Can 3D Generative Models Help 3D Assembly?

ICML 2026

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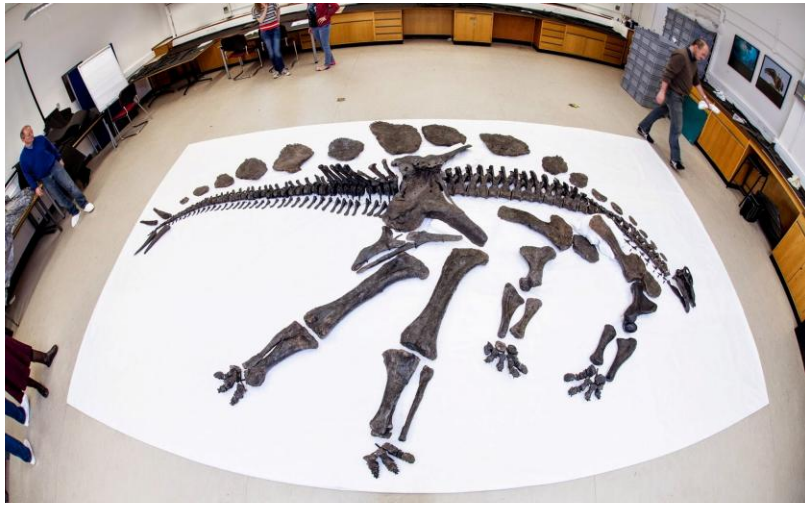
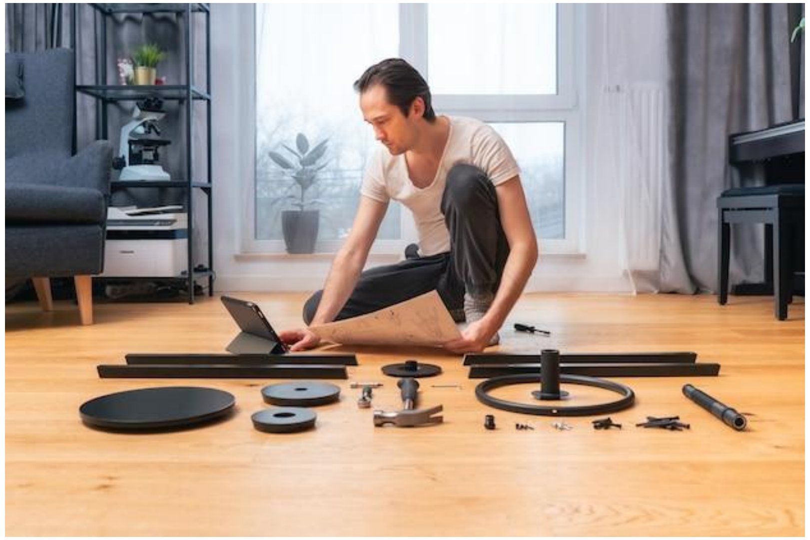
3D Assembly



Fossil

LEGO Toy



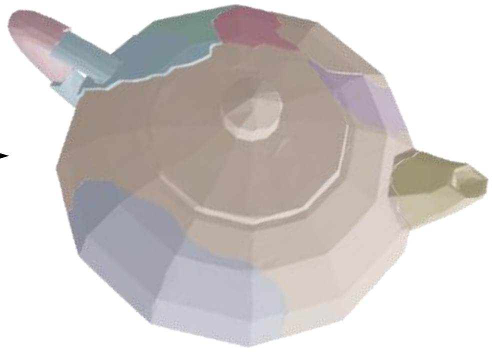
IKEA Furniture

Broken Item

3D Assembly

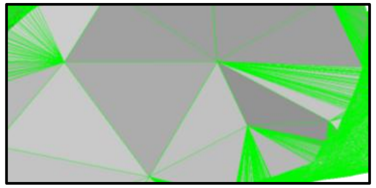
Rotation & Translation of Each Fragments

$$[\boldsymbol{R}, \boldsymbol{T}] = \mathcal{F}_\theta(\boldsymbol{P})$$

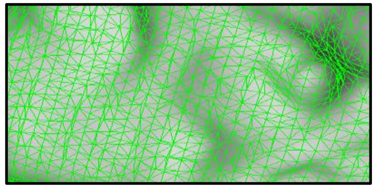


3D Assembly: Path to Physical Spatial Intelligence

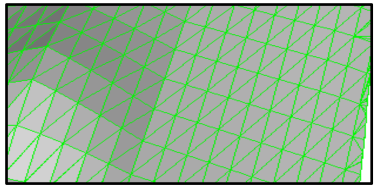
Diverse Local Feature



Physical Simulated



Real World Scan



Geometric Simulation

Diverse Object

PartNext[1]

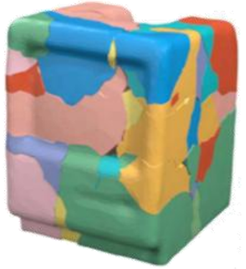
Bone, Ceramics, Lithics

Diverse Scale

N = 69

N = 41

N = 49



N = 45

1. Wang, Penghao, et al. "Partnext: A next-generation dataset for fine-grained and hierarchical 3d part understanding." NeurIPS(2025).

