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Implicit Representation Learning of Coronary Artery Vessels using Deep Generative Models

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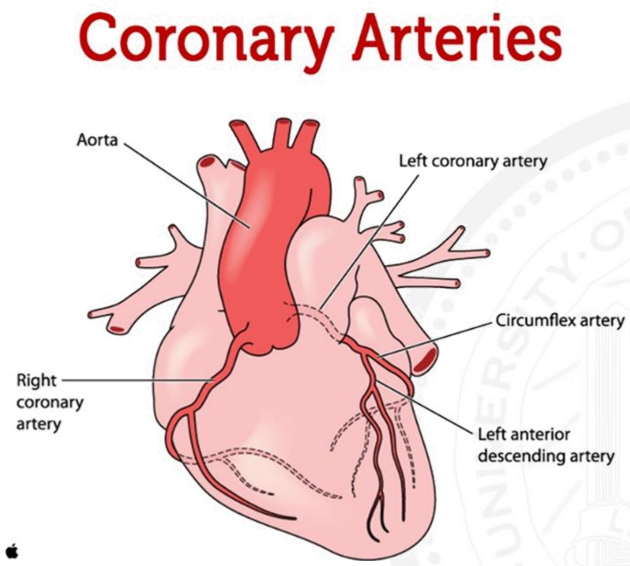
Outline

- Introduction
- Related Work
- Method
- Result

Introduction

- Cardiovascular diseases have the highest mortality in the world, posing extremely high risks and societal burdens.
- Analyzing the geometry and structure of coronary artery is important for downstream tasks, such as coronary artery segmentation.
- our objective is to develop a point cloud generative model to learn the Implicit representation of coronary artery dataset.



Introduction

- modeling coronary artery dataset is a challenging task due to the complexity of the vascular system.

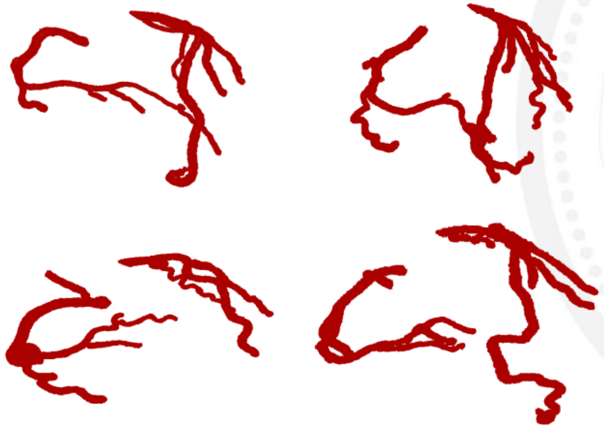
a. the complex geometric bending degree

b. intricate branching structures

c. significant variations among different samples

a. bending degree

b. branching structure



c. variations among samples

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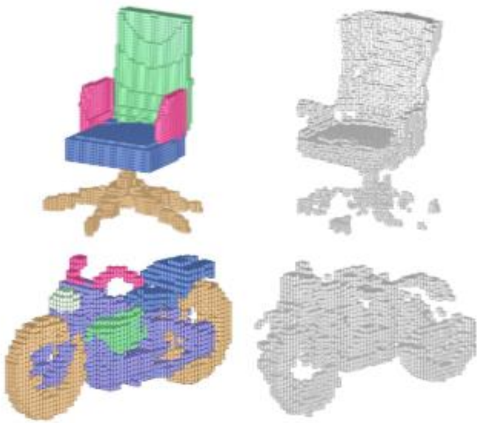
- Related Work
  - ✓ Part-based Generative Model
  - ✓ Disentangled Representation Learning
- Method
- Result

