NEURAL INFORMATION PROCESSING SYSTEMS

Flatten Anything: Unsupervised Neural Surface Parameterization

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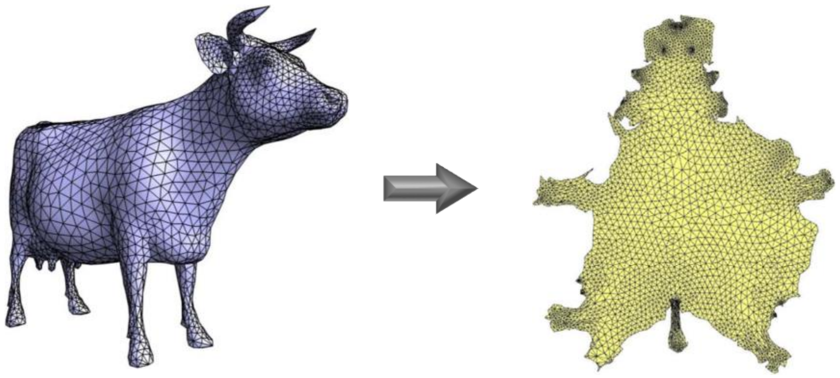
Background

➢ Surface Parameterization

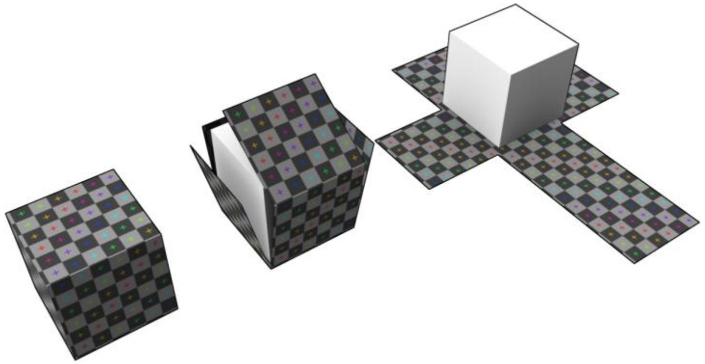
- ➢ 3D surface → *opened & unfolded & flattened* → 2D plane



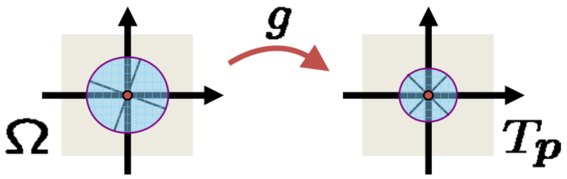
- ➢ Each 3D vertex **(x, y, z)** is mapped to a 2D UV coordinate **(u, v)**.
- ➢ Satisfy certain *continuity* and *distortion* constraints.

Background

- **Objectives**
  - Mimic the *actual physical process* of flattening a 3D surface onto a 2D plane.



  - High requirements and explicit constraints:
    - ***Global Mapping (Instead of Local)***
    - ***Free Boundary (Instead of Fixed)***
    - ***Conformal (Angle-Preserving)***