Previous

PuzzleFusion++ (ICLR25)

GARF (ICCV25)

RPF (NeurIPS25)

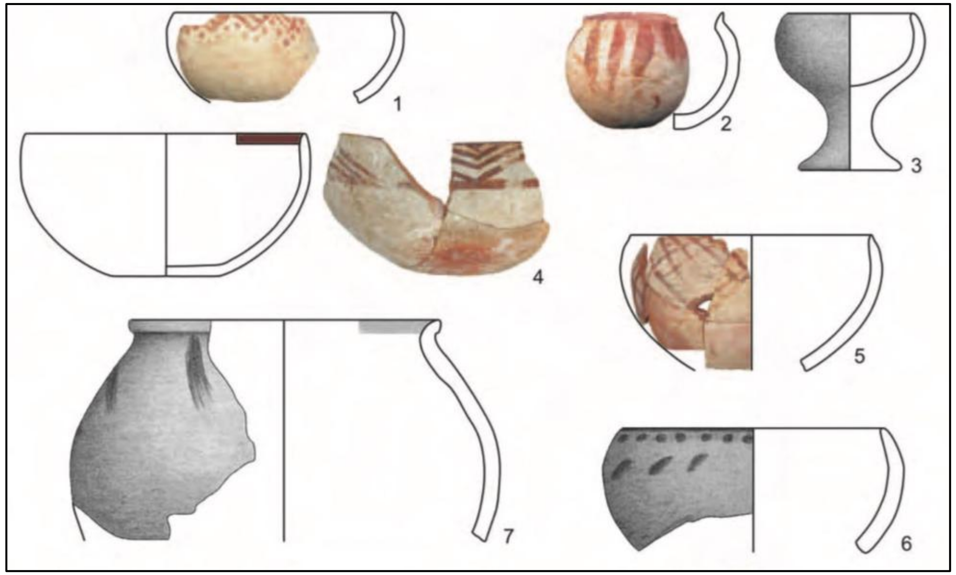
Previous

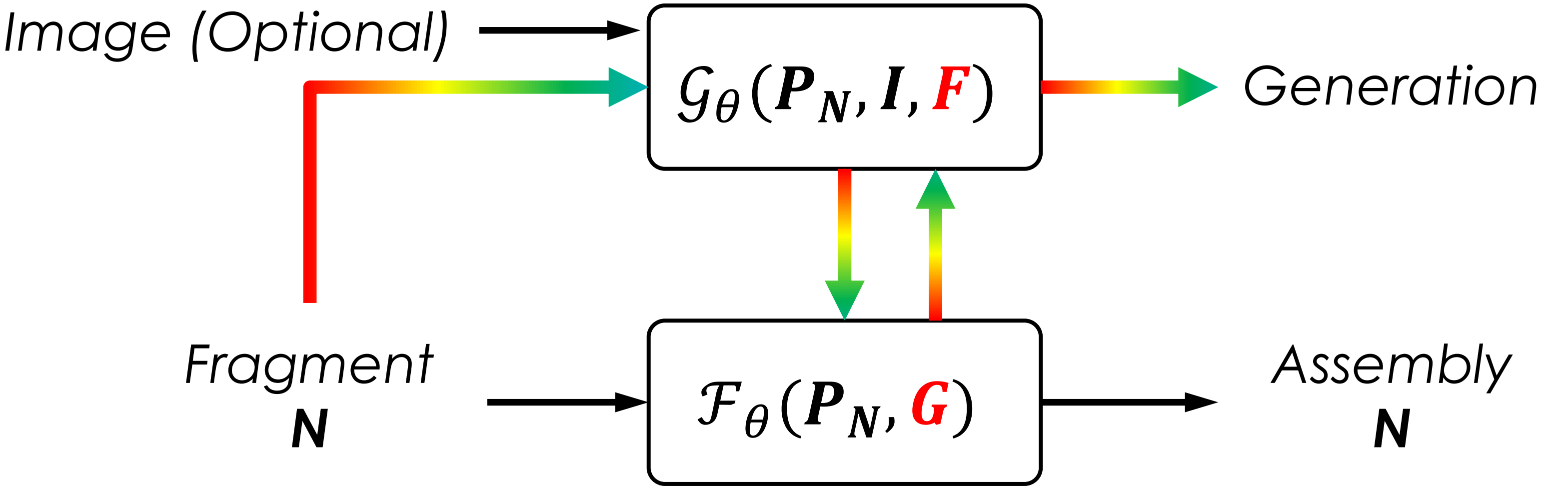
Fragment **N** → $\mathcal{F}_\theta(\boldsymbol{P}_N)$ → *Assembly* **N**

PuzzleFusion++ (ICLR25)	GARF (ICCV25)	RPF (NeurIPS25)
Noise ∈ $\mathcal{N}(\mu, \sigma^2)$	Noise ∈ $\mathcal{N}(\mu, \sigma^2)$	Noise ∈ $\mathcal{N}(\mu, \sigma^2)$
↓	↓	↓
Diffusion	Flow Matching	Rectified Flow
↓	↓	↓
Pose ∈ $\mathbb{R}^7$	Pose ∈ $\mathbb{R}^7$	Point Clouds ∈ $\mathbb{R}^{n \times 3}$
		↓ SVD
		Pose ∈ $\mathbb{R}^7$