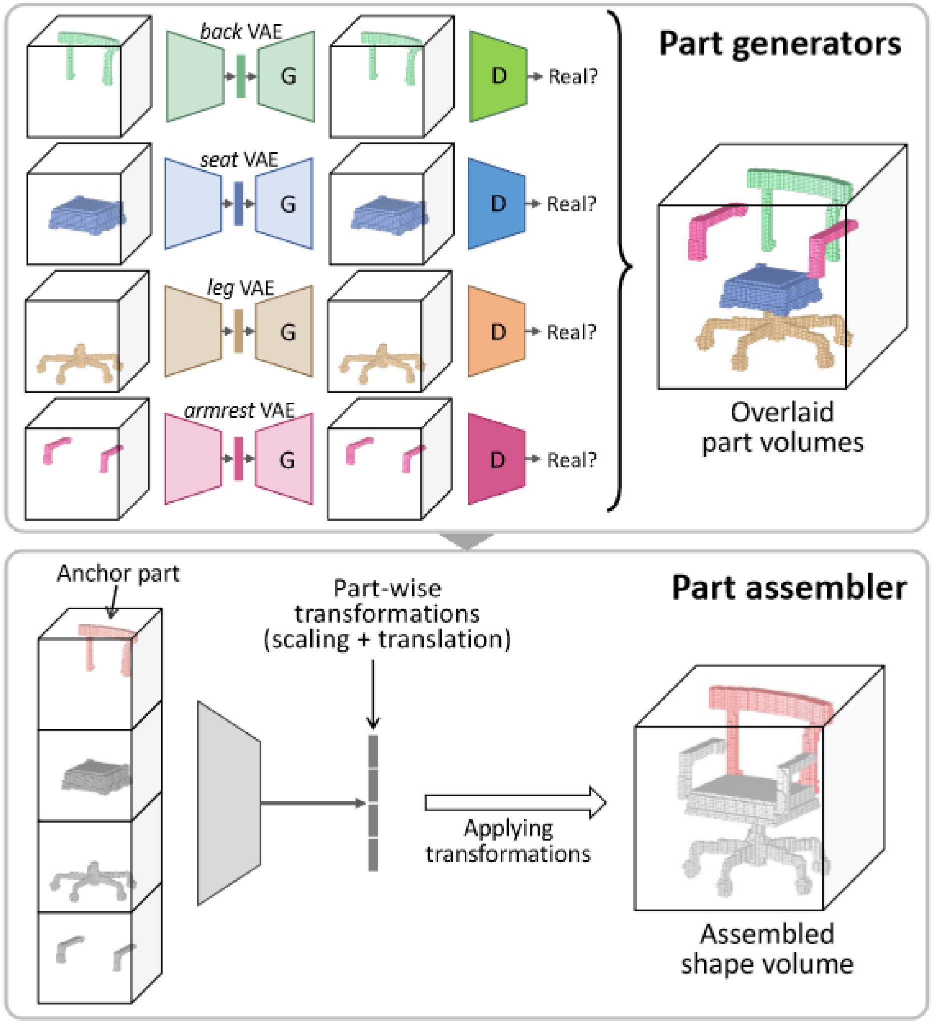
Related Work

- Part-based generative model

Unlike holistic model, part-based generative model **generates each part separately** and **then assemble** them together.

It can Improve the ability to model complex objects.



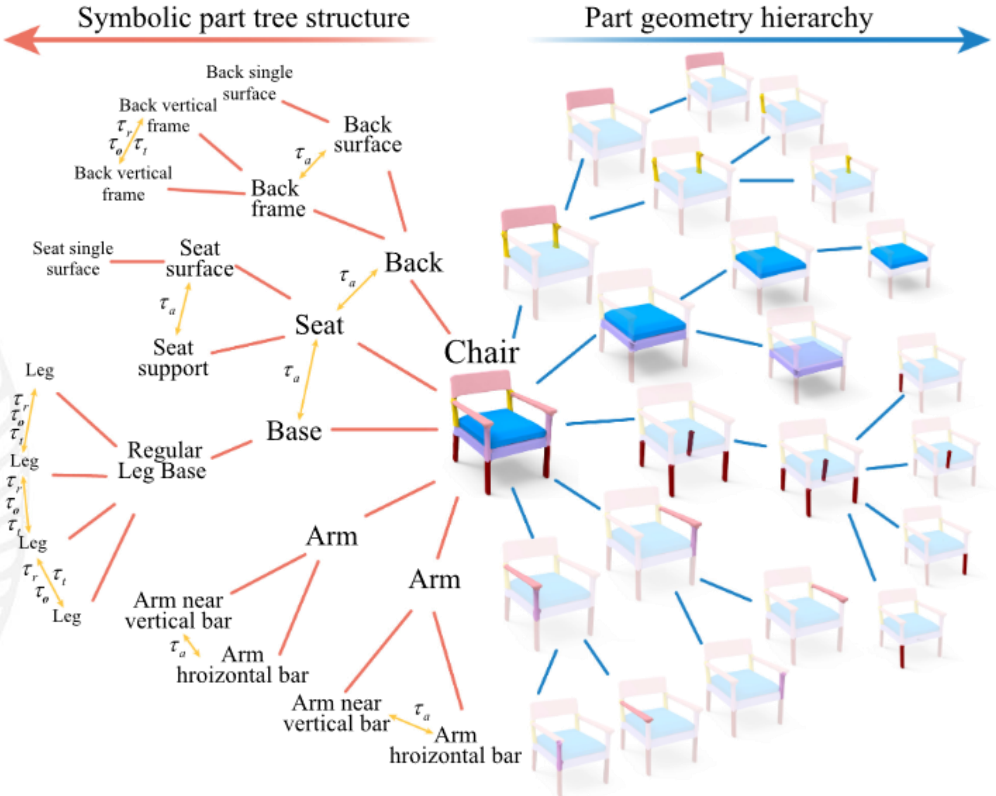


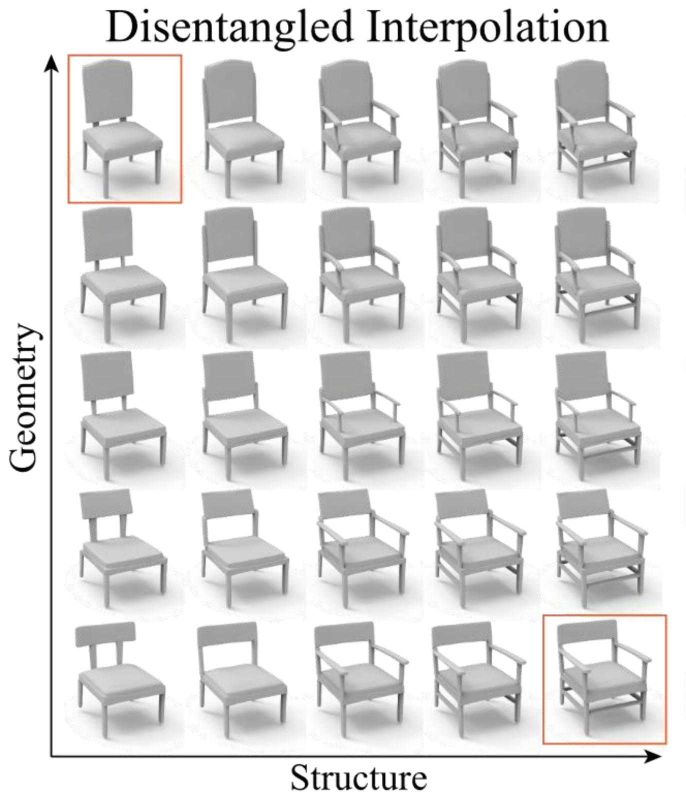
Li J, Niu C, Xu K. Learning Part Generation and Assembly for Structure-Aware Shape Synthesis. AAAI. 2020 Apr 3;34(07):11362–9.