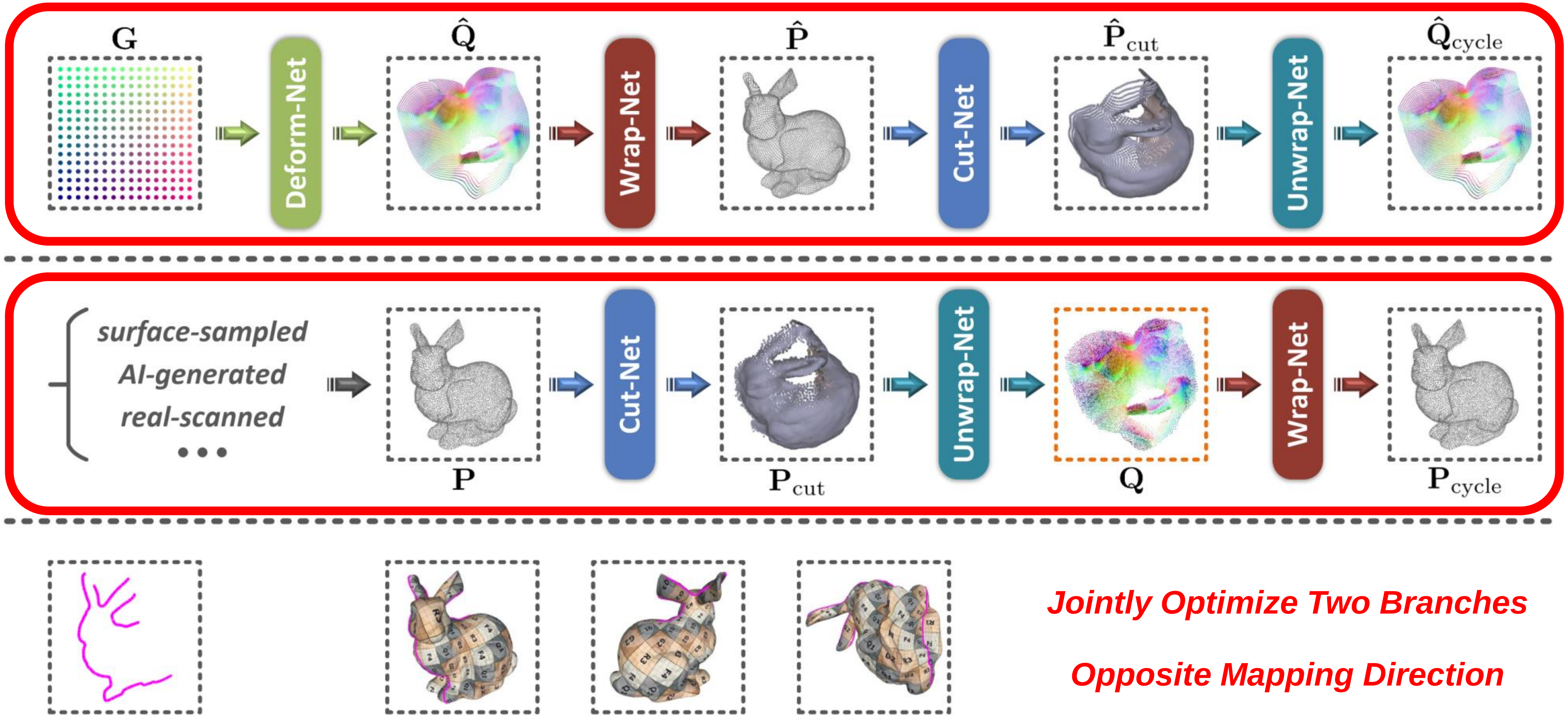


Flatten Anything Model (FAM)

- **Geometrically-Interpretable Network Components**
  - **Deforming Network (Deform-Net)**
    - Deform initial 2D grids to potentially-optimal UV coordinates.
  - **Wrapping Network (Wrap-Net)**
    - Fold from 2D to 3D.
  - **Surface Cutting Network (Cut-Net)**
    - Find cutting seams → highly-developable 3D surface manifold
  - **Unwrapping Network (Unwrap-Net)**
    - Unfold from 3D to 2D.

Flatten Anything Model (FAM)