However

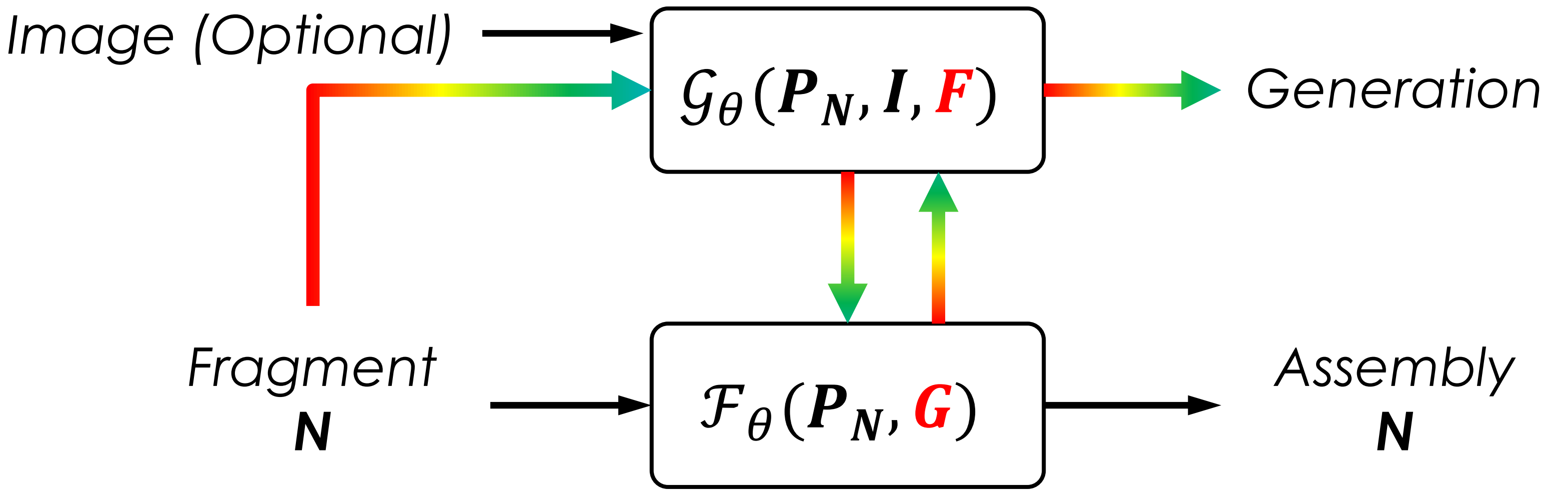
- *There are always* ***missing parts****: conservators often infer absent regions from the available fragments and perform gap-filling to restore a plausible, complete form.*





Could 3D assembly and generation be unified?

- Challenge 1: How to **infer the global shape** across diverse object categories.
- Challenge 2: a **shared latent space** that can embed an unordered set of variable-size, partial, and noisy fragments into a representation for both assembly and generation
- Challenge 3: effective **bidirectional information exchange**



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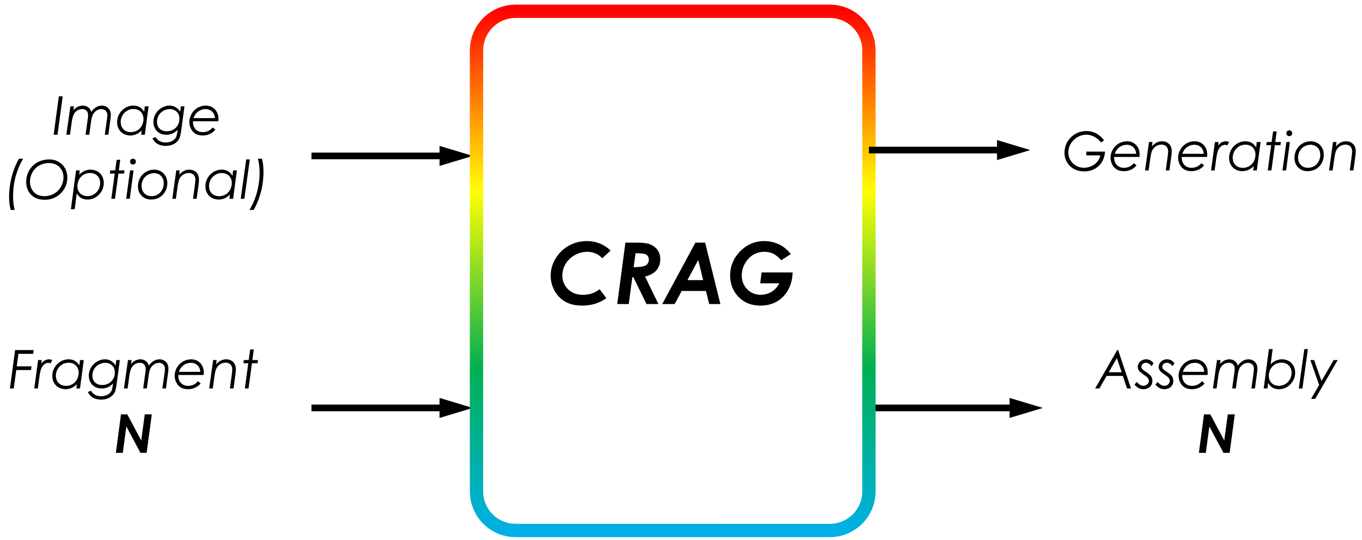
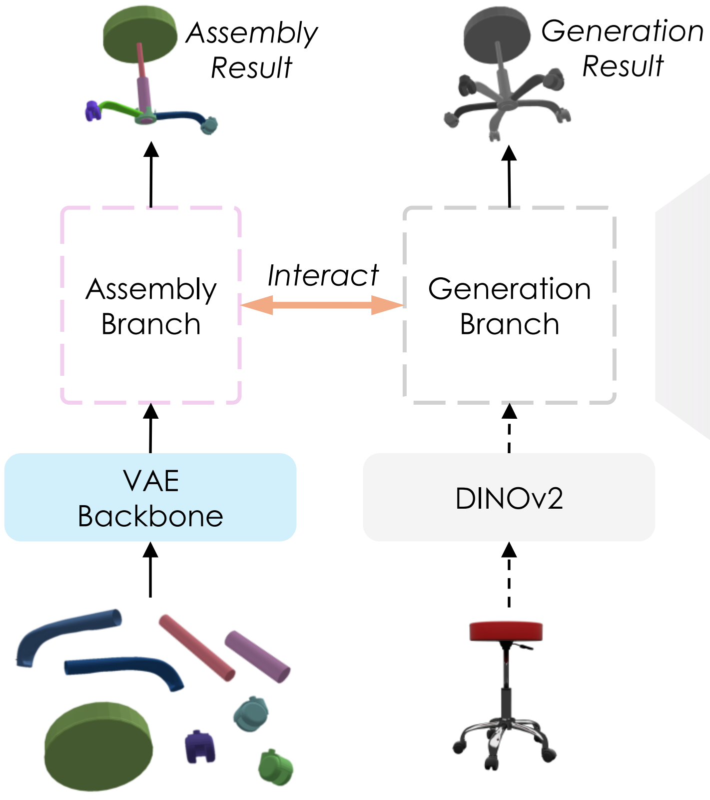