Related Work

➢ Disentangled Representation Learning

Disentangled representation aims to learn different aspects of data independently, so as to capture different factors or features in data.





Modeling the **geometry and structural** information of objects separately.

Yang J, Mo K, Lai YK, Guibas LJ, Gao L. DSG-Net: Learning Disentangled Structure and Geometry for 3D Shape Generation. ACM Trans Graph. 2023 Feb 28;42(1):1–17.

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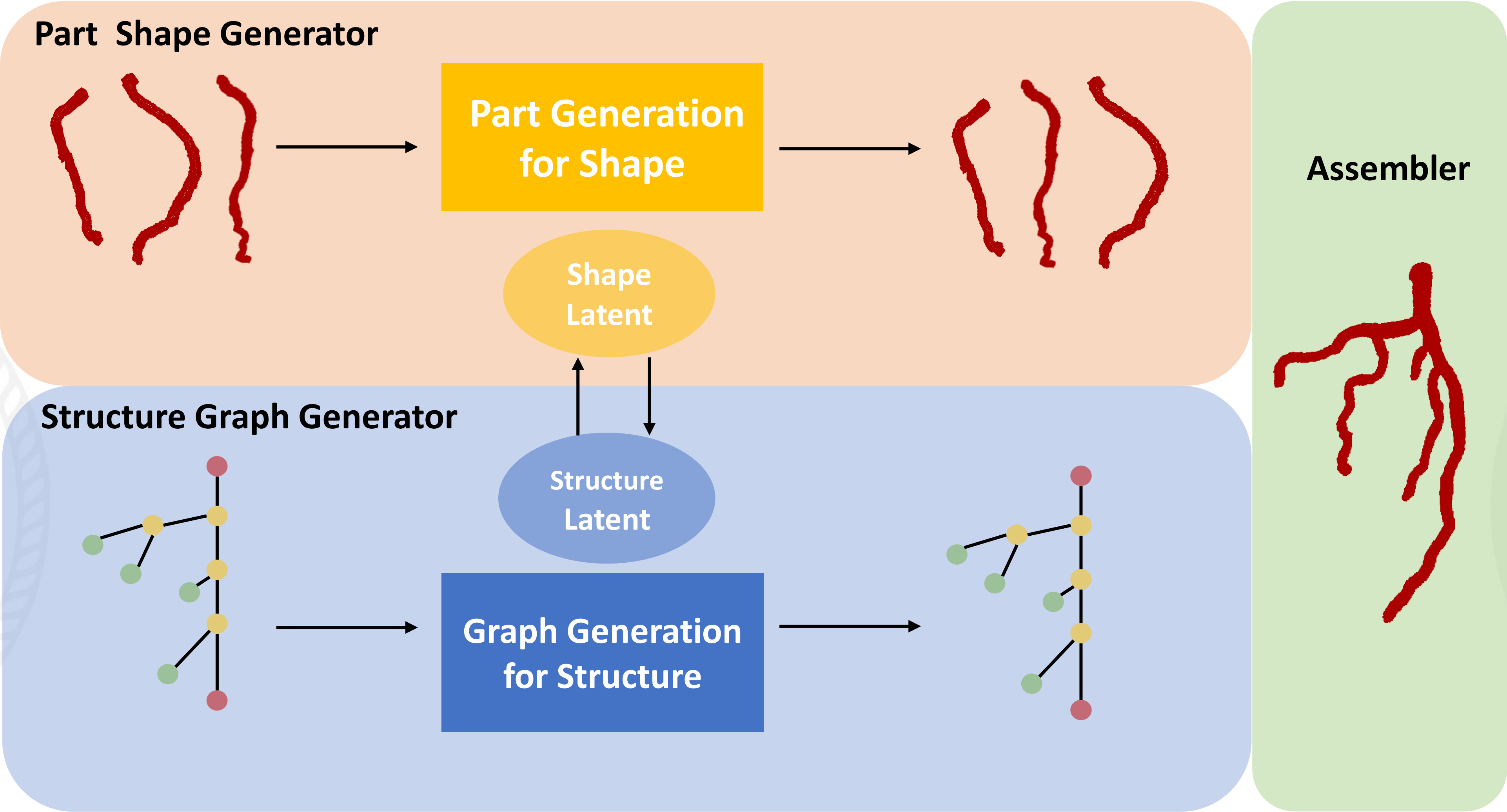
  - ✓ Part Shape Generation
  - ✓ Structure Graph Generation
- Result