➢ Bi-Directional Cycle Mapping

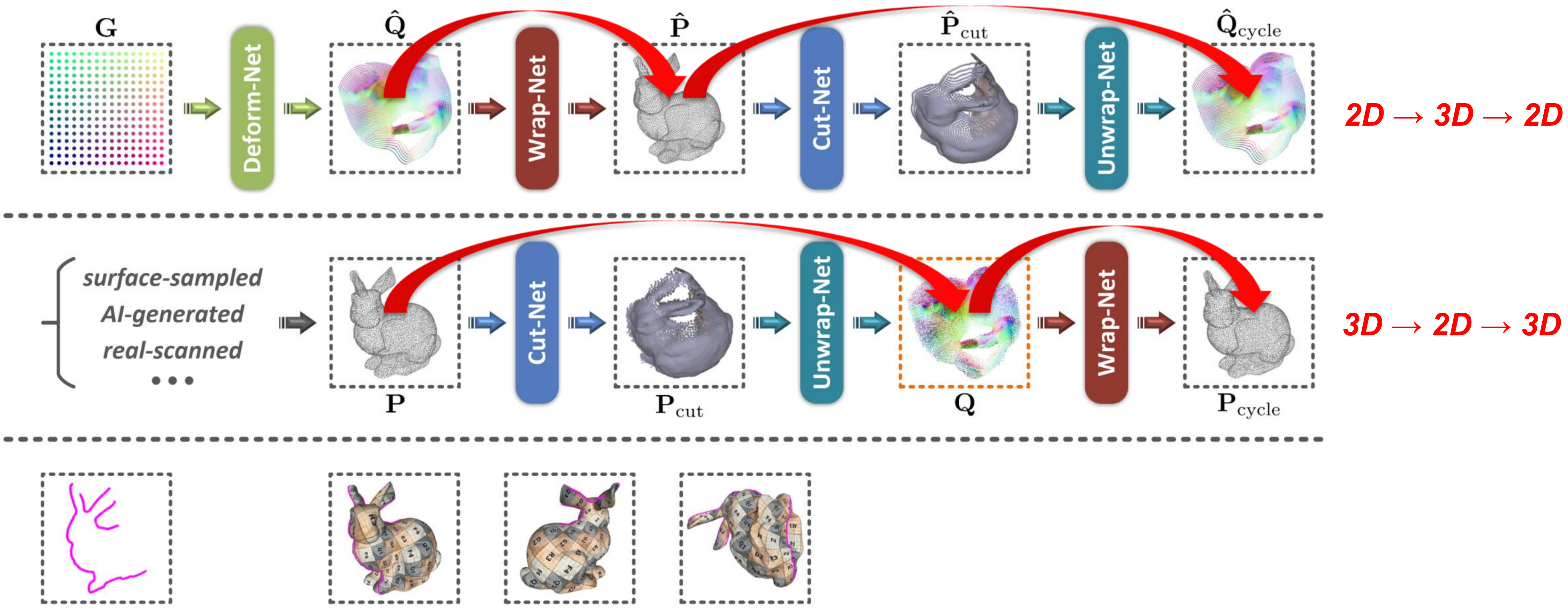


Jointly Optimize Two Branches

Opposite Mapping Direction

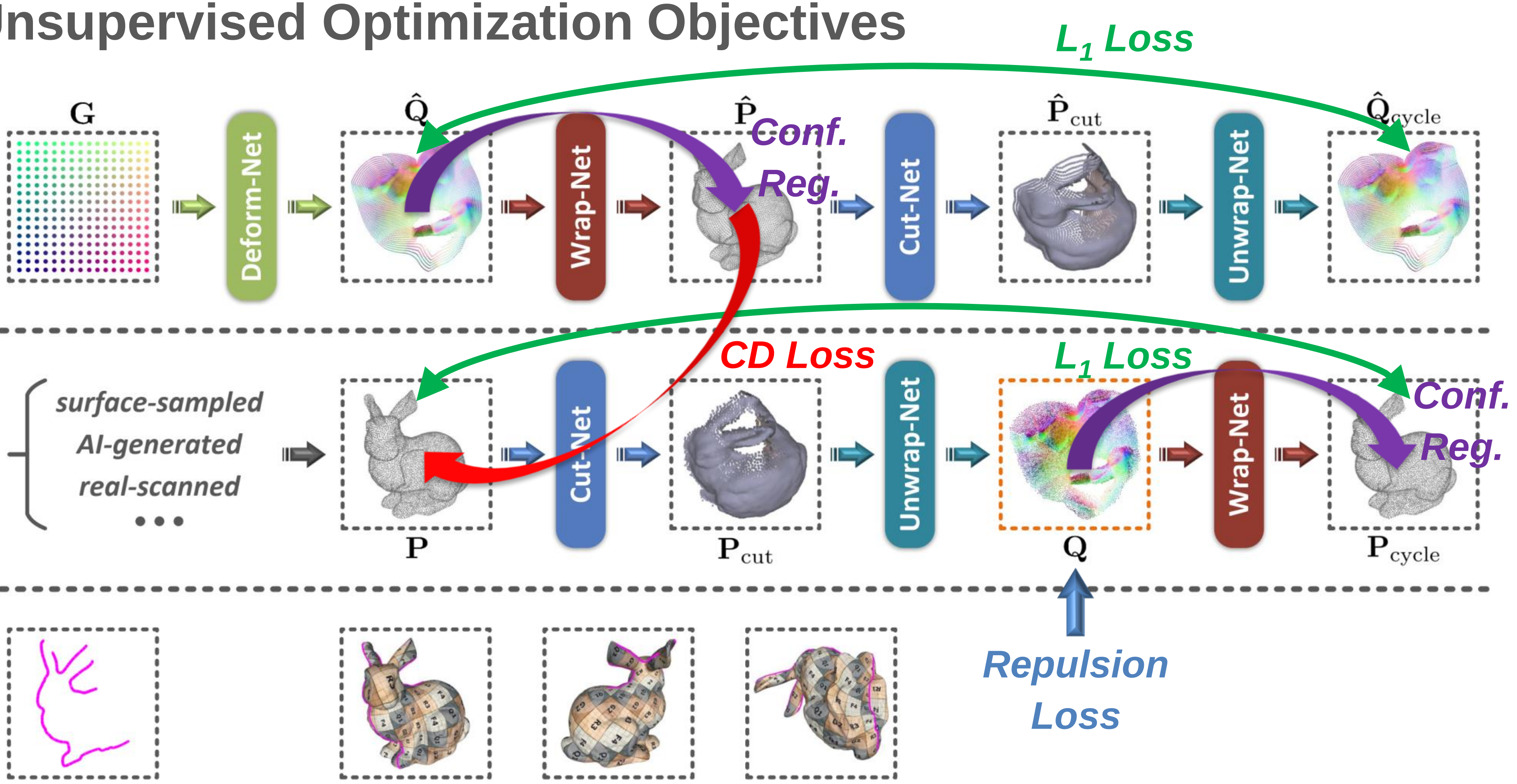
Flatten Anything Model (FAM)

- Bi-Directional Cycle Mapping



Flatten Anything Model (FAM)

- Unsupervised Optimization Objectives



Flatten Anything Model (FAM)

