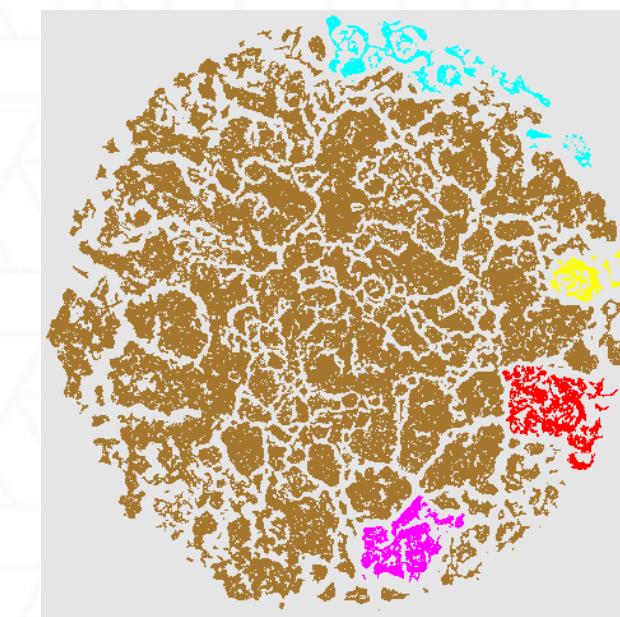
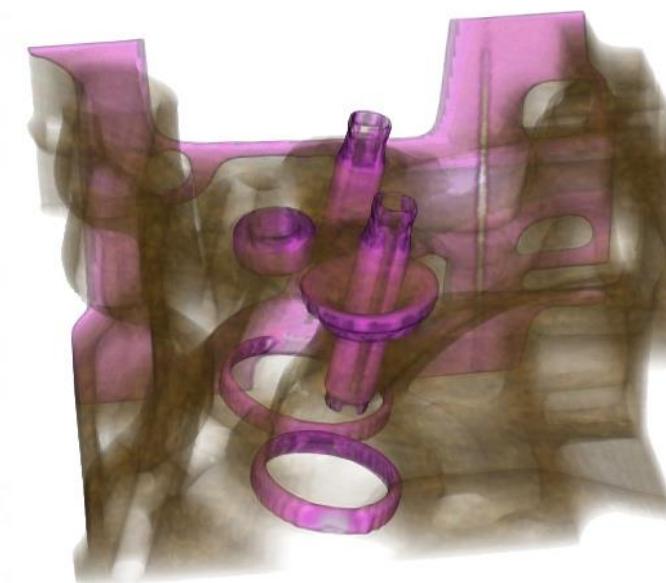


Engine Dataset

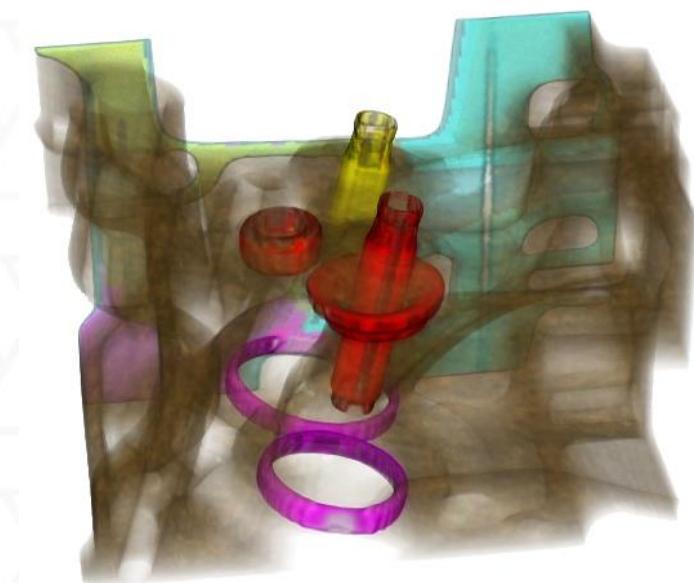
- 2D I-GM TF: inner cylinders and side panels
- With t-SNE TF: inner structures in engine data