Challenge 1: Infer the Global Shape



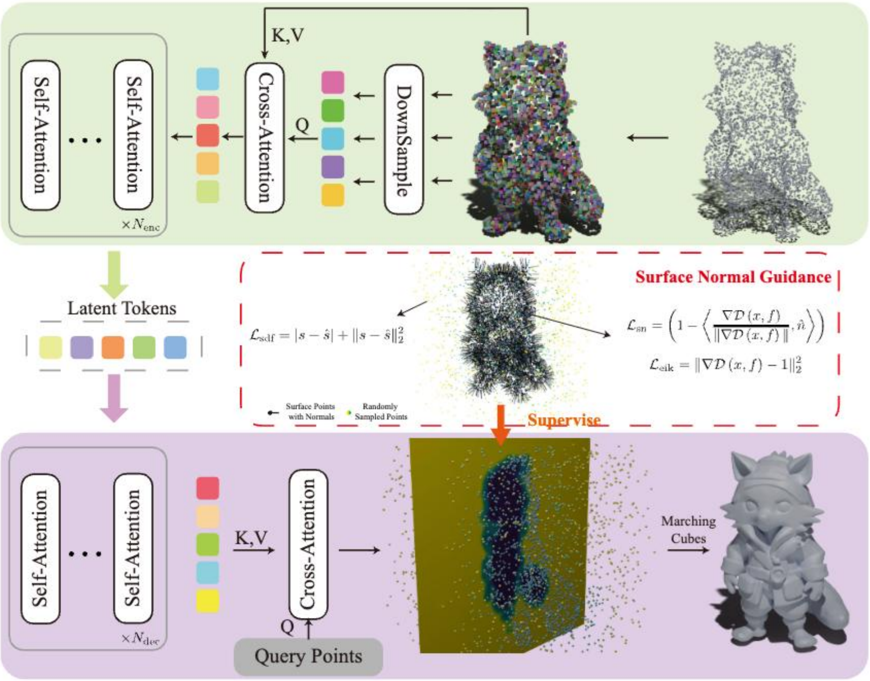
(a) Coupled Architecture

3M *Large-scale Object Dataset*

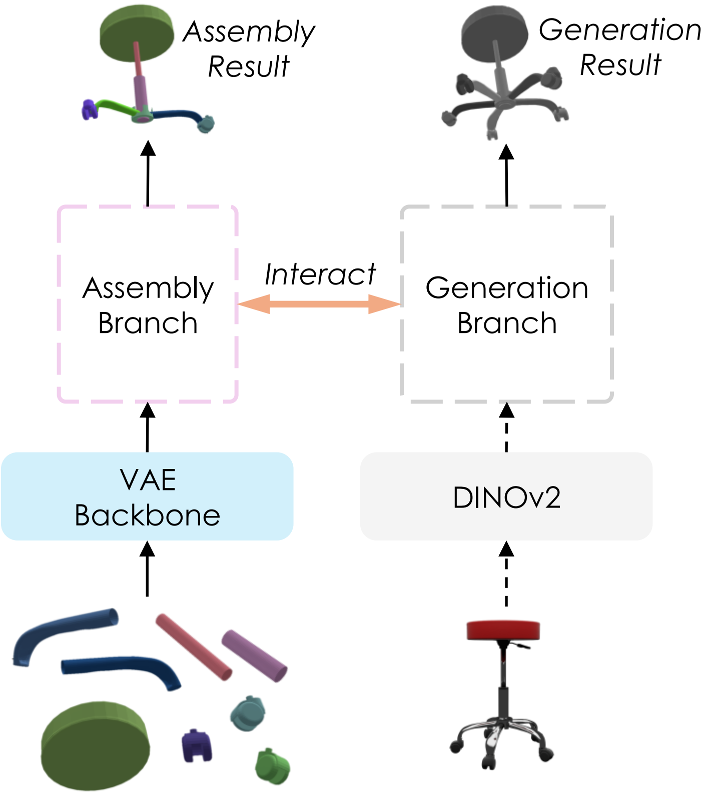
Pretrained TripoSG Model

Li, Yangguang, et al. "Triposg: High-fidelity 3d shape synthesis using large-scale rectified flow models." IEEE Transactions on Pattern Analysis and Machine Intelligence (2025).