Method

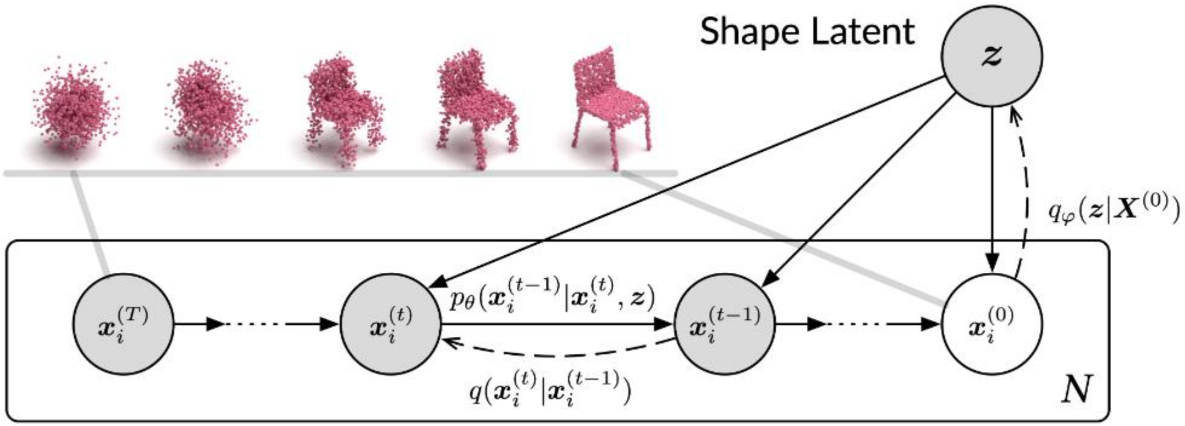
Model Architecture



Method

➢ Part Shape Generator

Diffusion Probabilistic Models for 3D Point Cloud Generation



Forward diffusion process: add noise

$$q\left(x^{(1:T)} \mid x^{(0)}\right) = \prod_{t=1}^{T} q\left(x^{(t)} \mid x^{(t-1)}\right)$$

Reverse diffusion process: denoise

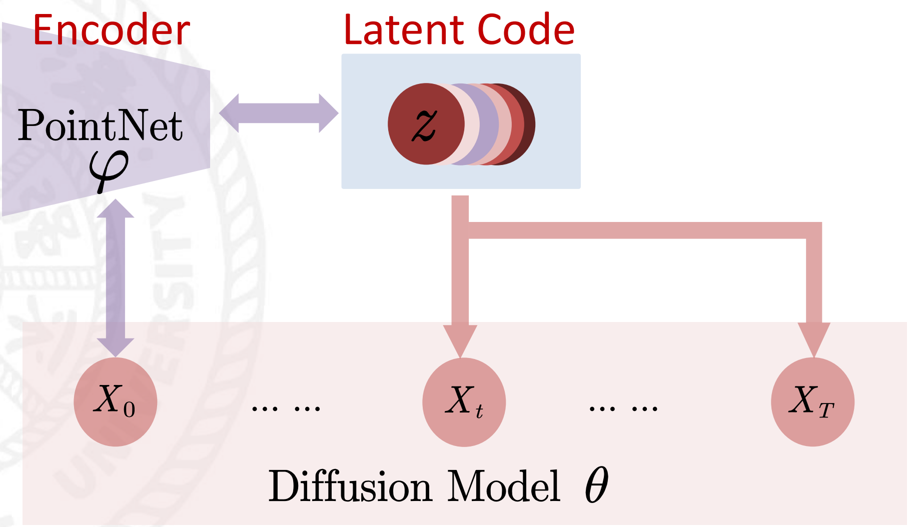
$$p_\theta\left(x^{(0:T)} \mid z\right) = p\left(x^{(T)}\right) \prod_{t=1}^{T} p_\theta\left(x^{(t-1)} \mid x^{(t)}, z\right)$$

Luo S, Hu W. Diffusion Probabilistic Models for 3D Point Cloud Generation. CVPR. 2021; pp. 2836-2844.

Method

➢ **Part Shape Generator:** Diffusion Probabilistic Models for 3D Point Cloud Generation

1. We use PointNet as the encoder to model the shape latent z
2. the shape latent z as a **conditional variable** guides the reverse process of each step.



Loss Function:

$$L(\theta,\varphi)=\mathbb{E}_q\Big[\sum_{t=2}^{T}\sum_{i=1}^{N}D_{KL}\big(q(x_i^{(t-1)}\mid x_i^{(t)},x_i^{(0)})\parallel p_\theta(x_i^{(t-1)}\mid x_i^{(t)},\boxed{E_\varphi(X^{(0)})})\big)$$

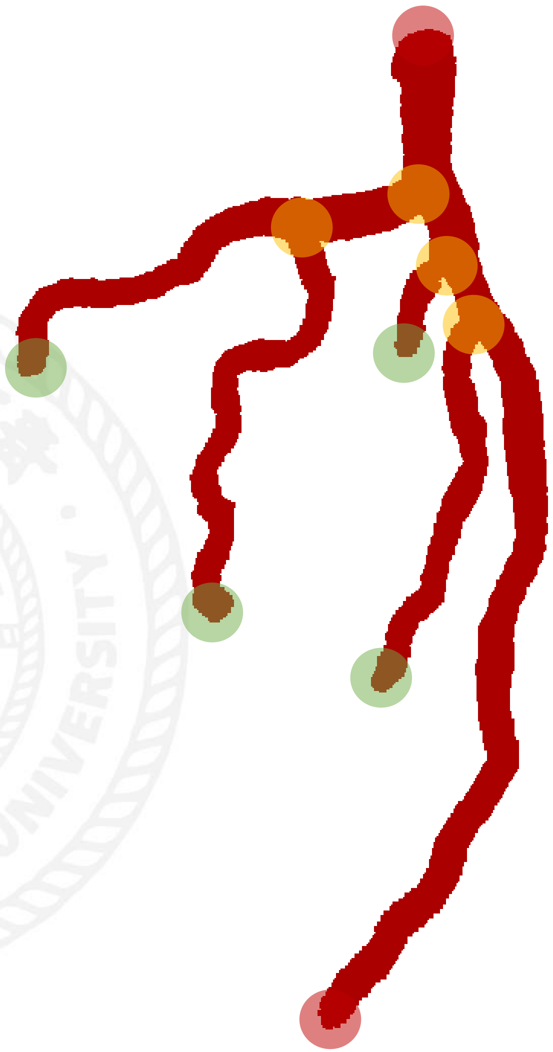
$$-\sum_{i=1}^{N}\log p_\theta(x_i^{(0)}\mid x_i^{(1)},\boxed{E_\varphi(X^{(0)})})\Big]$$