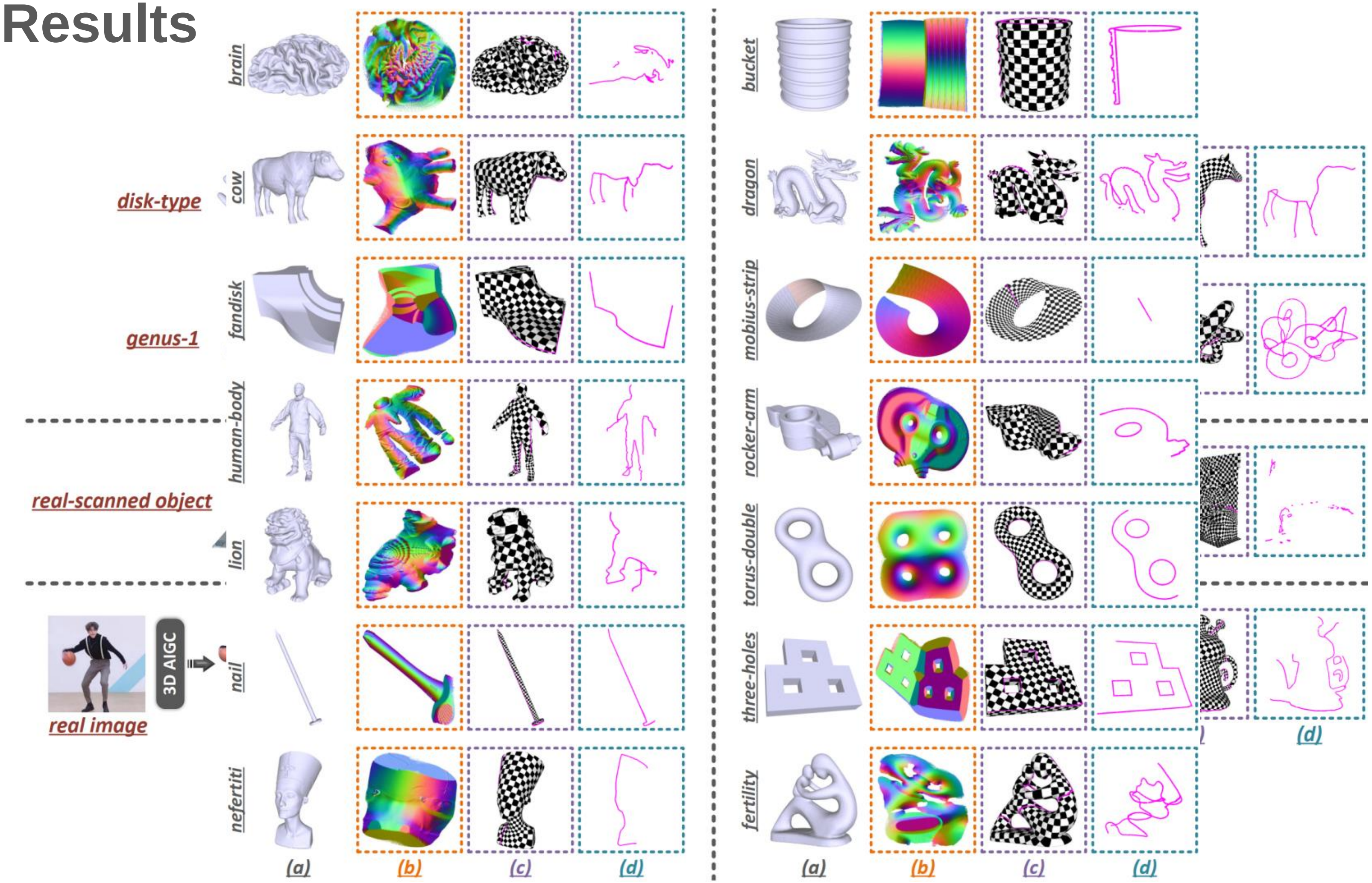
- Bi-Directional Cycle Mapping

Extraction of Cutting Seams

$$\eta_i = \max(\{\|\mathbf{q}_i - \mathbf{q}_i^{(k)}\|_2\}_{k=1}^{K_{\text{cut}}})$$

Experiments

- Our Results



UV Coordinates

Checker-Image Texture Mapping

Cutting Seams

Experiments

- Mesh Parameterization: Comparison with SLIM[R1]