Challenge 2: Shared Latent Space



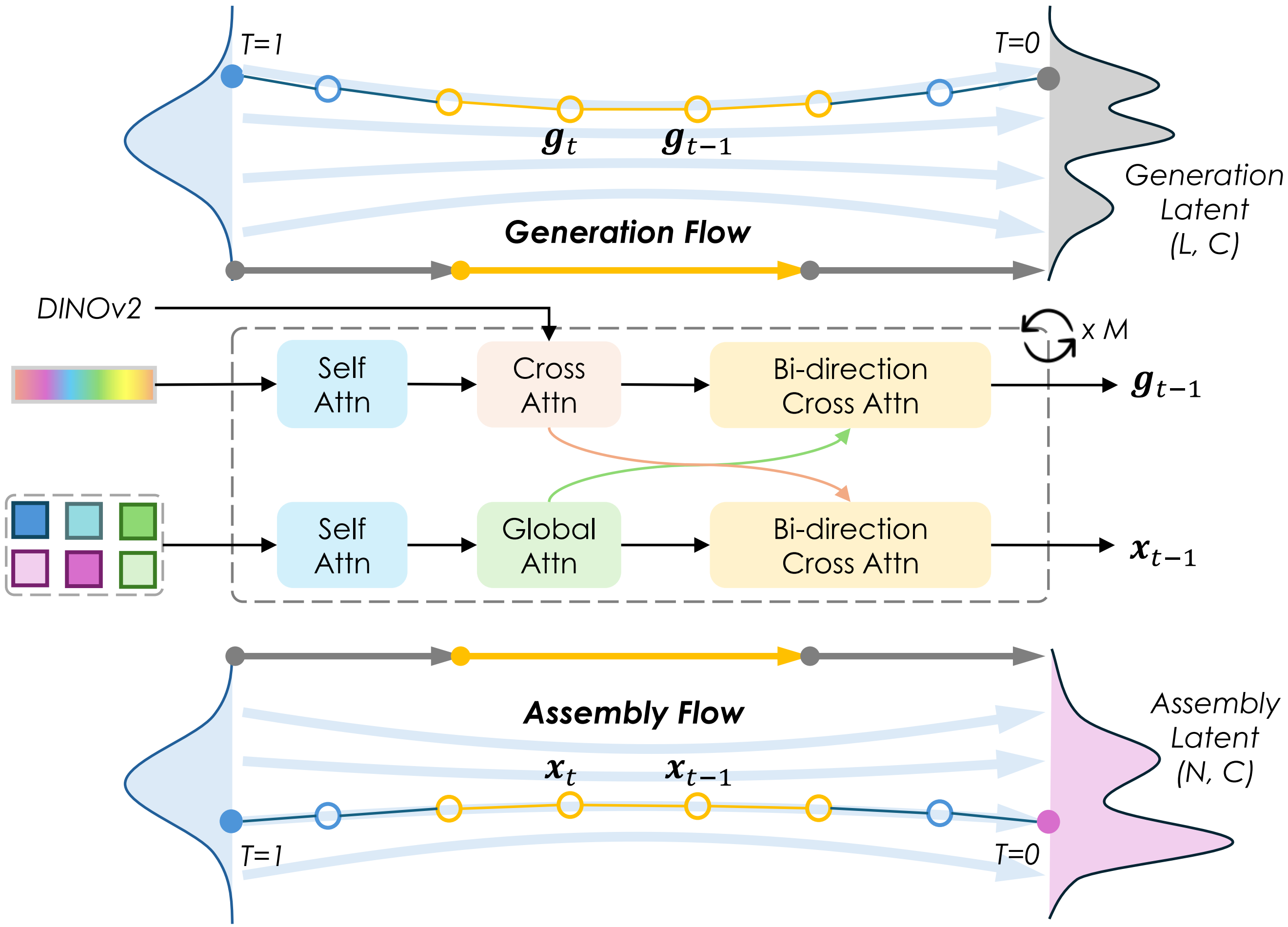
Shared VAE for Fragment Embedding



(a) Coupled Architecture

Li, Yangguang, et al. "Triposg: High-fidelity 3d shape synthesis using large-scale rectified flow models." IEEE Transactions on Pattern Analysis and Machine Intelligence (2025).

Challenge 3: Bidirectional Information Exchange



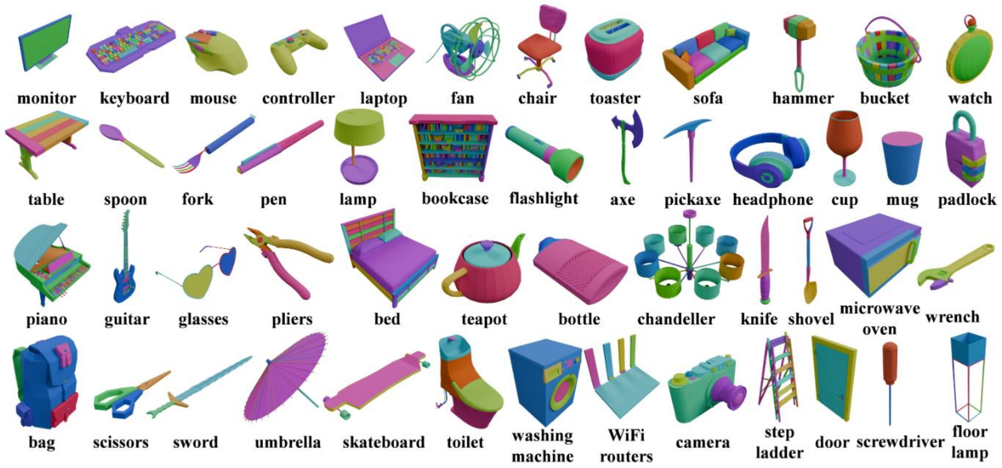
(b) Iteration with Joint Flow

Bi-direction Cross Attention

$$h_{\text{gen}}^{(\ell)} = h_{\text{gen}}^{(\ell)} + \mathrm{CrossAttn}\big(h_{\text{gen}}^{(\ell)}, h_{\text{asm}}^{(\ell)}\big),$$
$$h_{\text{asm}}^{(\ell)} = h_{\text{asm}}^{(\ell)} + \mathrm{CrossAttn}\big(h_{\text{asm}}^{(\ell)}, h_{\text{gen}}^{(\ell)}\big),$$