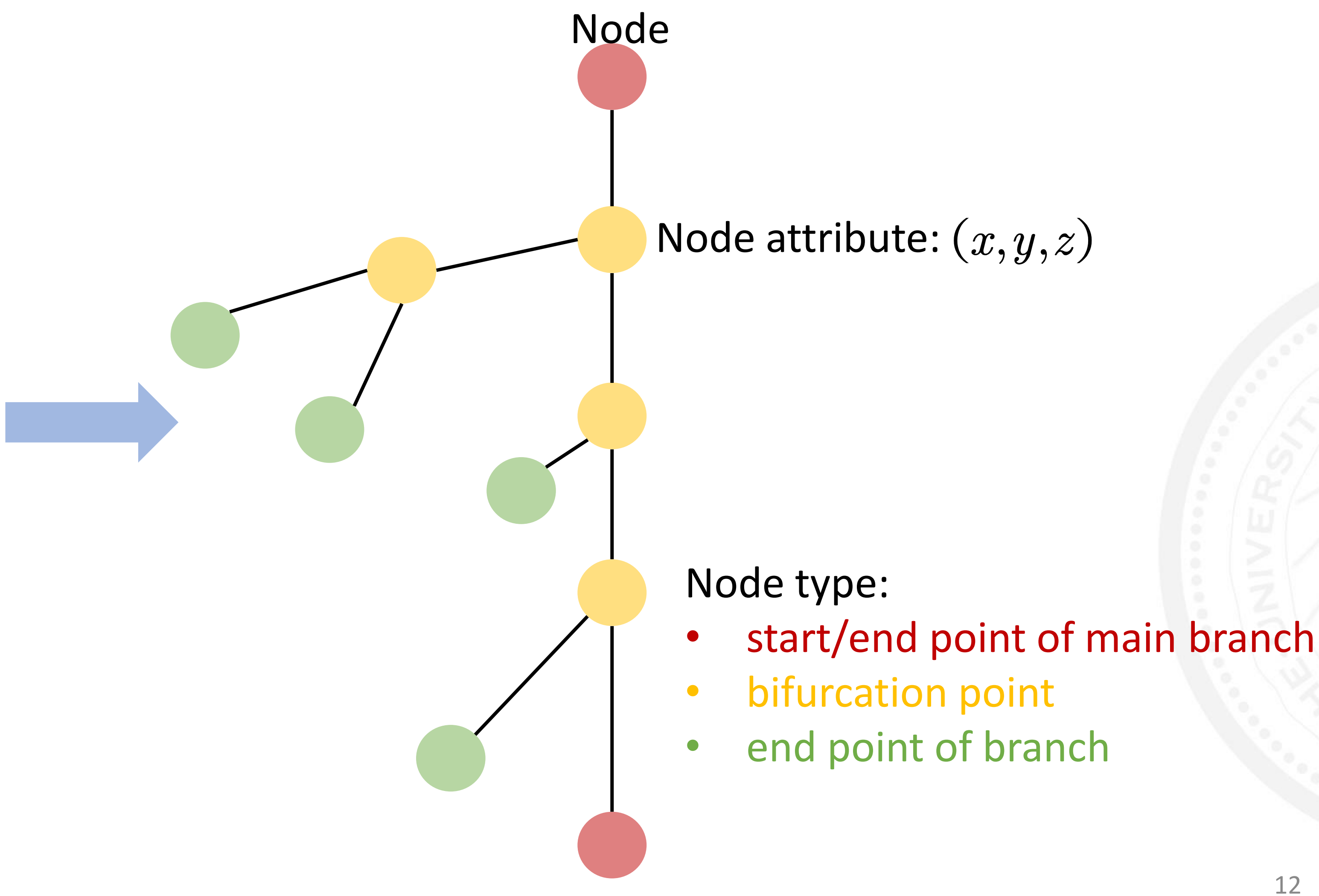
Latent code *Z*

Luo S, Hu W. Diffusion Probabilistic Models for 3D Point Cloud Generation. CVPR. 2021; pp. 2836-2844.

Method

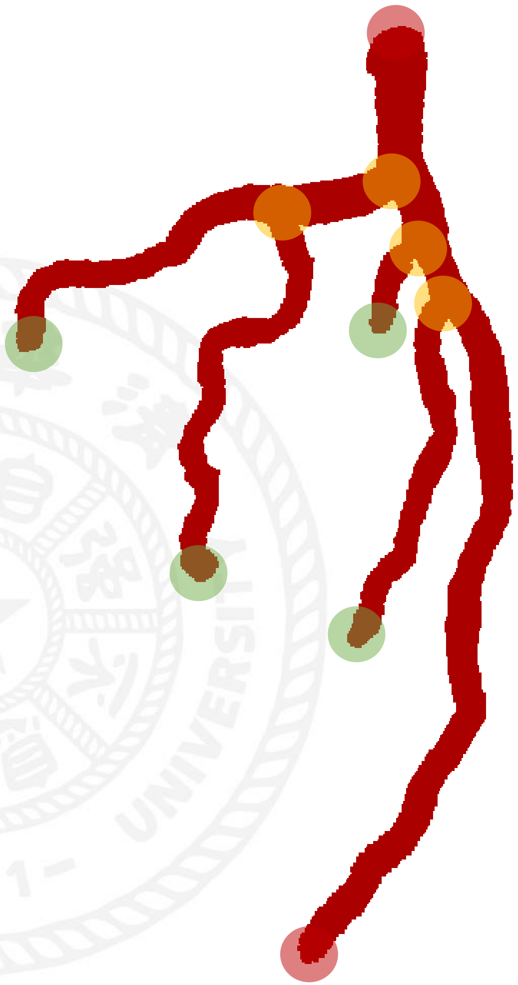
➢ **Structure Graph Generator:** Key Points Graph