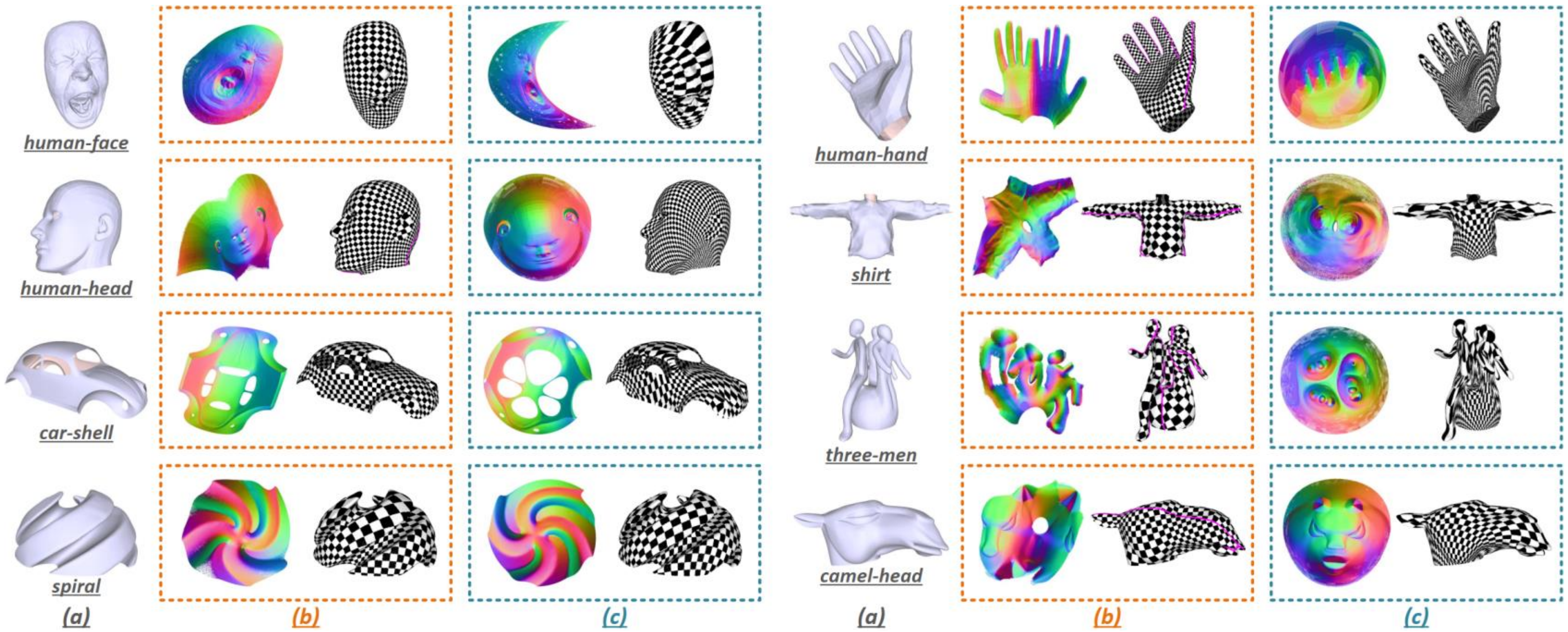


Table 1: Quantitative comparisons of our FAM and SLIM in terms of parameterization conformality.

Model	*human-face*	*human-head*	*car-shell*	*spiral*	*human-hand*	*shirt*	*three-men*	*camel-head*
SLIM	0.635	0.254	0.411	0.114	0.609	0.443	0.645	0.349
FAM	**0.074**	**0.094**	**0.037**	**0.087**	**0.145**	**0.166**	**0.162**	**0.088**

Testing Models	FAM	SLIM
Open-Surface Models (as in Figure 3)	0.156%	0.133%
Higher-Genus Models (as in Figure 4)	0.204%	N/A

Table 4: Quantitative self-intersection metrics of our parameterization results.

- [R1] M. Rabinovich, et al., "*Scalable Locally Injective Mappings*," in ACM Transactions on Graphics, 2017.

Experiments

➢ Point Cloud Parameterization: Comparison with FBCP-PC[R2]