Dataset

Part-level Assembly
PartNext[1]



Training set: 15563
Evaluation set: 3903

Fracture Assembly
Breaking Bad[2]

Training set: 7872
Evaluation set: 3697

Fracture Assembly
Morphosourse[3]

Training set: 1744
Evaluation set: 437

1. Wang, Penghao, et al. "Partnext: A next-generation dataset for fine-grained and hierarchical 3d part understanding." NeurIPS(2025).
2. Sellán, Silvia, et al. "Breaking bad: A dataset for geometric fracture and reassembly." NeurIPS(2022).
3. Boyer, Doug M., et al. "Morphosource: archiving and sharing 3-D digital specimen data." The Paleontological Society Papers 22 (2016): 157-181.

Experiment

Does generation improve assembly by providing a holistic prior?

Can we still assemble the observed parts and synthesize a complete object from incomplete fragment sets?

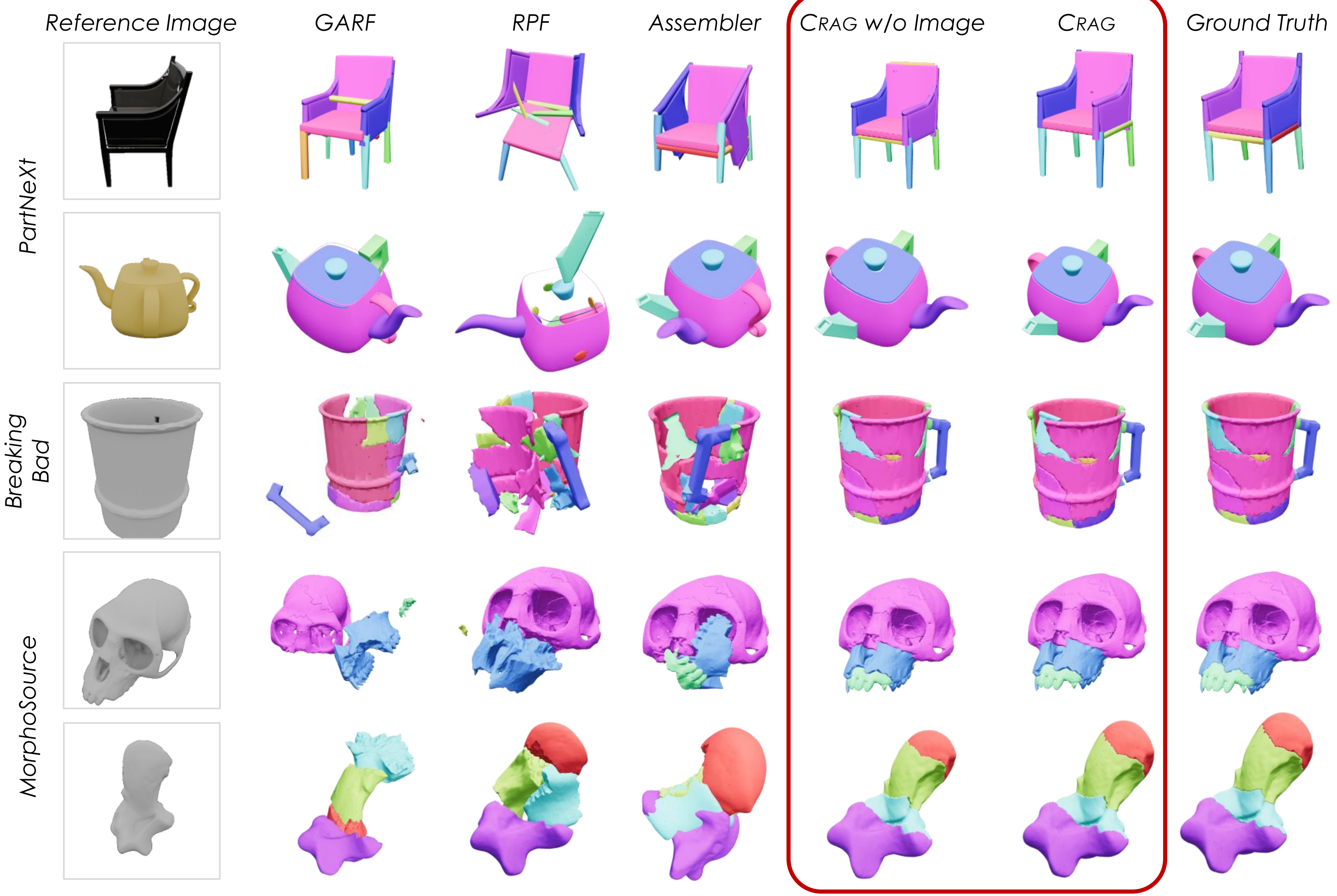
Does part-level evidence help disambiguate image conditioned 3D generation?

Does generation improve assembly by providing a holistic prior?