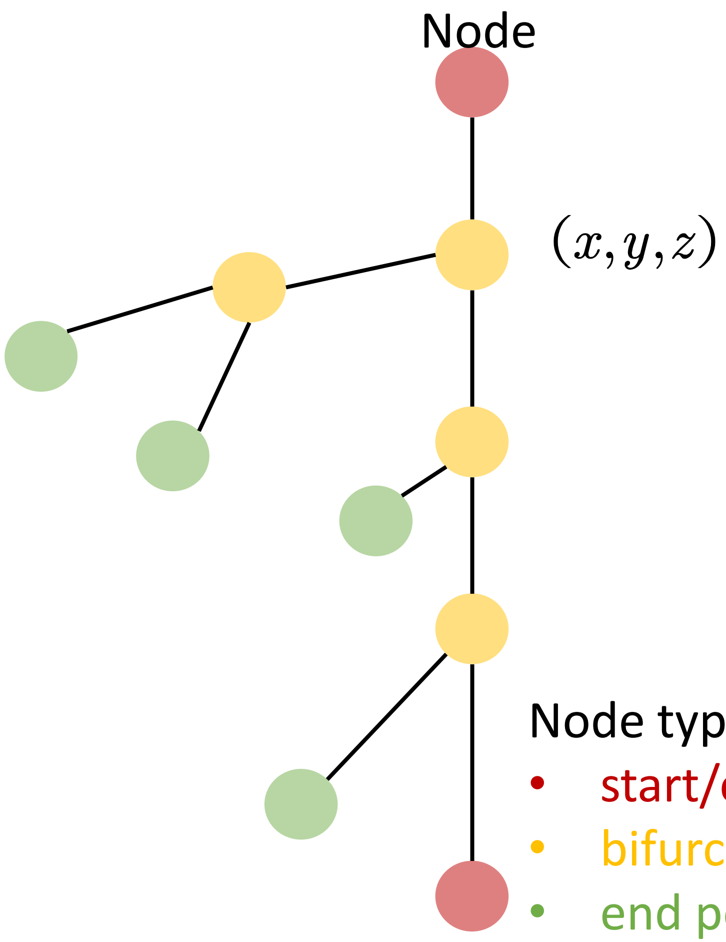




Method

- **Structure Graph Generator:** Key Points Graph





The information in the graph:

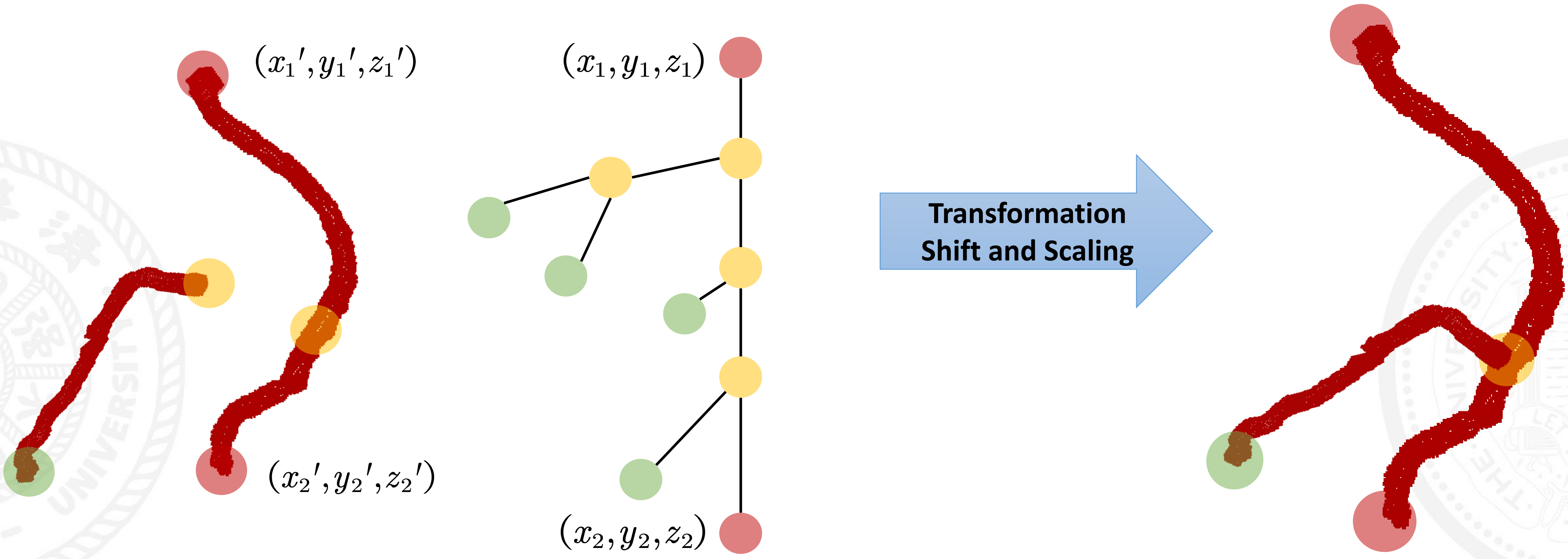
1. The number of branches
2. The direction of each branch
3. The length of each branch

Node type:

- start/end point of main branch
- bifurcation point
- end point of branch

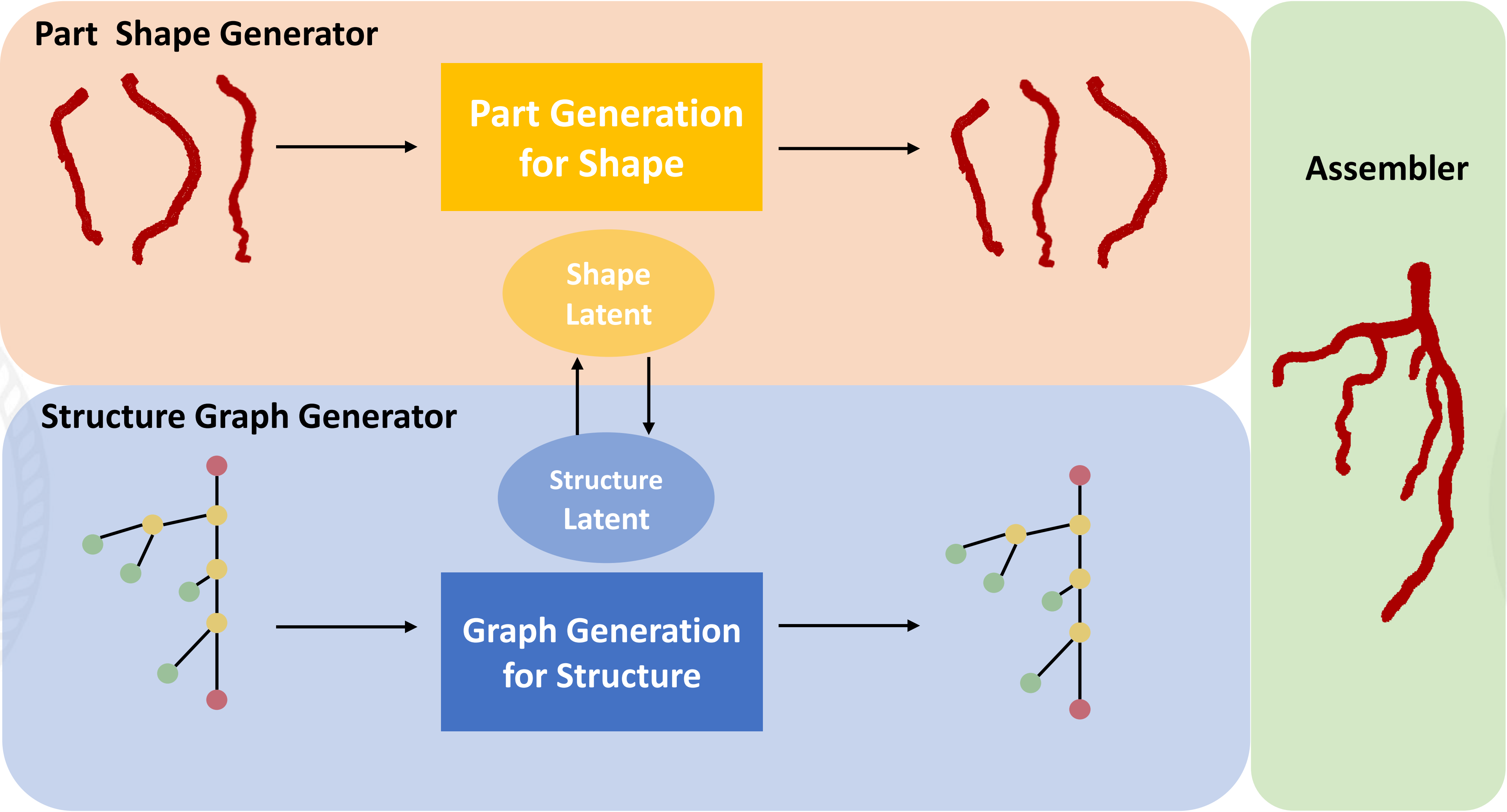
Method

➢ **Assembler**



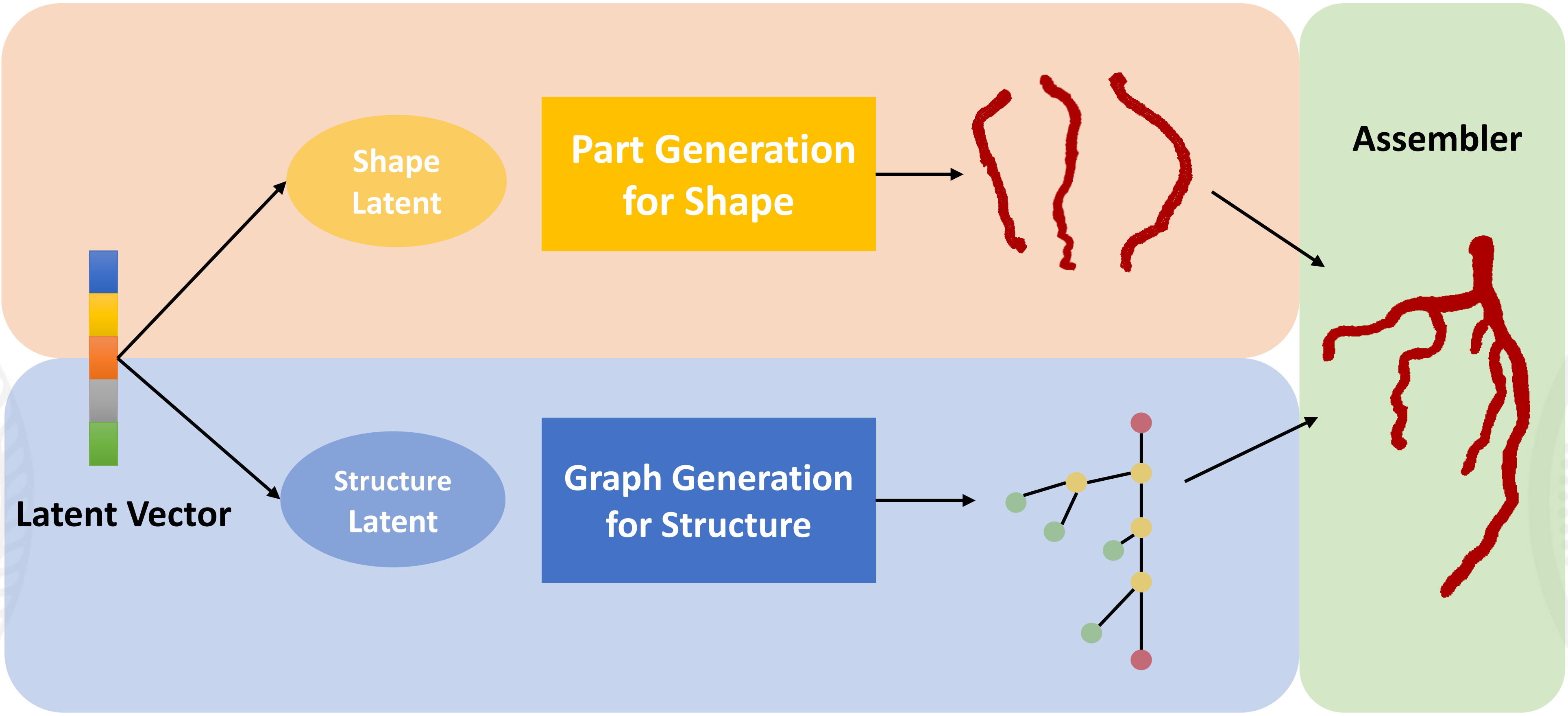
Method

➢ **Train**



Method

➢ Sample



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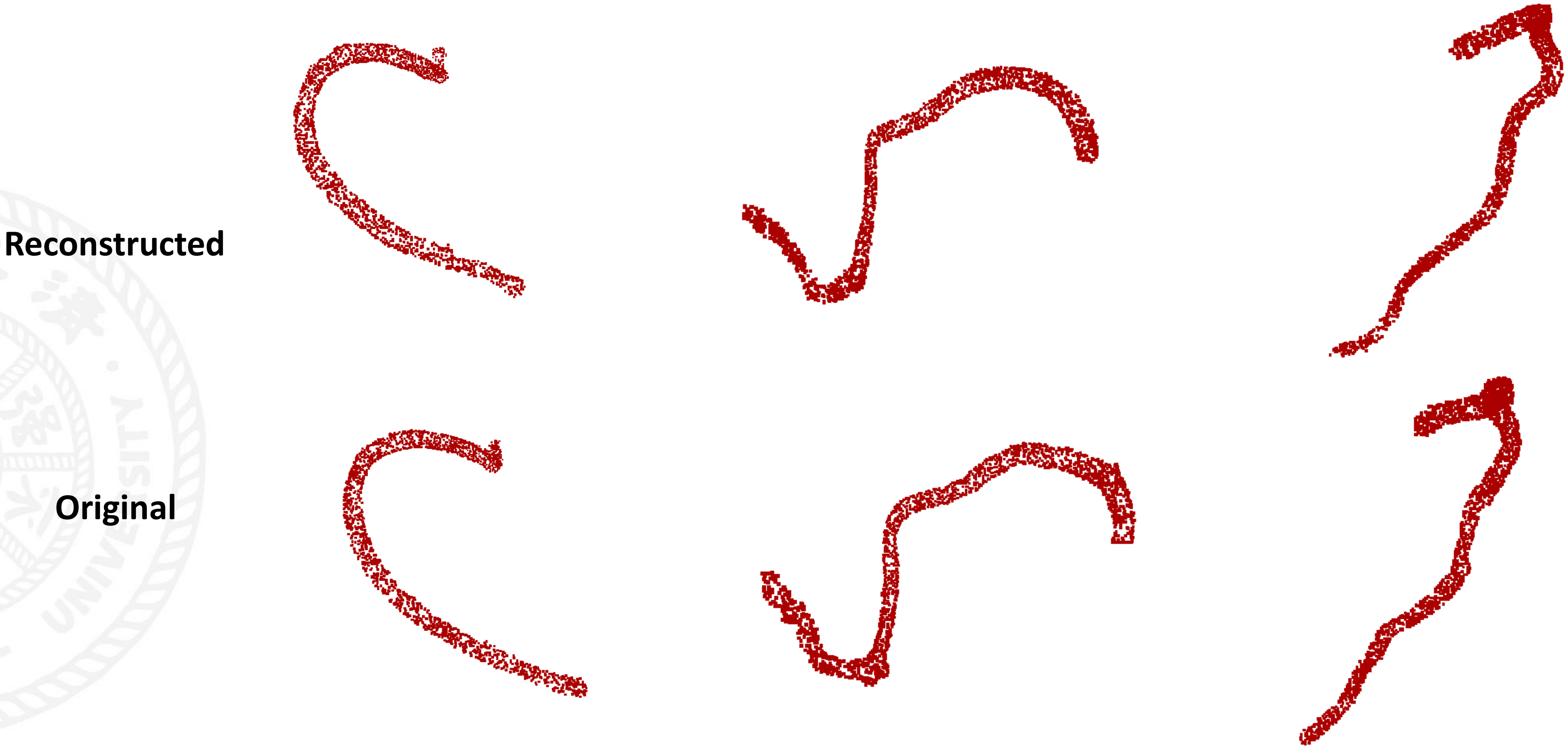
  - ✓ Geometry Shape Generation

Result

- the result of training each branch separately using the point cloud diffusion model



Discussion

Next step:

- Modify the Part Shape Generator and turn it into **label conditional** generator.
- Establish the **key point graph**
- Implementing the **Structure Graph Generator**.

Discussion

THANK YOU

Q & A