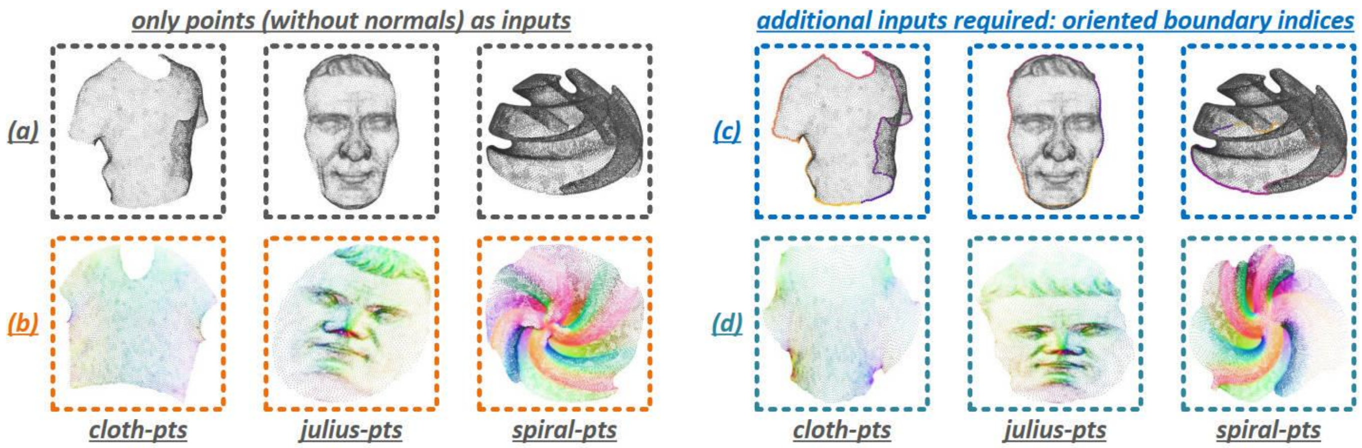


Figure 5: Point cloud parameterization achieved by our FAM (left) and FBCP-PC (right).

Table 3: Conformality metrics of our FAM and FBCP-PC for point cloud parameterization.

Model	*cloth-pts (#Pts=7K)*	*julius-pts (#Pts=11K)*	*spiral-pts (#Pts=28K)*
FBCP-PC	**0.021**	**0.019**	**0.023**
FAM	0.037	0.058	0.117

➢ [R2] G. P. Choi, et al., "*Free-Boundary Conformal Parameterization of Point Clouds*," in Journal of Scientific Computing, 2022.

Experiments

➢ Robustness to Noise

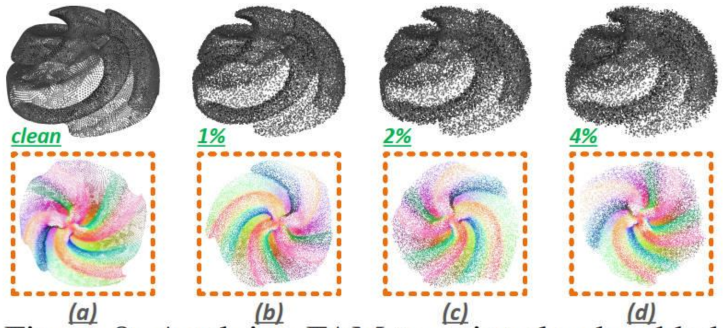
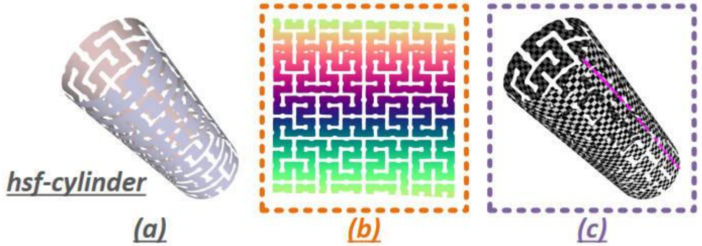


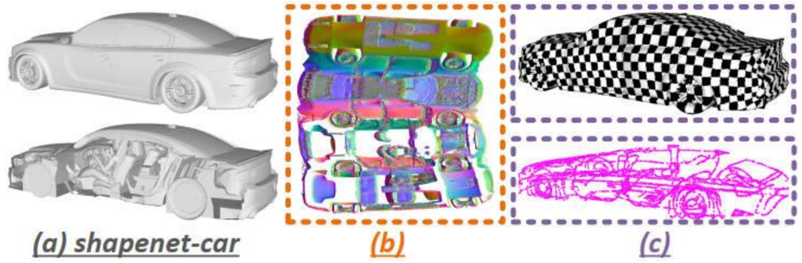
Figure 8: Applying FAM to point clouds added with different levels of Gaussian ***noises***.

➢ Stress Test



(a) Highly challenging stress tests of our FAM.

➢ Failure Case



➢ Running Efficiency

Table 5: Optimization time costs (minutes) of our FAM and SLIM.

Model	*human-face*	*human-head*	*car-shell*	*spiral*	*human-hand*	*shirt*	*three-men*	*camel-head*
SLIM	39 min	38 min	19 min	25 min	28 min	31 min	17 min	40 min
FAM	around 18 min (basically unchanged for different models)							

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