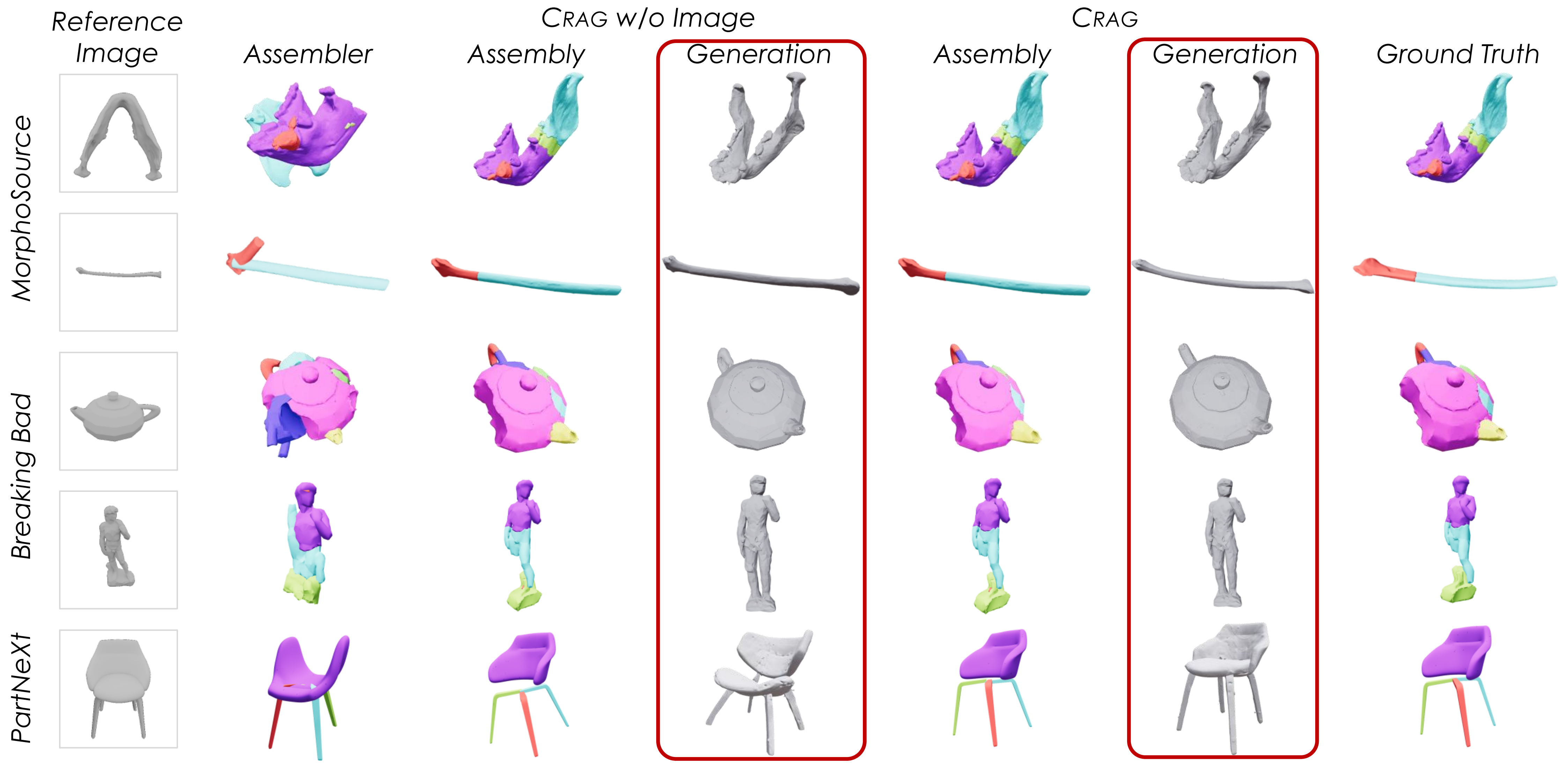
RE: Rotation Error *TE: Translation Error* *PA: Part Accuracy* *CD: Chamfer Distance*

	PartNeXt (Wang et al., 2025a)								Breaking Bad (Sellán et al., 2022)							
Part Status	Complete				Missing				Complete				Missing			
Method	RE ↓	TE ↓	PA ↑	CD ↓	RE ↓	TE ↓	PA ↑	CD ↓	RE ↓	TE ↓	PA ↑	CD ↓	RE ↓	TE ↓	PA ↑	CD ↓
GARF (Li et al., 2025a)	52.52	10.68	58.19	<u>3.10</u>	49.40	9.73	60.71	5.78	<u>8.75</u>	1.72	93.56	0.42	14.59	3.01	85.55	3.43
RPF (Sun et al., 2025)	54.99	29.54	46.17	10.46	42.49	22.95	57.20	8.21	30.59	13.67	80.23	1.01	31.04	14.96	77.05	1.20
CRAG w/o img (Ours)	<u>45.45</u>	<u>9.82</u>	<u>61.67</u>	3.31	<u>42.46</u>	<u>8.70</u>	<u>66.74</u>	<u>5.17</u>	**8.00**	<u>1.37</u>	<u>94.64</u>	<u>0.22</u>	**11.43**	<u>1.79</u>	<u>92.03</u>	<u>0.52</u>
Assembler (Zhao et al., 2025a)	85.82	17.14	44.18	27.93	83.80	15.00	49.86	24.71	74.92	13.22	48.38	7.46	74.45	13.43	45.93	7.78
CRAG (Ours)	**45.12**	**9.13**	**65.89**	**2.40**	**42.33**	**7.86**	**71.81**	**4.21**	**8.00**	**1.36**	**94.68**	**0.21**	<u>11.44</u>	**1.77**	**92.07**	**0.50**

Does generation improve assembly by providing a holistic prior?



Can we still assemble the observed parts and synthesize a complete object from incomplete fragment sets?