Volume rendering with 2D I-GM TF

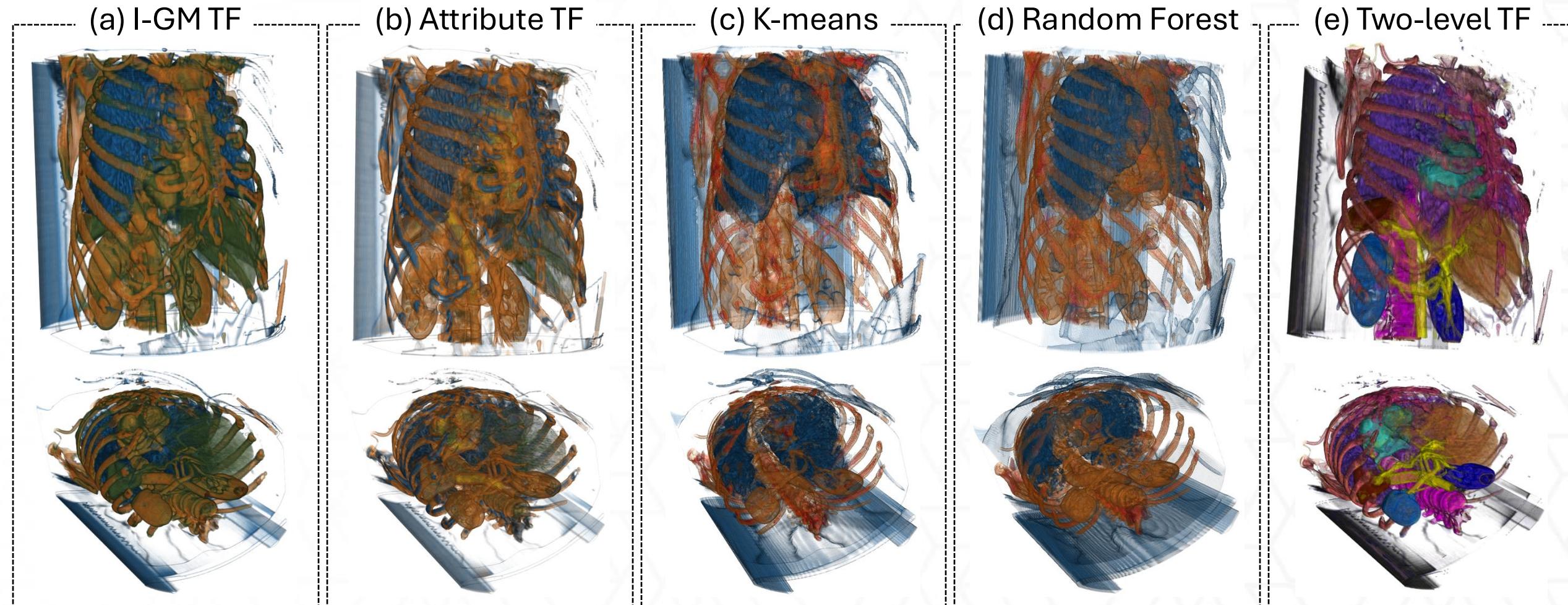


Volume rendering with t-SNE TF after I-GM TF
(Two-Level TFs)



Comparing TF-Based Feature Separation Methods

- (a), (b): distinguish only major organs such as bones, lungs, and liver
- (c), (d): enable structural separation but require training data



(a) Kniss et al., “Multidimensional Transfer Functions for Interactive Volume Rendering”, IEEE TVCG, Vol. 8, No. 3, 2002.

(b) Maciejewski et al., “Abstracting attribute space for transfer function exploration and design,” IEEE TVCG, Vol. 19, No. 1, 2013.

(c),(d) Soundararajan and Schultz, “Learning probabilistic transfer functions: A comparative study of classifiers,” CGF, Vol.34, No. 3, 2015.

User Study

- Two-level TF: more detailed feature separation than 2D I-GM TF
- Longer rendering time with Two-level TF ($\approx 2 \times$ I-GM TF)