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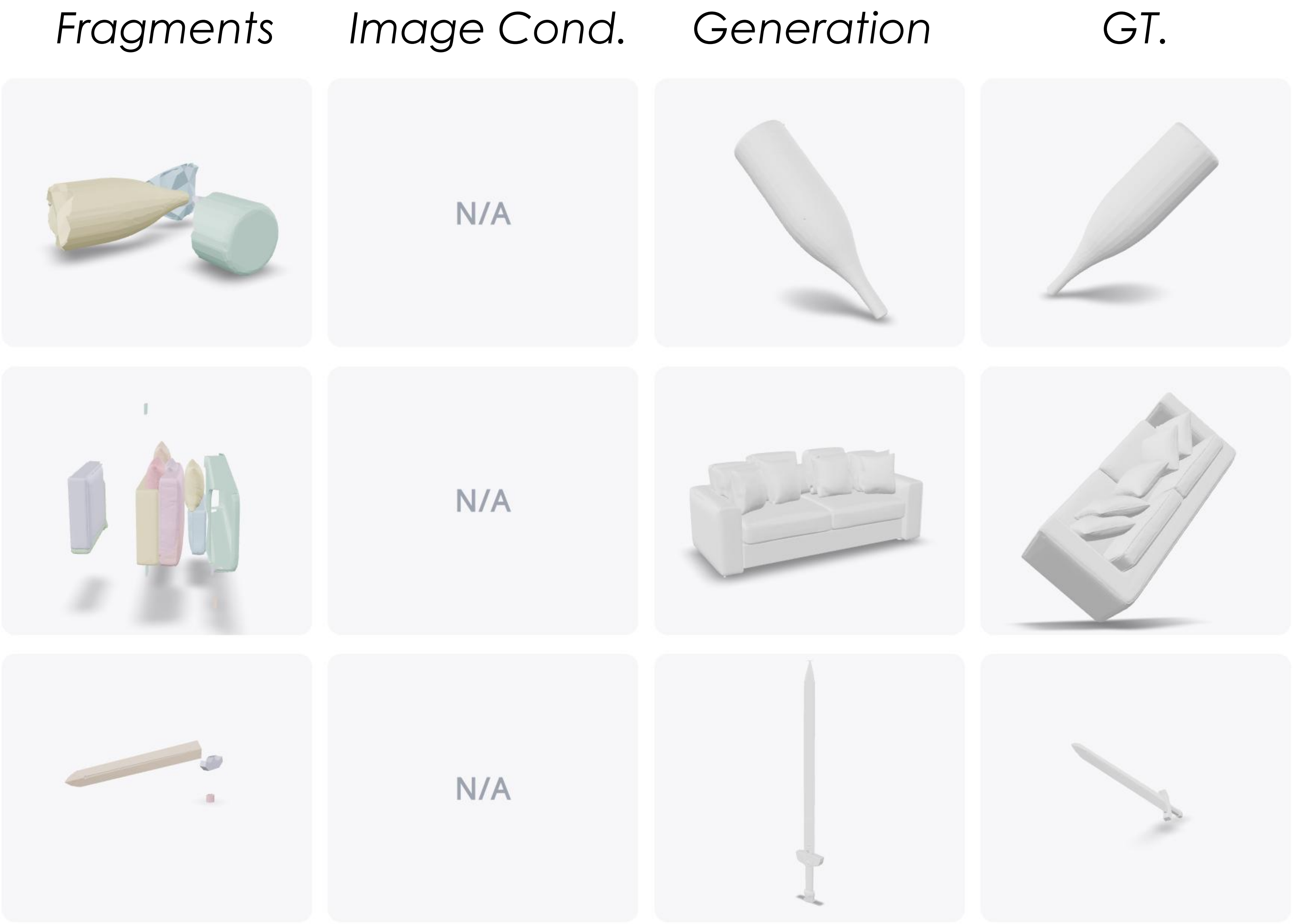

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20% Missing Part

Does part-level evidence help disambiguate image conditioned 3D generation?

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CRAG vs 3D Generation Model

Method	CD-L1 ($\times10^{-2}$) ↓	CD-L2 ($\times10^{-3}$) ↓	F-Score@1% (%) ↑	F-Score@5% (%) ↑	EMD ($\times10^{-3}$) ↓	Failure Rate ↓
TripoSG (Li et al., 2025b)	9.12	11.23	14.63	73.18	16.67	25.0% (1157/4626)
CRAG w/o img	9.26	11.46	15.02	72.61	16.96	**0%**
CRAG	**6.53**	**5.83**	**20.49**	**83.87**	**12.92**	**0%**

CRAG vs 3D Completion Model

Method	CD-L1 ($\times10^{-2}$) ↓	CD-L2 ($\times10^{-3}$) ↓	F-Score@1% (%) ↑	F-Score@5% (%) ↑	EMD ($\times10^{-3}$) ↓
SDFusion (Cheng et al., 2023)	22.51	23.93	1.90	28.58	28.60
MGPC (Liu et al., 2026)	12.59	11.54	12.75	70.54	16.99
CRAG w/o img	12.31	10.32	13.84	74.11	16.12
CRAG	**9.39**	**5.76**	**18.23**	**82.82**	**13.09**

Takeaways

- *Imagining the final global shape really helps 3D assembly.*
- *3D assembly can act as auxiliary task to promote 3D generation model.*
    - *You can try joint training (if you have enough computation resources)*
- *Data / Data Distribution matters in domain-specific 3D assembly, like in archaeology or medicine.*
    - *We observe some overfittings in MorphoSource.*

Future Works

- *Data!*
  - *How to synthesize diverse fragments with controllable fracture surface / simulate the real fracture for different domains.*
- *Agentic 3D assembly:*
  - *When you try to assemble object with more than **1000** pieces*
  - *Extract subgroup*
  - *Verifier and rewind*
  - *Combination of end-to-end and optimization-based method*
- *Language-driven arbitrary-shape assembly*
- *Learn from human video*
  - *Physical constraints for assembly*
  - *Novel object*

Thanks!











Project Page

Code Repo